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Bank for International Settlements
Information, Press & Library Services
CH-4002 Basel, Switzerland

E-mail: publications@bis.org

Fax: (+41 61) 280 9100 and (+41 61) 280 8100

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Foreword

During the 1990s, a number of countries successfully achieved low and stable inflation. Part of the decline reflects the large and negative output gaps in the early 1990s and favourable supply shocks later in the decade. However, inflation has remained relatively subdued as economic conditions have strengthened and some of the supply shocks have reversed. Moreover, actual inflation has remained well below the rates forecast by models based on historical data. This raises the issue of whether the inflation process has undergone structural changes and, if so, which have been the principal forces.

There are several plausible reasons why such changes could have occurred.

First, due to globalisation and increasing competition in both domestic and international markets, firms' pricing power may have been eroded. Put another way, prices have become more sticky or the inflation process has become more persistent. One result of such changes is that the pass-through of cost increases (including exchange rate changes) into prices has fallen. Moreover, when relative prices evolve more slowly, firms that are subject to menu costs will set prices for longer periods.

Second, with inflation in the 1-3% range for some time, inflation expectations may have become more firmly anchored, particularly if the public believes that the monetary authorities will successfully resist any persistent movements of inflation away from this level. This is likely to be the case as many countries have explicitly adopted price stability as the overriding target for monetary policy.

Third, increases in productivity growth may have raised the rates at which economies can grow without encountering inflationary pressures. To some extent, this change may appear as a decline in the sensitivity of inflation to measures of the output gap, which tends to be overestimated in such conditions. Another measurement or estimation problem is that higher productivity growth may be an endogenous response to increasing competition and firms' loss of pricing power.

To explore these issues further, economists from nine central banks were invited to a workshop, chaired by Lars Heikensten, First Deputy Governor of Sveriges Riksbank, and held at the BIS on 31 October 2000. The papers presented at the workshop and reproduced on the following pages covered various approaches to the issues raised above. While there was a consensus that most of the structural changes involved technological progress and productivity growth, the empirical evidence is not yet firm enough to draw clear lessons for monetary policy.

Participants in the workshop

Australia:	Mr David Gruen Ms Jacqueline Dwyer
Canada:	Ms Tiff Macklem Mr James Yetman
ECB:	Mr Geoff Kenny Mr Ricardo Mestre
Japan:	Mr Hideo Hayakawa Mr Hiroshi Ugai
Spain:	Mr Angel Estrada Mr J David López-Salido
Sweden:	Mr Lars Heikensten Mr Jörgen Eklund Mr Hans Dillén Mr Per Jansson
Switzerland:	Mr Thomas Jordan Mr Peter Stalder
United Kingdom:	Mr Jens Larsen Mr Hasan Bakhshi
United States:	Mr William L Wascher Ms Jane Ihrig
BIS:	Mr William R White Mr Renato Filosa Mr Jeffery Amato Mr Palle S Andersen Mr Claudio Borio Mr Stefan Gerlach

Changes in the determinants of inflation in Australia

Jacqueline Dwyer and Kenneth Leong[1]

1. Introduction

Low and stable inflation has been a feature of the Australian economy for the past decade. Australia's previous history of high and variable inflation encouraged many to discount the low inflation of the early 1990s as cyclical, even accidental.[2] As it turned out, low inflation has been maintained through a lengthy economic expansion and in the presence of various inflationary shocks. While a regime of inflation targeting has played a role in facilitating this outcome, inflation has been generally lower than expected, and certainly more stable. At the same time, inflation has been surprisingly subdued in a range of industrialised economies, including those without explicit inflation targets. A key question is whether these developments reflect a series of favourable shocks to prices or a more fundamental change in the inflation process.

It has been suggested that a more fundamental change in the inflation process might have occurred.[3] This view has gained currency because some types of shocks that previously had a conspicuous influence on inflation now appear to have much less influence. In the Australian case, this is best highlighted by the apparent change in the pass-through of exchange rate movements to final domestic prices. Since Australia is a small open economy, episodes of currency depreciation have usually generated an increase in inflation. But on two occasions during the 1990s, despite a sharp depreciation of the Australian dollar, and rising import prices "at the docks", growth in final retail import prices remained subdued, so that there was little effect on consumer price inflation.

The apparent reduction in exchange rate pass-through provides an example of a direct and visible change in pricing behaviour that has had a bearing on our recent inflation performance. However, other developments in the economy that have less direct or visible consequences for prices have also been at work. Over the past two decades in Australia, there has been a gradual but expansive programme of market liberalisation that extends from financial and product markets to labour markets. Its effects have now manifested themselves in a variety of ways. There has been an increase in domestic competition, a shift away from centralised wage setting towards a decentralised enterprise-based system, and an attendant rise in trend productivity growth. Each of these developments is conducive to achieving lower and more stable inflation, at least in the short to medium run, and may have reinforced the effects of reduced exchange rate pass-through.[4] Furthermore, these changes have occurred in an environment where financial markets demand disciplined behaviour of public policymakers.

This paper seeks to establish if a fundamental change in the inflation process has occurred in Australia. This task is challenging. There are many interactions between microeconomic conditions and macroeconomic management that influence inflation performance, but which are difficult to separately identify. The strategy adopted in this paper is to define the problem quite narrowly. We consider the inflation process in the context of a mark-up model, in which the domestic price level is set as a mark-up on unit costs of production. We then attempt to identify whether there has been a measurable change in the relationship between inflation and its main explanators. In other words, we are seeking direct evidence of a change in the inflation process. We do not address the more difficult

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[1] We are grateful to Adam Cagliarini and Sharon Wardrop for their technical assistance and to David Gruen for his helpful comments.

[2] Stevens (1999) provides an assessment of Australia's inflation experience over the 1990s.

[3] Bootle (1996) is a prominent example of this claim.

[4] In the long run, these developments are likely to lower the price level rather than the ongoing rate of inflation, which is determined by monetary policy.

and important question of whether the change in the inflation environment has altered the propagation of shocks in the economy in a way that reinforces price stability.

The paper is organised as follows. First, we present trends in inflation outcomes and show that inflation in the 1990s was unusually benign, but not dissimilar to that in other countries. Second, we explore developments in each of the key explanators of inflation, highlighting changes that are unusual or structural. Third, we seek to establish the importance of these changes by comparing the properties of a mark-up model of inflation estimated in different periods. In particular, we test whether the impulse to inflation from a given shock has changed through time. Finally, implications and conclusions are drawn.

2. Inflation performance

Australia's inflation performance over the past four decades is illustrated in Figure 1. Two measures of inflation are shown: the Treasury underlying series, which, until recently, was the main measure of core inflation in Australia, and the Statistician's new inflation series.[5] The shaded band indicates the current target of 2-3% inflation over the medium term that has been the objective of monetary policy since 1993. There are several striking features of the graph. When viewed over the longer run, inflation has been highly variable, so that the 1990s emerge as a period of unusual stability. Also striking is that since the 1970s, there has been a tendency for each cyclical peak in inflation to be lower than the one before it. Since the early 1990s, inflation has been maintained at a rate not witnessed for more than a generation. Furthermore, in the period since the adoption of the inflation target, it is clear that inflation has been below 2% for longer than above 3%.

Many of these features are not, however, unique to Australia. Comparing inflation performance in Australia with that in the OECD, it is clear that there is a fair degree of similarity (Figure 2).[6] The timing of most major swings in inflation is roughly coincident, reflecting some commonality of shocks, rough correlation of business cycles and broad similarities in the stance of monetary policy. A trend reduction in inflation since the 1970s is common to many countries. So too is the shift to a regime of low, stable inflation and the tendency for inflation outcomes to be either below target or in the lower part of tolerance intervals. However, until recently, inflation in Australia tended to be higher, on average, than in the OECD and subject to greater oscillations.

Stevens (1992) provides a detailed episodic analysis of inflation in Australia for the period 1950-91 and demonstrates that, as a small open economy, foreign shocks have played a prominent role in inflation outcomes. This is particularly evident during the 1970s, when there were several major commodity price shocks. Under a fixed exchange rate regime, higher world prices were transmitted to domestic prices directly, and indirectly through their effects on income. This partly explains why oscillations in inflation during the 1970s were higher in Australia than in the OECD generally. The adoption of a floating exchange rate (in 1983) has made it easier to insulate the economy from foreign shocks, but they remain a significant influence on domestic prices.[7] They explain much of the difference between Australian and OECD inflation during the mid-1980s, when, following a sharp fall in the terms of trade, Australia experienced a record depreciation of the currency.

While episodes of inflation in Australia have tended to be triggered by foreign shocks, domestic shocks have also played an important role, often amplifying the effects of external factors. In particular, outbreaks of wage inflation occurred in the early to mid-1970s, the late 1970s and early 1980s that

---

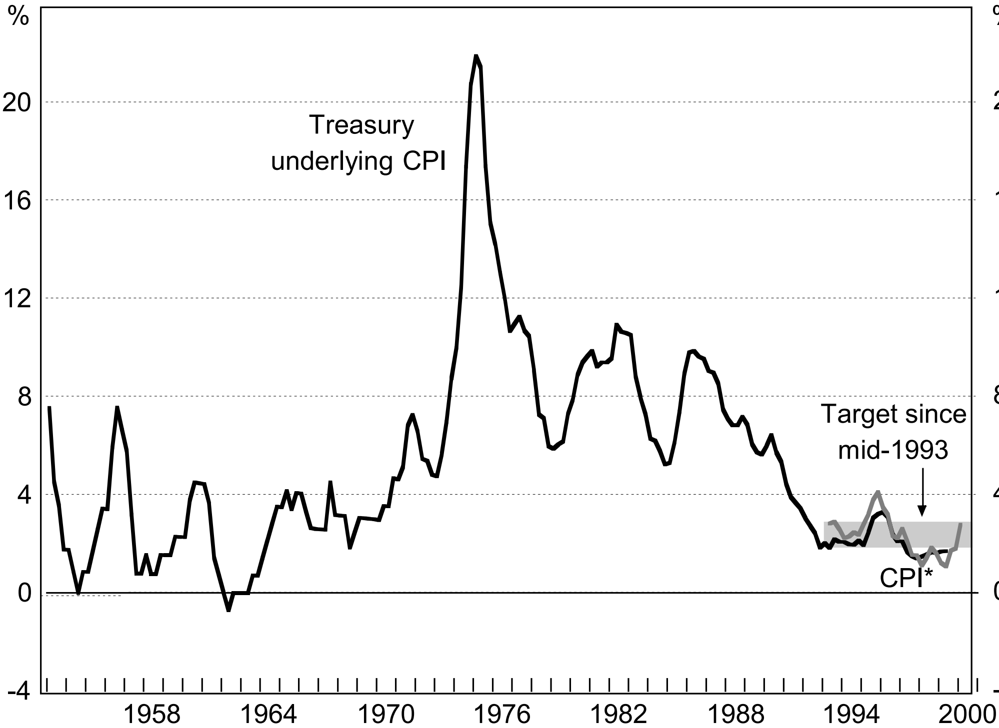
5 Following a regular five-year review of the Consumer Price Index by the Statistician, the measurement of the CPI was changed from the outlays approach (in which interest charges were included) to the acquisitions approach (in which they are not). For a description of these and other data, see Appendix A.

6 To permit a direct comparison with inflation in the OECD, CPI less interest is the measure of Australian inflation. (It peaks at a lower rate in the 1970s than our narrower measure of core inflation because it includes some items that experienced relatively low price rises in the September quarter 1974.)

7 Gruen and Dwyer (1995) describe the mechanisms through which a terms-of-trade shock influences domestic prices under a fixed and a floating exchange rate and present empirical evidence of the relationship for Australia and how it has evolved.

were more pronounced than in other OECD countries.[8] These provided a powerful impulse to inflation, leading to a more exaggerated cycle in inflation in Australia than in most of the OECD.[9]

Figure 1: Inflation over the long run



* Excludes interest charge components where relevant.

While Australian inflation has since fallen, and converged with that of other industrialised nations, the inflation process has remained subject to shocks. Volatile currency movements continue, as do fluctuations in wage growth, and there has been a pronounced and sustained upswing in real output. Certainly, the absolute size of these shocks has tended to be smaller in the past decade than previously. But notwithstanding this, the disturbances to inflation in Australia have been less than a casual reading of history would suggest. One very simple way of demonstrating this is to compare the variability of inflation with the variability of the inflationary shock. As Table 1 shows, the standard deviation of inflation fell significantly in the 1990s, while the standard deviation of import prices fell by a much smaller proportion, so that the ratio of the shock to the inflation outcome rose. A similar result can be found for the output gap and, to a lesser extent, wages in the manufacturing sector (often the wage leaders).[10] At face value, this points to an increased resilience of the inflation environment to shocks.

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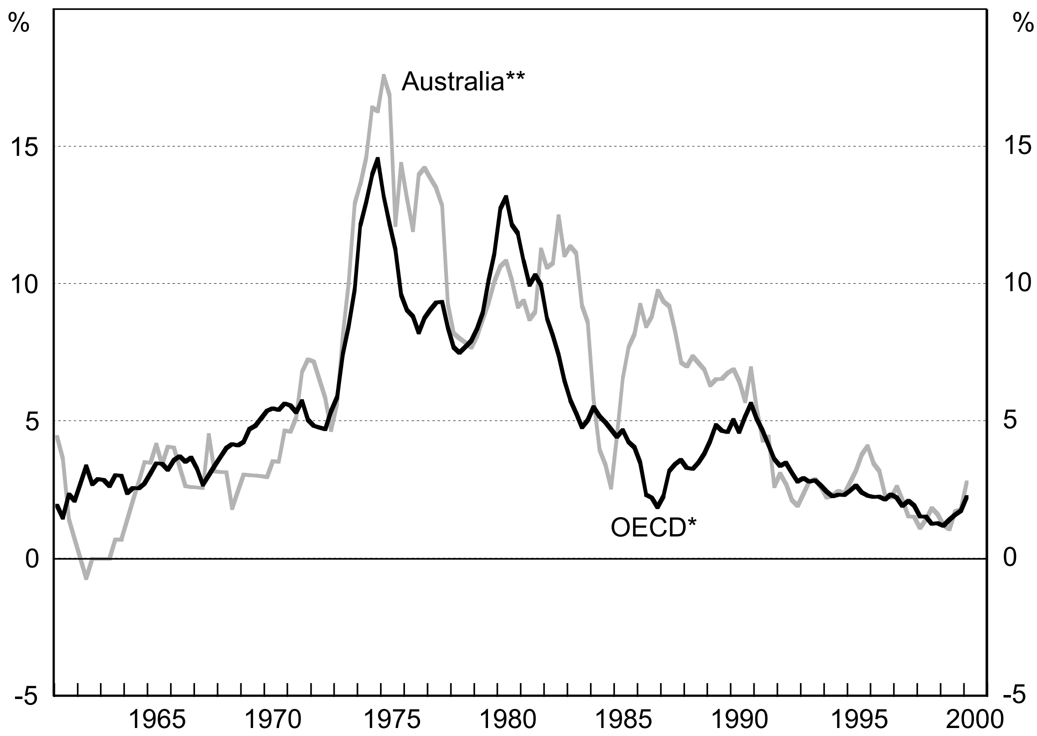
8 The first reflected the government's intention to increase labour's share of income and establish "equal pay for equal work", while in the late 1970s labour secured wage rises outside the centralised system. In the early 1980s, formal centralised wage fixing was abandoned but coordinated union campaigns resulted in a generalised wage rise.

9 In contrast, the Prices and Incomes Accord secured generalised wage restraint during the second half of the 1980s, which helped to counteract the inflationary consequences of prevailing external shocks.

10 For aggregate wages, the relationship appears to be unchanged. The stability of this relationship may reflect the fact that much of a given rise in wages is an endogenous response to rising prices.

Figure 2: Inflation in Australia and the OECD



*Excluding Turkey.

** Excludes interest charge components where relevant.

Table 1

The variability of inflation and its explanators

	Pre-1990s	1990s
Standard deviation		
CPI	3.9	1.5
Import prices	8.7	5.5
Wages	4.9	2.3
Output gap	0.7	0.6
Standard deviation relative to that of the CPI		
Import prices	2.2	3.6
Wages	1.3	1.5
Output gap	0.2	0.4

Note: The pre-1990s period spans from the March quarter 1965 to the December quarter 1989. The CPI is less interest charges, import prices are the implicit price deflator for imports, wages are the average earnings of adult males in the manufacturing industry, and the output gap is calculated using a Hodrick-Prescott filter. Standard deviations of year-ended percentage changes in price and wage variables are presented.

So why does the experience of the past decade appear to be so different? The framework of inflation targeting has no doubt been helpful, providing a new price stability rule where others had broken down and an anchor to inflation expectations (Grenville (1997), Clarida et al (1998), Taylor (2000)).

Furthermore, it has encouraged policymakers to be more disciplined and forward-looking.[11] In doing so, it has demanded greater effort in forecasting inflation. But despite these efforts to account for influences on the inflation process, actual inflation has been surprisingly low.[12]

The extent of this surprise in Australia can be summarised by an Assistant Governor of our Bank. Commenting on the fact that inflation has been below target more often than above it, he says "I cannot recall anyone predicting this outcome when we set out on the track of having an inflation target: in fact, I cannot recall anyone even contemplating it as a serious possibility. The scepticism we faced for quite some time over whether we would be able to prevent a return to high inflation seems like another world now" (Stevens (1999), p 50).

Having highlighted the apparent increase in resilience to foreign and domestic shocks, in the following section we explore developments in some of the main influences on inflation, focusing on the experience of the past decade.

3. Influences on inflation

Inflation in Australia has typically been considered in the context of a mark-up model so that, in the long run, the domestic price level is a mark-up on total unit costs of production.[13] For an open economy, these costs include imported inputs to production as well as domestic inputs. Consequently, estimated mark-up models present us with a set of key variables, both foreign and domestic, that have played a significant role in explaining actual inflation outcomes. Prominent in this set are import prices, wages and productivity. We explore the behaviour of these variables over the 1990s and identify changes that are conducive to low and stable inflation.

3.1 Import prices

In recent years, import prices have contributed surprisingly little to consumer price inflation. This has invited claims of a structural change in the pass-though relationship that has increased the immunity of the inflation process to external shocks. The basis of these claims can be well summarised in Figure 3, which shows how import prices have moved during three episodes of currency depreciation. (The exchange rate index comprises the currencies of Australia's major trading partners, weighted by import shares. It is expressed in Australian dollars per unit of foreign currency so that a rise indicates a depreciation.)

In each episode of depreciation, import prices "at the docks" moved approximately in line with changes in the exchange rate. In the 1980s, these price movements at the docks were also translated into sharply rising retail import prices that provided considerable impetus to domestic inflation. In the early 1990s, however, import prices at the docks appeared to have a much smaller effect on retail import prices (measured here by the imported component of the CPI).[14] By the late 1990s, they appeared to have little or no effect on retail import prices so that, despite a significant depreciation, domestic inflation remained undisturbed.

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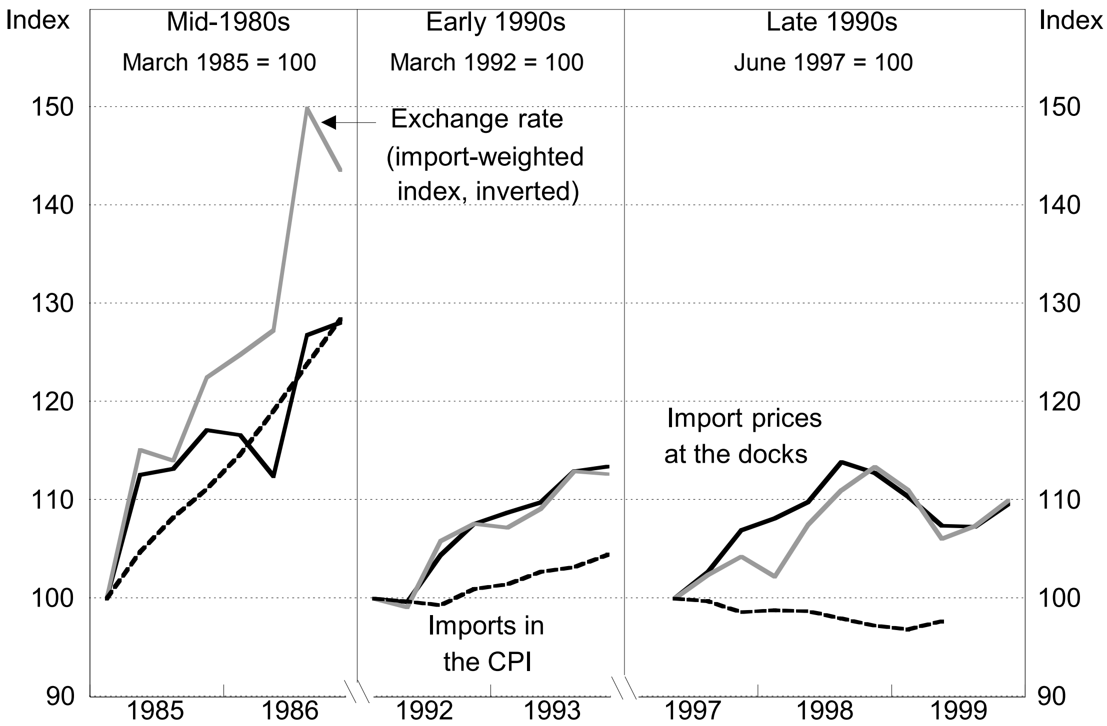
[11] These issues are explored comprehensively elsewhere (see Lowe (1997)). For a comment on how the target has conditioned Australian decisions on monetary policy specifically, see Stevens (1999).

[12] Internal Bank forecasts of inflation one and two quarters ahead have been well realised. In contrast, when forecasting over longer periods of six quarters, outcomes have, on average, been lower than expected. Although these forecasts are made with an assumption of no change in the exchange rate, when we revisit them, with the actual path of the exchange rate known, outcomes remain lower than predicted (by, on average, around ½ percentage point).

[13] See, for example, Cockerell and Russell (1995), de Brouwer and Ericsson (1995) and Beechey et al (2000).

[14] The imported component of the CPI was discontinued in June 1999 and replaced with a broader measure of tradables prices that is not directly comparable.

Figure 3: Import prices and the exchange rate



While these stylised facts provide a strong prima facie case of a change in the pass-through relationship, careful examination of events leads to more modest conclusions. In this section, we present estimates of the pass-through of changes in the exchange rate to import prices at the docks, or "first stage pass-through". We also present estimates of the responsiveness of final consumer prices to changes in import prices at the docks, or "second stage pass-through". In both cases, we pay particular attention to the experience of the 1990s.

3.1.1 First stage pass-through

First stage pass-through is, in essence, an application of the law of one price. In its absolute form, the law states that the price of a traded good should be the same in both domestic and foreign economies, when expressed in a common currency, and can be written as:

$$P = P^{*}E \tag{1}$$

where *P* is the domestic price of imports at the docks, *P** is the corresponding foreign price and *E* is the exchange rate (a basket of rates expressed in units of domestic currency per unit of foreign currency). The extent of first stage pass-through is represented by the elasticity of the domestic at the docks import price with respect to the exchange rate. It is complete when this elasticity is unity so that all of a change in the exchange rate is passed on to a change in the import price at the docks.

Since Australia is a small open economy, theory predicts that import price pass-through should be complete.[15] This prediction is usually borne out with aggregate import data (Dwyer et al (1993)).[16] For a given world price, changes in the exchange rate are fully passed on to changes in import prices at the docks. Furthermore, the typical finding is that first stage pass-through is completed rapidly, with

15 Because in a small open economy importers face perfect elasticity of supply, foreigners will not adjust the foreign currency price of the import following a change in the exchange rate, so that the domestic price will move in exact proportion to the exchange rate.

16 Although researchers examining pass-through of exchange rates to the prices of individual classes of goods find it to be incomplete (see, for example, Menon (1991) with respect to motor vehicles).

most of the adjustment occurring within one year.[17] However, a recent challenge to estimating the extent of first stage pass-through has arisen with the Asian financial crisis.

Most often, there is a high degree of co-movement between each of Australia's bilateral exchange rates so that most measures of an effective exchange rate move similarly, regardless of country coverage or weighting systems. But during the Asian financial crisis, the Australian dollar appreciated against the currencies of the troubled Asian economies and depreciated markedly against the major currencies, making the choice of effective exchange rate important. To assess the impact of these divergent currency movements on domestic import prices, it is necessary to properly control for changes in the foreign prices of goods exported from each trading partner. While bilateral exchange rates are readily available for all of Australia's trading partners, timely or reliable estimates of the relevant export prices are not. These are largely confined to the G7 countries.

Our approach is to view the G7 countries as price makers that set a notional world price for goods and services and estimate first stage pass-through using the currency and export prices of these G7 countries, rather than those of a broader group. In other words, our approach is to investigate whether $P = P_{G7}\ E_{G7}$.

In Appendix B, we present the estimated import price equation from the small model of the Australian economy presented in Beechey et al (2000). This import price equation is of the standard error correction type, but has two special features. These are designed to control for the fact that export prices from non-G7 countries may deviate from the notional world price. Beechey et al (2000) include a dummy variable to capture price undercutting by Asian exporters following the Asian crisis, and a time trend to capture the secular shift in Australia's imports towards lower-priced goods from non-G7 countries (particularly those in Asia). Incorporating these two variables into an otherwise conventional pass-through equation returns the results found in previous studies: changes in the exchange rate (and world prices) are completely passed through to changes in domestic import prices in the long run. Also consistent with earlier findings is the rapid adjustment to equilibrium, shown in Figure 4 by the response of import prices "at the docks" to a 1% depreciation.

In fact, this rapid adjustment has been a stable feature of the pass-through relationship, even during the 1990s. This is demonstrated by estimating the pass-through relationship recursively (that is, we estimate the equation up until the March quarter 1990 and successively re-estimate by extending the sample period by one quarter). The lines in Figure 5 trace the extent to which pass-through of a permanent 1% depreciation is estimated to have occurred by the quarter shown. Clearly, the path of adjustment towards long-run equilibrium has remained remarkably stable. In other words, the relative stability of inflation in Australia cannot be attributed to a reduction in exchange rate pass-through, at least at the first stage. This makes second stage pass-through central to assessments of the direct inflationary consequences of currency movements.

[17] And much of it after one quarter. See also Dwyer and Lam (1994).

Figure 4: First stage pass-through impulse response function

Pass-through to at the docks import price

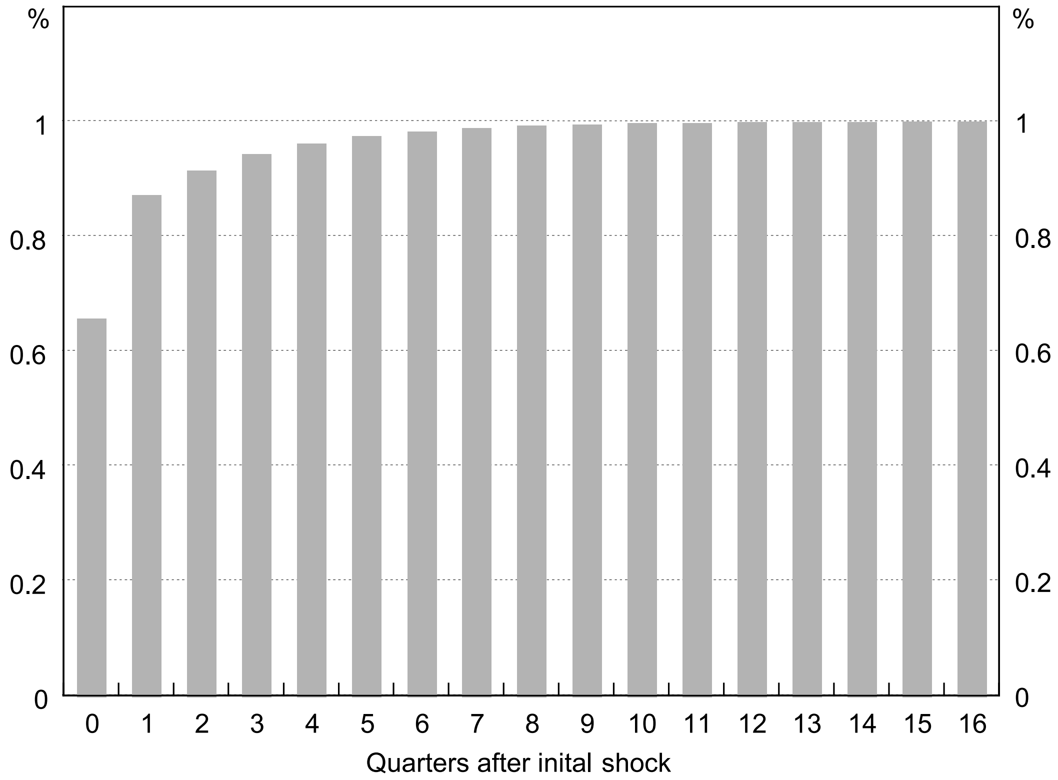
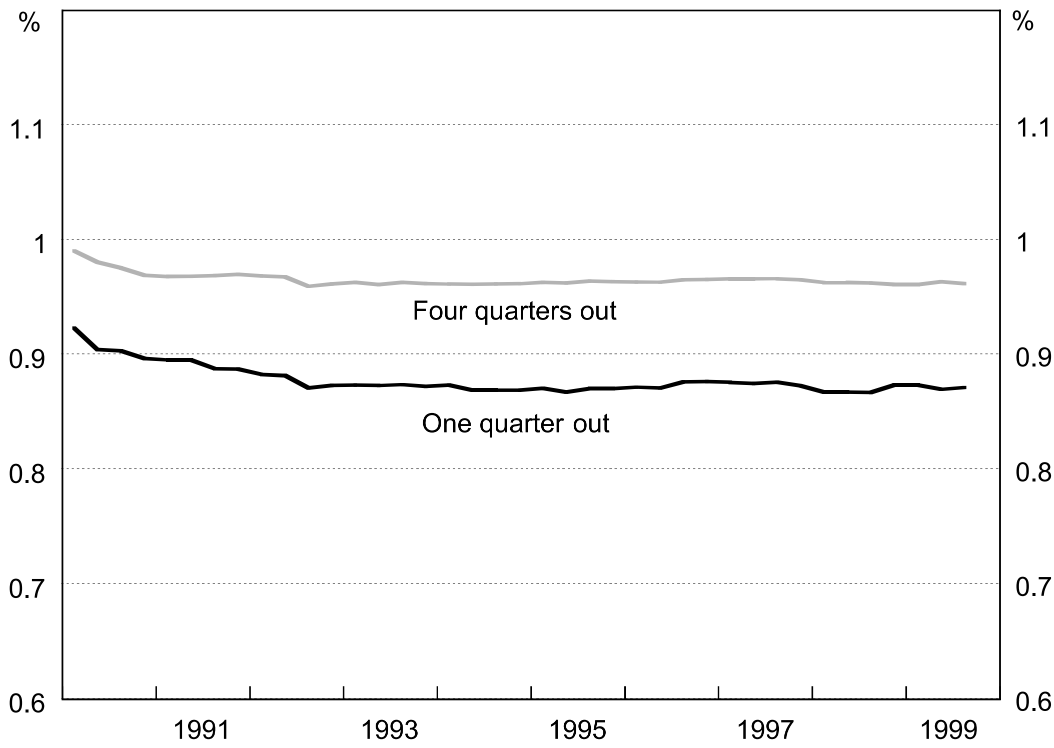


Figure 5: Stability of adjustment to an exchange rate shock

Pass-through to at the docks import price



3.1.2 Second stage pass-through

If prices are set as a mark-up on costs, the price of the retail import will be determined by the cost of the import itself and the cost of domestic inputs used in the process of distribution and sale:

$$R = P^{\alpha} C^{(1-\alpha)} \lambda \qquad (2)$$

where *R* is the retail import price, *C* is the cost of domestic inputs, λ is the mark-up and α is the share of the import in total costs.[18] In this framework, the extent of second stage pass-through is represented by the elasticity of a retail import price with respect to an at the docks price. Although the full increase in *P* (and *C*) will be passed on to *R*, the proportional change in *R* will be less than unity because the imported good is only one element in the total bundle of costs faced by the retailer. In other words, complete pass-through is defined by the share of the imported item in total costs. For Australia, this share appears to be around two thirds (Prices Surveillance Authority (1989), Dwyer and Lam (1994)).

This characteristic of second stage pass-through is important because, in popular discussion, when movements in retail import prices are observed to fluctuate by less than those at the docks, there has been a tendency to claim that pass-through is incomplete. This need not be so. Investigations of second stage pass-through in Australia that include the experience of the early 1990s have found it to be complete in the long run. That is, around two thirds of a change in import prices (equal to the estimated share of imports in total costs) is eventually passed on at the retail level. But adjustment is very slow, implying that distributors sometimes vary their mark-ups substantially and for considerable periods of time. Furthermore, Dwyer and Lam (1994) found that the mark-up is usually inversely related to changes in the exchange rate so that, in the short run, there is some tendency to absorb the effects of currency depreciation.[19]

We estimate the second stage pass-through relationship, with retail import prices modelled as a mark-up on landed import prices and unit labour costs; the mark-up is allowed to vary over the cycle.[20] Again, we use a standard error correction model, as detailed in Appendix C. Initially, we make no allowance for special factors that may have affected the pass-through relationship and our model yields broadly similar results to those in Dwyer and Lam (1994). The actual and fitted values from this basic model are illustrated in Figure 6. The model explains retail import prices reasonably well (even during earlier episodes of exchange rate shocks). However, since mid-1998, actual prices have been less than predicted.

Does this represent a change in the pass-through relationship or is it the result of special factors? In the Australian case, there would appear to be at least some role for special factors. Motor vehicles account for a substantial share of retail imports,[21] and their prices have been depressed by increased domestic competition in the automotive industry following the efforts of Asian suppliers to expand their share of the Australian market. This culminated in aggressive discounting of motor vehicles sourced from Asia, particularly during the Asian financial crisis.[22]

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18 Assuming a Cobb-Douglas production function.

19 However, Dwyer and Lam (1994) found that the inverse relationship between the mark-up and the exchange rate was less evident during the large depreciation of the mid-1980s. They concluded that the magnitude of the depreciation appeared to force many firms out of their “band of inaction” and pass on higher import prices much more quickly. So despite the fact that the experience of the mid-1980s was itself unusual, it has influenced popular expectations about the behaviour of retail import prices.

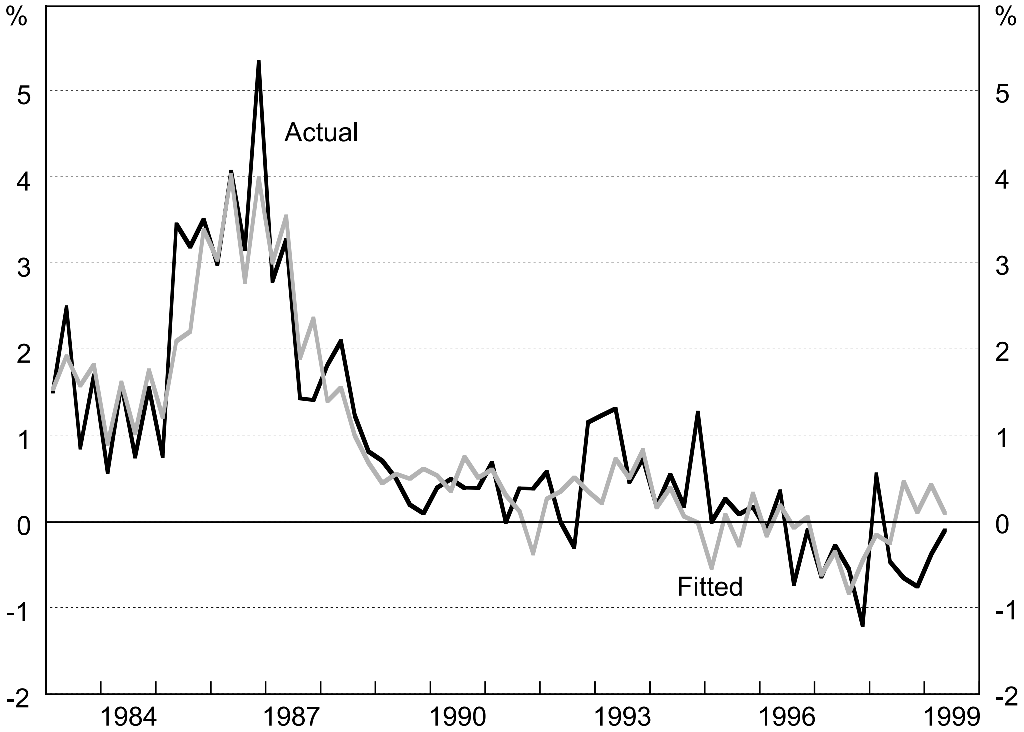
20 In our model, domestic costs are represented only by unit labour costs rather than the more comprehensive cost index used by Dwyer and Lam (1994).

21 With a weight of 16% in the imported component of the CPI.

22 For a more detailed discussion, see Reserve Bank of Australia (1999).

Figure 6: Actual and fitted retail import prices

Quarterly percentage change



We model the second stage pass-through relationship excluding motor vehicles, also detailed in Appendix C. The results are summarised in Figure 7, which compares actual and fitted retail import prices. The extent of over-prediction has been reduced, so that the experience of the late 1990s now looks less unusual. But although the prediction error is not exceptionally large, it remains slightly more persistent than was previously the case. This persistence is statistically significant: only by employing a dummy variable (from the June quarter 1998) is the familiar second stage pass-through relationship restored.[23] Since these developments occur at the end of the sample period, it is difficult to determine whether there has been a temporary disturbance to the pass-through relationship, or a permanent change. Indeed, it is too soon to tell.

One interpretation is that there has been a temporary disturbance to the pass-through relationship, perhaps stemming from a widespread but short-lived discounting of goods sourced from Asia following the Asian financial crisis. Alternatively, there may be more pervasive forces at work that are placing sustained downward pressure on either the domestic costs involved with the distribution and sale of imports, or the mark-ups expected by retailers. These forces would imply a structural change in second stage pass-through and diminish the inflationary consequences of a given shock to import prices at the docks.

We can obtain some insights into the possible behaviour of the distributors' mark-up. Deviations of retail import prices from their long-run equilibrium, which are captured by the error correction term in our equations, imply a variation in the mark-up. We use the error correction term as a measure of the mark-up.[24] These terms, from both models, are plotted in Figure 8.

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[23] See Appendix C.

[24] The mark-up is $\lambda_t = r_t - (a)p_t - (1-a)c_t$, where *r* is the log of retail import prices, *p* is the log of landed import prices, *c* is the log of unit labour costs and *a* and *1-a* are the long-run elasticities reported in Appendix C.

Figure 7: Retail import prices, excluding motor vehicles

Quarterly percentage change

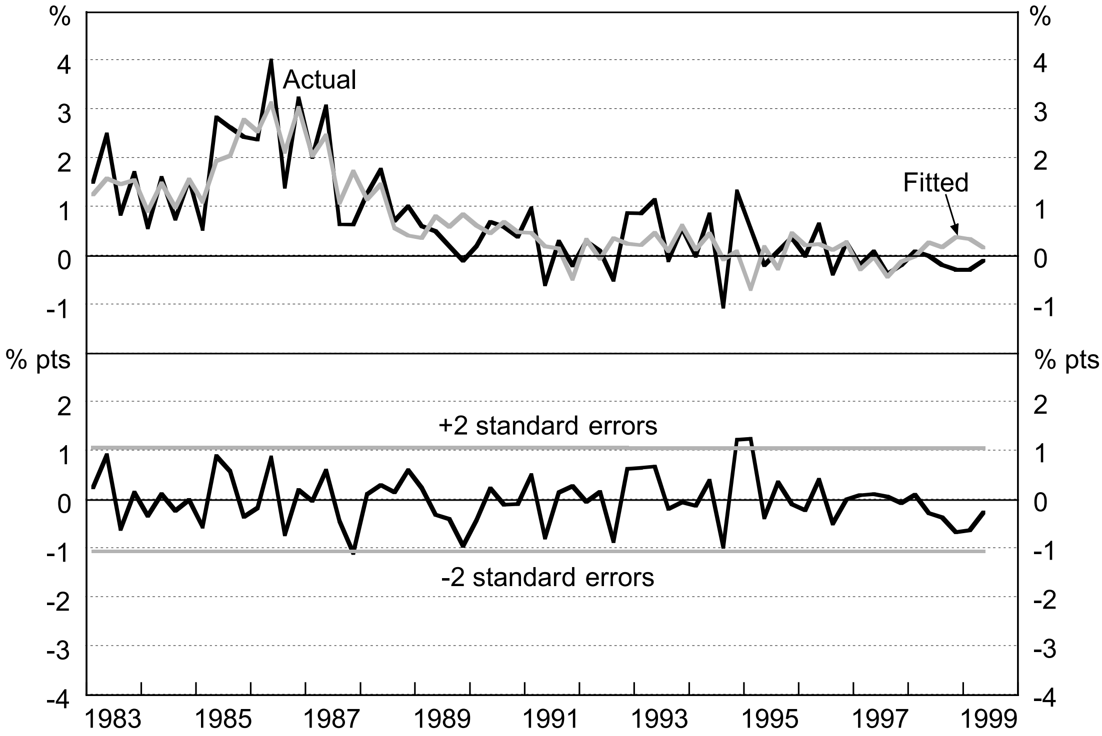
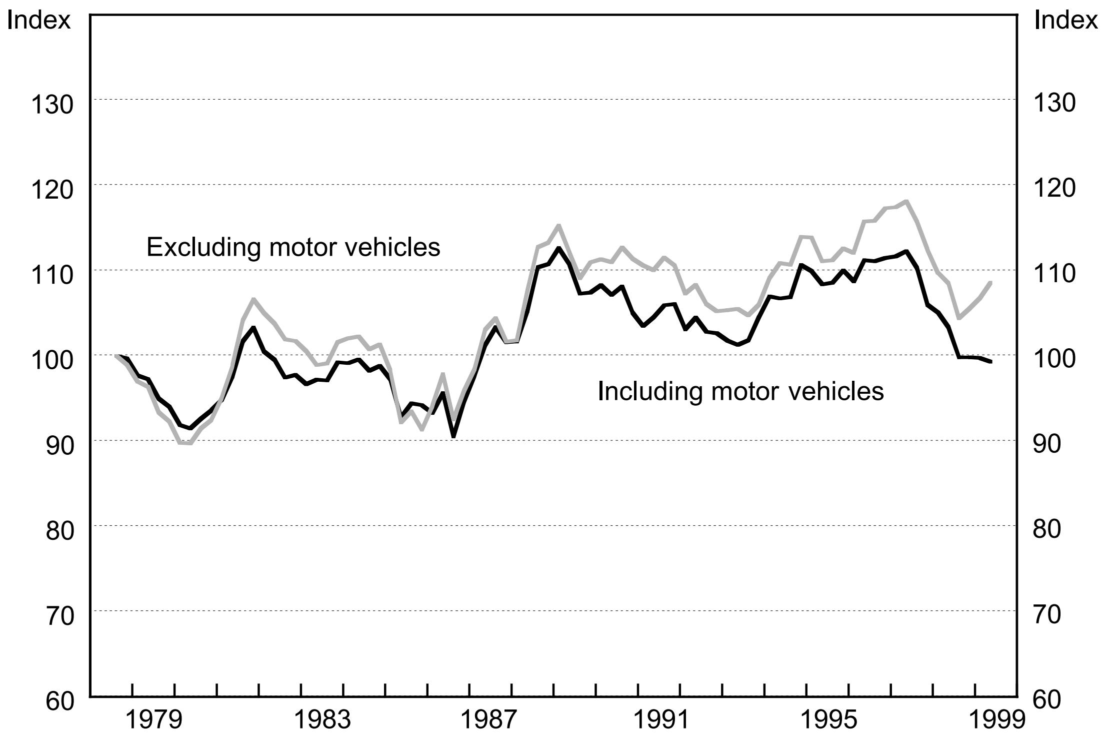


Figure 8: The importers' mark-up

September 1979 = 100



A protracted or unusually large change in the mark-up could suggest the possibility of structural change in the pass-through relationship. However, there is no suggestion of a downward drift in the mark-up during the 1990s. Neither is it clear that the mark-up is now established at a rate below historical norms. The two recent episodes of sharply falling mark-ups follow a period in which the mark-up was high.[25]

The recent behaviour of retail import prices has clearly been helpful for inflation. While the behaviour is unusual, it is too soon to tell whether it stems from temporary influences or is the result of a more fundamental change in the pass-through relationship.

3.2 Wage developments

Of all the influences on final prices, unit labour costs have the largest long-run effect. Furthermore, in the Australian experience, they are passed on more quickly than changes in other costs.[26] So, for a given rate of labour productivity, wage developments are central to inflation performance.[27] The 1990s witnessed significant changes in the wage setting system in Australia, which have implications for the propagation of wage shocks and thereby inflation.

For much of the last century, wage determination in Australia had two defining features: the bulk of wages were centrally determined, and they were indexed (either partially or fully) to the cost of living.[28] In the 1990s, however, there was a move towards enterprise-based agreements.[29] Consequently, at present, roughly 40% of employees are covered by enterprise agreements, 40% are covered by individual contracts and roughly 20% remain in the centralised system (DEWRSB (2000)).[30] The resultant changes in the process of wage bargaining served to undo some longstanding traditions, the first of which was the tendency to preserve wage relativities between workers.

The tradition of preserving wage relativities, known as "comparative wage justice", had the result that an increase in wages in one sector was usually quickly transmitted to other sectors and resulted in a generalised wage increase. However, under the more recent decentralised system, there has been a greater tendency for wage rises in a given sector to be "quarantined" and not to lead to a generalised wage increase. The effects of this can be summarised by the coefficient of variation in industry wages, shown in Figure 9.[31] Variation in wage growth between industries appears to have increased in the 1990s. Consequently, the pockets of high wage growth during the mid-1990s did not become generalised, leaving aggregate wage growth at a rate consistent with low inflation.

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25 Even though the mark-ups shown here are the error correction terms of our equations, a very similar pattern of mark-up behaviour in the 1990s can be found in independent estimates of the mark-up obtained by dividing earnings (before interest and depreciation) by sales, and measures of profitability recorded in surveys.

26 See de Brouwer and Ericsson (1995) and Dwyer and Lam (1994). This may reflect perceptions that changes in wages are permanent while changes in other costs, such as those stemming from exchange rate fluctuations, are temporary.

27 Indeed, proponents of purchasing power parity would argue that any shock to foreign prices will be associated with an offsetting currency movement so that domestic prices are unchanged. In this case, in the long run, domestic inflation should be determined by domestic costs, such as wages.

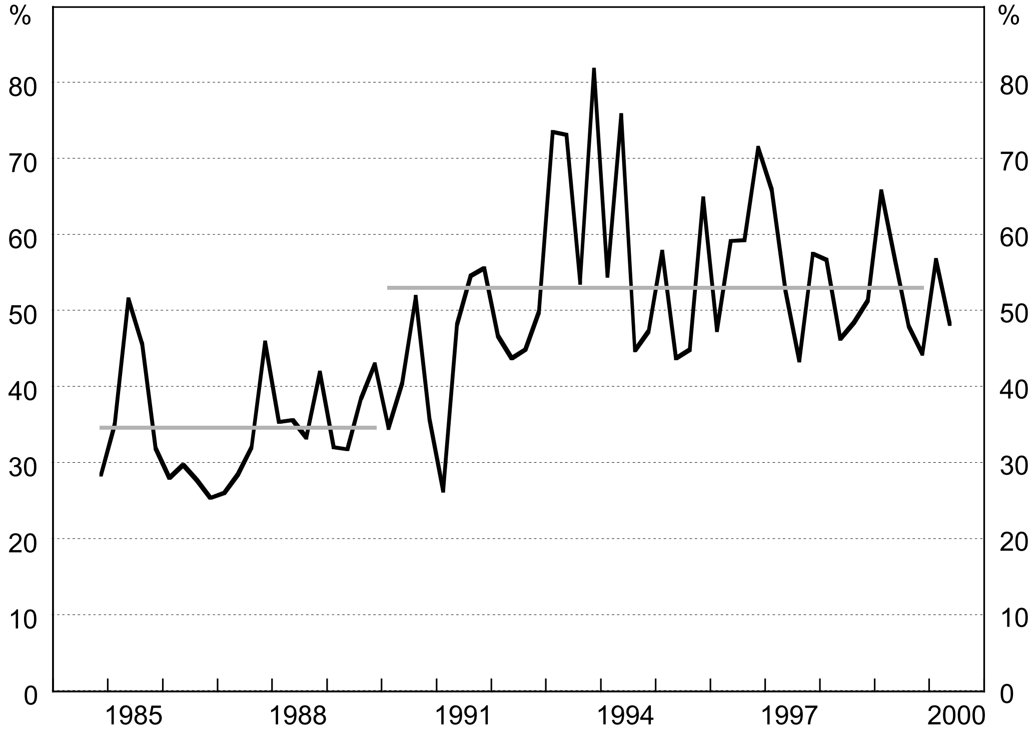
28 This is, of course, a gross simplification. For a detailed discussion of the wage determination system in Australia, see Niland (1986) and for the period of the Prices and Incomes Accord between labour and the government that operated in the 1980s, see Lewis (1993).

29 For a detailed discussion, see Wooden (2000).

30 Workers who are unable to secure wage rises through enterprise bargaining receive "safety net" adjustments of their awards which are determined centrally by the Australian Industrial Relations Commission.

31 A consistent series of industry-based wage data is not available for the run of years that we wish to consider. We are confined to using the average ordinary-time earnings of adults working full-time in each industry. These data are available from 1983. Before calculating the coefficient of variation, extreme wage changes (that are likely to reflect sampling problems) were trimmed from the distribution.

Figure 9: Coefficient of variation in annual industry wage growth



Note: The horizontal lines represent period averages.

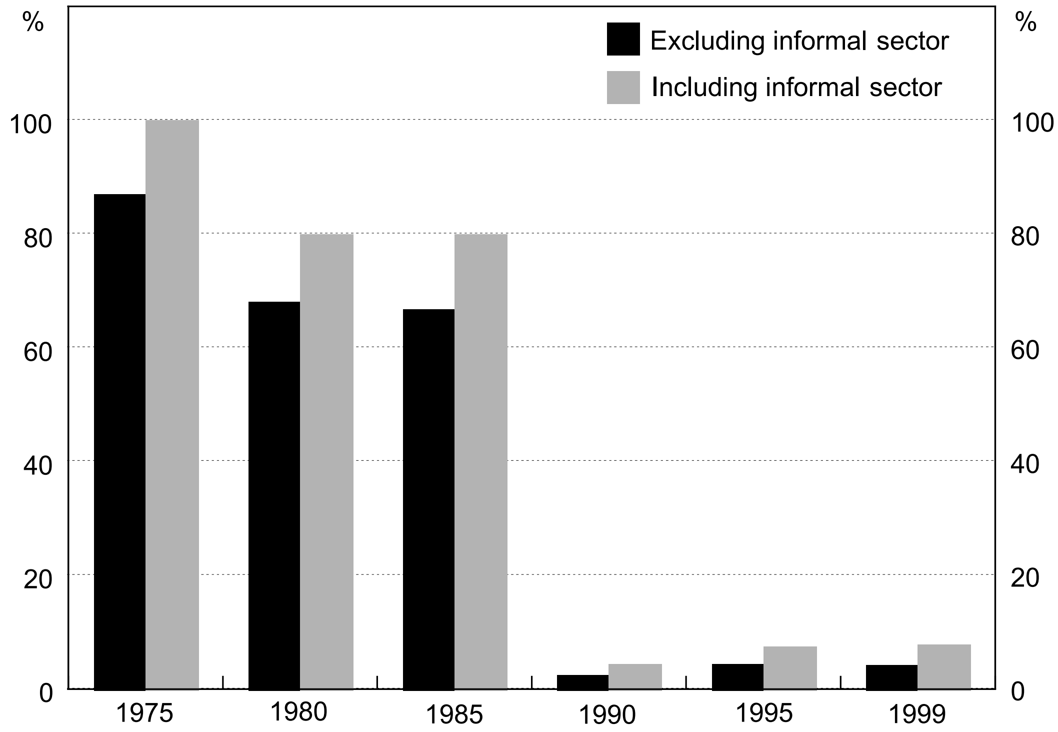
Another important consequence of more decentralised wage bargaining is the reduced tendency for automatic indexing of wages to prices, removing a mechanism for the direct transmission of prices to wages. For much of the period of centralised wage determination, there was some form of regular indexation of wages to the cost of living (usually measured by the CPI). In the current system, though, indexation does not generally occur. Rather, it occurs if there is a cost of living adjustment clause in the enterprise agreement or a clause that permits wages to be renegotiated in the event of surprise inflation. However, relatively few enterprise agreements have explicit clauses of this nature. Indexing has, in effect, been replaced by incorporating expected inflation into initial wage demands.

A crude indication of the shift away from automatic wage indexation is given in Figure 10, which attempts to capture the extent to which wages are indexed to the CPI.[32] Two sets of estimates are presented. One set assumes that informal sector contracts (about which there is little published information) are not indexed. The second set assumes that informal sector contracts are indexed in the same way as other types of wage contracts. Regardless of the assumptions, though, there has been a clear regime change in the 1990s. No longer are the bulk of wages in the economy subject to automatic indexation. This diminishes the transmission of price shocks to wages and the potential for a wage-price spiral.

32 For details about how these estimates have been derived, see Appendix A.

Figure 10: Indexation of wages to prices

Share of wages subject to indexation



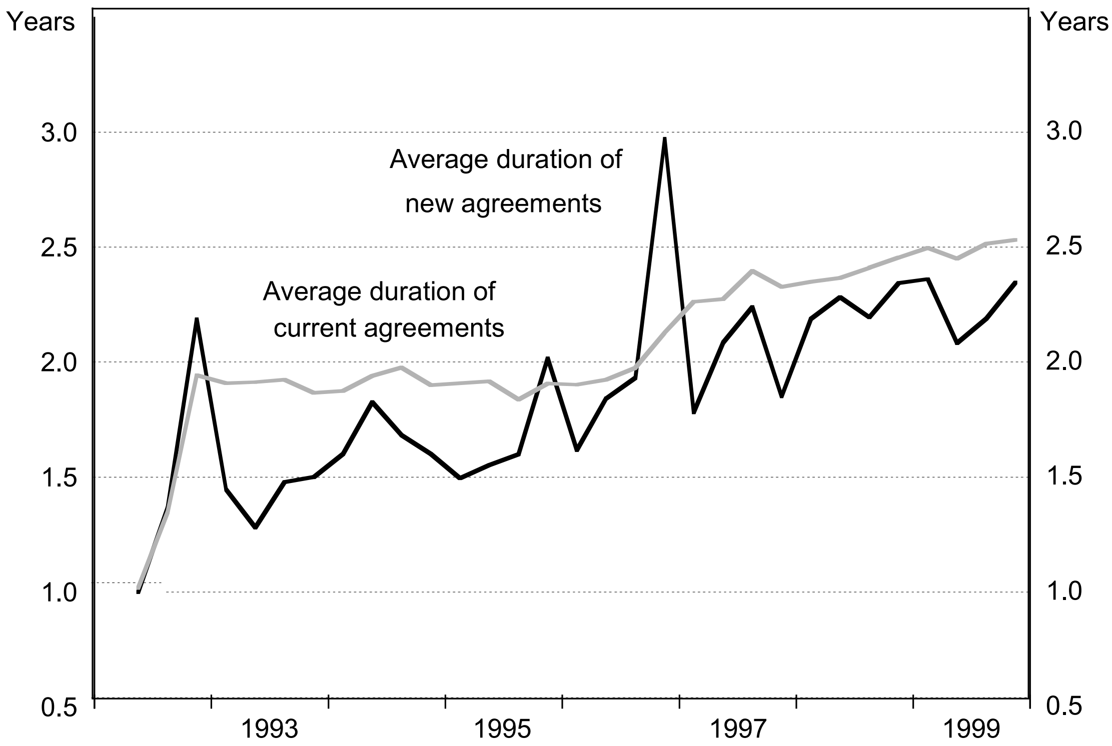
Along with these changes, there has been an increase in contract duration, which has imparted some inertia into the wage setting process. This is highlighted in Figure 11, which plots the average duration of formal federal enterprise agreements since the introduction of the new wage setting system. The duration of new federal agreements registered in each quarter and the duration of all currently active agreements are shown.[33] The general increase in duration is consistent with an environment of low and stable inflation; with lower uncertainty about inflation, agents are likely to revise contracts less frequently.[34] At the same time, the nominal rigidity introduced by longer contract duration means that wage changes may represent a more persistent shock to prices than previously. As it happens, in the second half of the 1990s, this shock was a small one, and so was helpful to the maintenance of low inflation.

The permanency of the regime change in wage setting arrangements can, however, be overstated. The economies of scale in bargaining are encouraging some labour market participants to seek more coordinated industry-wide bargaining rather than negotiating at the workplace level. If uncertainty about the future path of inflation increases, wage indexation may become fashionable again. And a reduction in macroeconomic stability may encourage more frequent resetting of wage contracts. But notwithstanding these possibilities, the containment of sectoral wage pressures, combined with an increase in the duration of contracts with modest rates of wage growth, has made it easier to maintain the low inflation outcomes of the 1990s.

[33] The Department of Employment, Workplace Relations and Small Business (DEWRSB) maintains a census of formal enterprise agreements in the federal jurisdiction.

[34] While reduced uncertainty about inflation reduces the need to revise contracts, under the new system of enterprise bargaining in Australia, increased contract duration is also a function of increased maturity in the bargaining process.

Figure 11: Duration of registered federal enterprise wage agreements



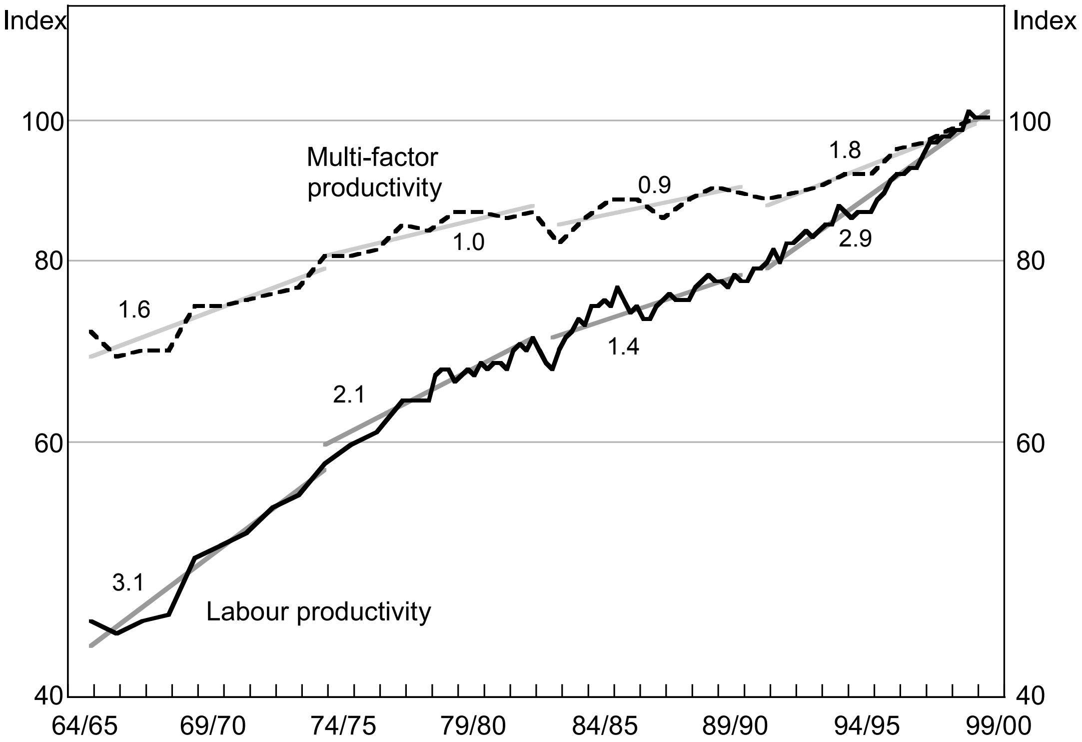
3.3 Productivity

Another important influence on inflation performance in the 1990s has been the sustained strength of labour productivity growth which, like inflation, has returned to rates not witnessed for more than a generation.

Figure 12 presents trends in market sector productivity since the mid-1960s, and is taken from Gruen and Stevens (2000). Measured productivity growth tends to vary during the course of a business cycle, as inputs are used more intensively when demand is increasing than when it is slowing. Consequently, we focus on average rates of productivity growth over entire economic expansions, depicted here by the trend lines.[35] Growth rates of both labour and multi-factor productivity are clearly faster than in the economic expansions of the previous two decades, while growth in multi-factor productivity now exceeds that in the 1960s. The pickup in labour productivity growth tends to attract most attention. However, the growth in multi-factor productivity (which abstracts from the effects of substitution between labour and capital) provides even more compelling evidence that there was an increase in the rate of technological progress in the 1990s.

35 That is, from troughs to peaks in output. See Gruen and Stevens (2000) for a more detailed discussion.

Figure 12: Productivity in the market sector
1998/99=100, log scale



Workers do not appear to have captured all of the productivity gains in the form of higher real wages.[36] Consequently, the increase in trend productivity growth has been associated with low growth in unit labour costs, which has imparted a clear disinflationary impulse. In fact, in Australia over the past decade, the weakness in unit labour cost growth has resulted in a fall in labour's share of income, suggesting that the strength of productivity growth in the current expansion may not have been fully appreciated by wage negotiators.

While the trend increase in productivity has lowered growth in unit labour costs, it has also increased potential output in the economy, so that supply side constraints on prices are less binding. However, the extent to which this has occurred is difficult to determine. Assessments of potential output, and the attendant output gap, are better done in retrospect than in real time. There is the inherent "end point problem" involved in determining the trend rates of output growth from which we gauge potential, and a tendency for output data to be revised. Consequently, real-time assessments of output gaps are often wrong (Orphanides (2000)).[37] If there has been belated recognition of the strength of productivity improvements in the 1990s, actual output gaps may be wider than those that have informed policy decisions, playing a role in the surprisingly low inflation outcomes of recent years.

Although the structural improvement in productivity during the 1990s would appear to have been a helpful influence on inflation outcomes, it is less clear that its effects will be ongoing. High productivity is not a sufficient condition to achieve low inflation. Rather, it makes it easier to achieve low inflation once monetary policy is "committed to that end" (Gruen and Stevens (2000)).[38] And much depends on how the gains from productivity are distributed between prices, profits and wages. While the

[36] Certainly, real wages (both real product and consumption wages) have grown at a rate less than trend productivity.

[37] For example, in the 1970s policymakers thought that output gaps were much larger than they actually were, because of belated recognition of a productivity slowdown (Orphanides (2000)).

[38] As Gruen and Stevens (2000) point out, the experience of the second half of the 1970s is a reminder of how high productivity can be associated with high inflation.

experience of the 1990s was one in which a significant share of the gains from higher productivity was reflected in lower prices, in another episode the distribution of gains may be quite different, and may carry different implications for inflation.

4. The inflation process

The 1990s witnessed changes in the behaviour of key explanators of inflation that have been conducive to low inflation. Some of this behaviour was unusual and some has been indicative of a more structural, although not necessarily permanent, change. Taken together, have these developments generated a change in the inflation process?

To answer this question, we first appeal to econometric evidence of structural breaks in a mark-up model of inflation for Australia. We refer to the inflation equation, detailed in Beechey et al (2000), in which prices are modelled as a mark-up on import prices and unit labour costs; the mark-up is allowed to vary cyclically with the output gap and is also influenced by oil prices.[39] (The equation has been estimated using an error correction specification.)

Beechey et al (2000) have examined the stability of this equation, focusing on whether a structural break is evident in the March quarter of 1993, which corresponds to the introduction of the inflation targeting regime. While their purpose was to test the relevance of the Lucas critique for the model, given the change in articulation of monetary policy objectives the same break point usefully defines the beginning of the current low-inflation episode. They found that a structural change in the inflation process in the post-break period is not indicated by standard Chow-type tests (on the significance of individual dummies or on their joint significance). However, this standard test of structural stability may mask useful details of changes in the way shocks to inflation are propagated.

An alternative insight into possible structural changes in the inflation process can be gleaned by examining the speed with which inflation responds to disequilibrium in the long-run relationship between prices and costs. The error correction specification of the inflation equation is helpful in this regard because it features a speed of adjustment parameter. We re-estimate the Beechey et al inflation equation over a slightly longer sample, and test the stability of the speed of adjustment parameter by using recursive estimation. (That is, we estimate the equation from the March quarter of 1985 up until the March quarter of 1990, and then successively re-estimate the equation over samples that have been extended by one quarter.)[40] The speed of adjustment parameter is plotted for each sample period in Figure 13.

A widely held view is that the low-inflation environment of the 1990s was accompanied by an increase in inertia in the inflation process. If so, we would expect to see a fall in the speed of adjustment. Within the bounds of our confidence interval, such a fall is possible. However, our point estimates of the speed of adjustment parameter were fairly stable during the 1990s.

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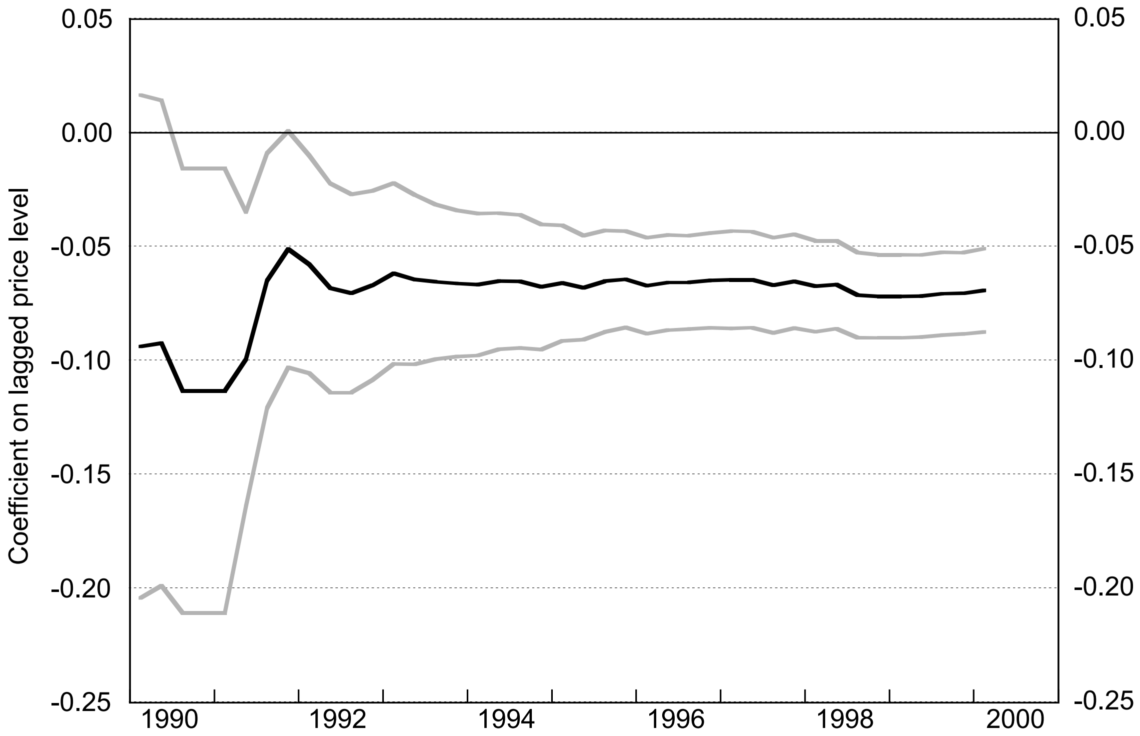
39 See Beechey et al (2000) for a detailed discussion of the properties of this equation.

40 See Appendix D. The start date for estimation of the inflation equation remains the March quarter of 1985 but our sample end point is more recent than that in Beechey et al (2000). Earlier start dates are often associated with structural instability that stems from the major shifts in labour's share of income in the mid-1970s and early 1980s.

Figure 13: Speed of adjustment



Note: The black line is the point estimate of the speed of adjustment parameter and the shaded lines represent the 95% confidence interval of this estimate.

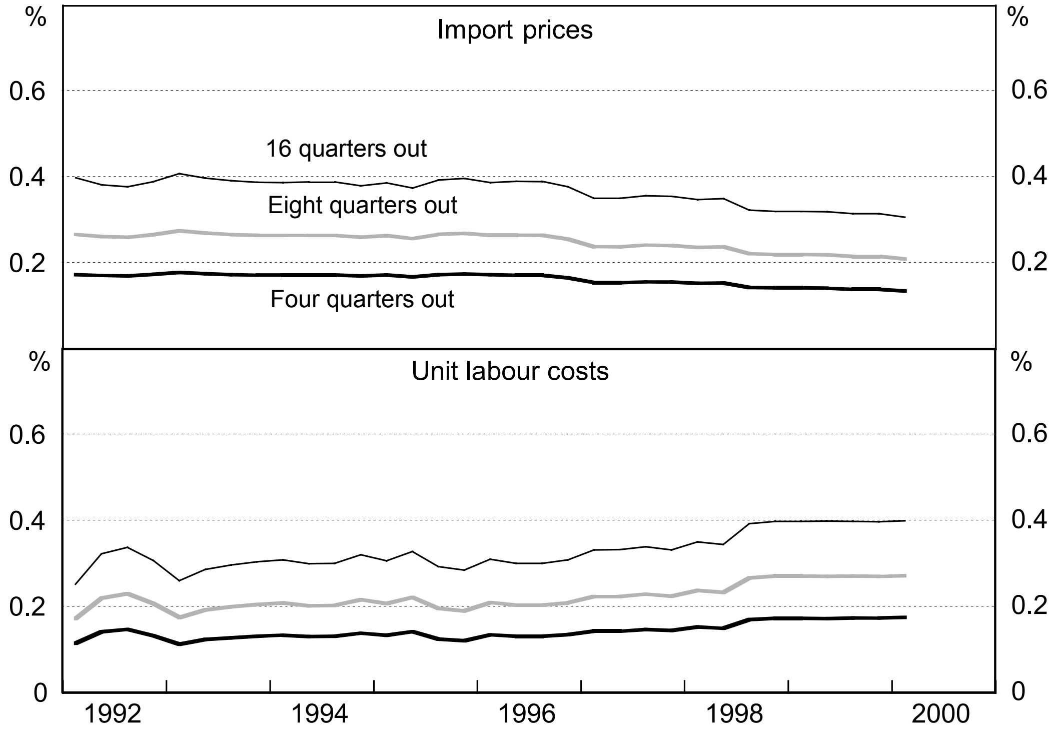
While the speed of adjustment parameter determines the eventual length of time taken to restore long-run equilibrium following a shock, the path of adjustment to equilibrium is also influenced by short-run dynamic terms. To examine this path of adjustment, we use impulse response functions. We identify the magnitude of the response to a shock that has occurred after a given number of quarters. By using recursive estimation, we identify whether this magnitude has changed through time. The top panel of Figure 14 presents results for a permanent 1% increase in import prices. Each line traces the extent to which adjustment is estimated to have occurred by the period shown. The bottom panel presents the corresponding results for unit labour costs.

Our estimation suggests that since the mid-1990s, there has been a slight downward drift in the degree of response of consumer price inflation to a shock to import prices. This is most evident over time horizons greater than four quarters. The corollary of this change has been a slight upward drift in the degree of response of inflation to a shock to unit labour costs.[41] In each case, the degree of change is not statistically significant. The confidence intervals around the point estimates in the early part of the sample overlap with those at the end of the sample, making it unlikely that any statistical test will reject the hypothesis of "no change" in the adjustment process.[42] The changes in point estimates that we observe would, however, be economically significant in the presence of large shocks to either import prices or unit labour costs.

[41] Linear homogeneity is accepted and imposed in the model. Therefore, a change in the estimated long-run response of consumer prices to a (permanent) import price shock is offset by an equal but opposite change in the response to a unit labour cost shock.

[42] To avoid clutter, the confidence intervals around each set of point estimates have not been drawn in Figure 14.

Figure 14: Response of consumer prices to shocks; stability of adjustment



Suppose that these point estimates of the degree of response to shocks capture actual changes in the nature of adjustment. Since the incentive to reset prices increases with the persistence of the shock to costs, one interpretation of the results is that, over the past decade, there has been a growing tendency for price setters to perceive import price shocks as transitory and unit labour costs shocks as persistent.[43] Such a change in responsiveness to shocks is consistent with low inflation outcomes because shocks to unit labour costs - that is, the more persistent of the shocks - were relatively small, especially during the second half of the 1990s.

Two of our tests of structural stability (the Chow-type test and the examination of the speed of adjustment parameter) fail to provide evidence of a change in the inflation process during the 1990s. Our third test, which focuses on the dynamics of adjustment to a shock, gives a much stronger suggestion that a change has occurred, although the results are not statistically significant. Ideally, to obtain a clearer picture, we would compare the degree of response to shocks in the 1990s with that in an earlier decade. In principle, this could be achieved by choosing an earlier start date for estimating our mark-up model of inflation and performing recursive regressions that, say, captured the experience of the 1980s. However, estimation of a mark-up model over longer samples is difficult, due to the major shifts in labour's share of income during the 1970s and 1980s.[44] Equations estimated over some longer samples display structural instability. Perhaps part of this instability reflects a change in the inflation process that we have not uncovered. But the popular view is that such change, should it have occurred, would be evident during the 1990s. Our results hint at some evolution of the inflation process over this period.

[43] See Taylor (2000) for a detailed analysis of the impact of perceived persistence of shocks in pricing behaviour.

[44] Given that labour's share of income is, in effect, the reciprocal of a mark-up. For a detailed discussion of the difficulty in estimating mark-up models in the presence of shifts in labour's share of income, see Cockerell and Russell (1995).

5. Conclusion

Inflation in the past decade in most industrialised countries, including those without inflation targets, has been surprisingly low. At issue is whether this outcome is the product of favourable shocks or a fundamental change in the inflation process.

We find that some of the determinants of inflation in Australia have undergone unusual or structural change in recent years, the effects of which have been clearly disinflationary. Consequently, an unexpectedly benign inflation environment has played an important role in the low inflation outcomes of the 1990s. We also find tentative evidence that, for some determinants, there has been a change in their relationship with inflation. These changes are not very statistically significant, and should be interpreted cautiously. They may, however, be economically significant. Furthermore, they appear to have been evolving throughout the past decade. This leaves open the possibility that some forces may be emerging that could help reduce the variability of inflation in response to shocks.

Despite this possibility of change, it cannot be said that the inflation process in Australia has become permanently more immune to shocks. The future may hold unhelpful influences on inflation. If these influences are large or persistent, inflation may not turn out to be as well behaved as it was in the 1990s. There remains an important role for monetary policy to anchor price expectations and convince the community that, while some variation in inflation is inevitable in the face of shocks, price stability will be quickly restored.

Appendix A: Data

Nominal exchange rate

Definition: Australian dollar against a nominal GDP-weighted average of G7 currencies. Indexed to 1980 = 100.

Source: Reserve Bank of Australia, unpublished data.

Import prices at the docks

Definition: Implicit price deflator for merchandise imports, excluding fuels and lubricants, civil aircraft and Reserve Bank of Australia imports of gold. Indexed to 1989/90 = 100.

Source: *National Income, Expenditure and Product*, ABS Cat No 5206.0.

Reserve Bank of Australia imports of gold data not publicly available.

Tariff rate

Definition: Customs duty receipts divided by the value of merchandise imports (excluding fuels and lubricants, civil aircraft and Reserve Bank of Australia imports of gold). Seasonally adjusted.

Source: Australian Customs Service.

Retail import price

Definition: Final price of items wholly or predominantly imported in the consumer price index.

Source: *Consumer Price Index; Effect of Change in Prices of Imported Items*,

ABS Cat No 6444.0.

Foreign export prices

Definition: Nominal GDP-weighted average of G7 export price indices. Indexed to 1990 = 100.

Source: Export price indices from Datastream.

Foreign consumer prices

Definition: Geometric import-weighted average of core consumer prices of G7 countries. Calculated as the ratio of nominal and real G7 import-weighted exchange rates. Indexed to 1989/90 = 100.

Source: Reserve Bank of Australia, unpublished data.

Oil price

Definition: Australian dollar price of West Texas Intermediate crude oil per barrel. Calculated using the US dollar price per barrel of West Texas Intermediate crude oil and the AUD/USD exchange rate. Indexed to 1989/90=100.

Source: Bloomberg, nearest contract price CL1 CMDTY.

Consumer price index (CPI)

Definition: Acquisitions consumer price index. Indexed to 1989/90 = 100.

Source: *Consumer Price Index*, ABS Cat No 6401.0.

Treasury underlying CPI

Definition: Consumer price index excluding selected items defined to be seasonal, volatile or non-market determined. Indexed to 1989/90 = 100.

Source: Commonwealth Treasury Department published in *Consumer Price Index*, ABS Cat No 6401.0.

Unit labour costs

Definition: Non-farm unit labour costs per hour per wage and salary earner.
Indexed to 1989/90 = 100.

Total non-farm labour costs (wage and salary earners) per hour divided by productivity per hour in the non-farm sector.

Source: *National Income, Expenditure and Product*, ABS Cat No 5206.0.

Non-wage labour costs data obtained by special request from the ABS.

Industry wages

Definition: Average ordinary-time earnings of adults working full-time, by industry. These data are only available since 1983. For manufacturing wages used in Table 1, in the period prior to 1983, average total earnings for all adult males are used.

Source: *Average Weekly Earnings*, ABS Cat No 6302.0.

Type of wage contract

Definition: Awards are determinations of federal or state industrial tribunals that apply to workers in their jurisdiction. Enterprise agreements are those wage contracts negotiated collectively at the enterprise or workplace level that are registered with the Australian Industrial Relations Commission. Awards and registered collective agreements are said to comprise the "formal" sector. All other wage contracts are defined as "informal".

Sources: *AWIRS95*, *AWIRS90*, *Award and Agreement Coverage Survey* (1999), *Award Coverage in Australia*, ABS Cat No 6315.0.

Indexation of wages to prices

Method: In each period, the share of the wage contracts eligible for indexation is identified and then multiplied by the degree of indexation. Initially, only wage contracts in the formal sector (about which there is more data) are considered eligible for indexation. Subsequently, assumptions are made about the possible extent of indexation in the informal sector.

Formal sector:

From 1975 to 1985, only awards are considered eligible for indexation. Awards as a share of wage contracts are multiplied by the rate of indexation awarded in the national wage case of that year to give a measure of the extent to which all wage contracts are indexed.

From 1990, with the cessation of wage indexation in national wage cases, only those enterprise agreements with indexation clauses are considered eligible for indexation. For simplicity, full indexation is assumed.

Informal sector:

From 1975 to 1985, non-award contracts comprise the informal sector. In each period, these contracts are assumed to receive the same rate of indexation as that prevailing in the formal sector.

From 1990, the informal sector comprises wage contracts other than awards and registered collective enterprise agreements. In each period, it is assumed that the share of informal wage contracts subject to indexation is the same as that for enterprise agreements with indexation clauses. For simplicity, full indexation is assumed.

Sources: *AWIRS95*, *AWIRS90*, *Award and Agreement Coverage Survey* (1999), *Award Coverage in Australia*, ABS Cat No 6315.0, national wage cases summarised in Plowman (1986) and ACTU (1996).

Output gap (economy wide and retail)

Definition: Potential output less actual output. Potential output is obtained by smoothing actual output with a Hodrick-Prescott filter. To avoid “starting point problems”, the filter is commenced five years before the beginning of the estimation period for the output gap.

Source: *National Income, Expenditure and Product*, ABS Cat No 5206.0.

Appendix B: First stage import price equation

The first stage pass-through relationship is estimated from the March quarter of 1985. Results from an error correction equation are shown below. In the equation, linear homogeneity is accepted and has been imposed.

Table B1

Explaining import prices[1]

(estimated from 1985 Q1 to 1999 Q3)

	Coefficient	**Std error**
Independent variable		
Constant	153.2712	40.2754***
Import prices (lag 1)	– 0.3345	0.0889***
World prices (lag 1)	0.3345	0.0889***
Exchange rate (lag 1)	– 0.3345	0.0889***
Change in the exchange rate (lag 0)	– 0.6572	0.0303***
Change in the exchange rate (lag 1)	– 0.0998	0.0462**
Change in world prices (lag 0)	0.5669	0.2115***
Change in world prices (lag 1)	0.3887	0.2113*
Trend[2]	– 0.1077	0.0261***
Dummy 1998 Q2-1999 Q3[3]	– 2.7964	0.6993***
Long-run elasticities		
World prices	1	
Exchange rate	– 1	
Adjusted R^2	0.9199	
Residual autocorrelation LM(4)		{0.0715}
Breusch-Pagan heteroscedasticity test		{0.0022}
Jarque-Bera normality test		{0.0302}
Linear homogeneity[4]		{0.9843}

[1] The equation is from Beechey et al (2000). ***, ** and * represent significance at the 1, 5 and 10% levels. Numbers in braces {} are p-values. All variables in log-levels are multiplied by 100 (so growth rates are in percentages). Given the evidence of heteroscedasticity, the standard errors reported are White heteroscedasticity-consistent standard errors. [2] The trend captures the shift in imports towards lower-priced goods from non-G7 countries. [3] The dummy captures price undercutting by Asian exporters following the Asian crisis. [4] Linear homogeneity implies that the coefficients of the world price and exchange rate are 1 and -1, ie the PPP restriction holds.

Appendix C: Second stage import price equation

The second stage pass-through relationship is estimated from the September quarter of 1978 to the June quarter of 1999, after which the retail import price series is discontinued. Results from error correction equations are shown below. The first table presents results for the case in which motor vehicles are included in the retail price of imports. The second table presents results for the case in which they are excluded and a dummy is imposed from the June quarter of 1998 to control for the effects of the Asian financial crisis. In both cases, linear homogeneity is accepted and has been imposed.

Table C1

Explaining import prices[1]

(estimated from 1978 Q3 to 1999 Q2)

	Coefficient	Std error
Independent variable		
Constant	– 16.6578	3.7844***
Retail import prices (lag 1) – Unit labour costs (lag 1)	– 0.0834	0.0166***
Landed import prices (lag 1) – Unit labour costs (lag 1)	0.0541	0.0088***
Change in retail import prices (lag 2)	0.4261	0.0996***
Change in retail import prices (lag 3)	– 0.0014	0.0858
Change in retail import prices (lag 4)	0.2352	0.0972**
Retail output gap (lag 2)	0.0017	0.0004***
Long-run elasticities		
Unit labour costs	0.3509	0.0939
Landed import prices	0.6491	0.0939
Adjusted R2	0.8048	
Residual autocorrelation LM(4)		{0.0664}
Breusch-Pagan heteroscedasticity test		{0.2251}
Jarque-Bera normality test		{0.2143}
Linear homogeneity[2]		{0.2672}

[1] ***, ** and * represent significance at the 1, 5 and 10% levels. Numbers in braces {} are p-values. All variables in log-levels are multiplied by 100 (so growth rates are in percentages). [2] Linear homogeneity implies that the long-run elasticities on unit labour costs and landed import prices sum to unity.

Table C2

Explaining retail import prices, excluding motor vehicles[1]

(estimated from 1978 Q3 to 1999 Q2)

	Original		With dummy variable	
	Coefficient	**Std error**	**Coefficient**	**Std error**
Independent variable				
Constant	–15.3484	3.5867***	–15.5766	3.5026***
Retail import prices (lag 1) – Unit labour costs (lag 1)	– 0.0583	0.0196***	– 0.0652	0.0194***
Landed import prices (lag 1) – Unit labour costs (lag 1)	0.0506	0.0109***	0.0561	0.0110***
Change in retail import prices (lag 2)	0.2657	0.0957***	0.2365	0.0944**
Change in retail import prices (lag 3)	0.0207	0.0830	– 0.0140	0.0826
Change in retail import prices (lag 4)	0.3021	0.0939***	0.2841	0.0921***
Retail output gap (lag 2)	0.0015	0.0004***	0.0016	0.0003***
Dummy 1998 Q2-1999 Q2			– 0.5589	0.2616**
Long-run elasticities				
Unit labour costs				
Landed import prices	0.1315	0.1669	0.1396	0.1439
	0.8685	0.1669	0.8604	0.1439
Adjusted R2	0.7399		0.7522	
Residual autocorrelation LM(4)		{0.3884}		{0.1421}
Breusch-Pagan heteroscedasticity test		{0.9904}		{0.9131}
Jarque-Bera normality test		{0.5714}		{0.6600}
Linear homogeneity[2]		{0.5983}		{0.8968}

[1] ***, ** and * represent significance at the 1, 5 and 10% levels. Numbers in braces {} are p-values. All variables in log-levels are multiplied by 100 (so growth rates are in percentages). [2] Linear homogeneity implies that the long-run elasticities on unit labour costs and landed import prices sum to unity.

Appendix D: Inflation equation

The inflation equation is estimated from the March quarter of 1985. Results from an error correction equation are shown below. In the equation, linear homogeneity is accepted and has been imposed.

Table D1

Explaining consumer prices[1]

(estimated from 1985 Q1 to 2000 Q1)

	Coefficient	**Std error**
Independent variable		
Constant	– 0.4277	0.3879
Consumer prices (lag 1)	– 0.0690	0.0091***
Unit labour costs (lag 1)	0.0391	0.0135***
Landed import prices (lag 1)	0.0299	0.0061***
Unit labour cost growth (lag 0)	0.0467	0.0308
Landed import price growth (lag 0)	0.0363	0.0139**
Oil price growth (lag 1)	0.0075	0.0030**
Output gap (lag 3)	0.1699	0.0270***
Change in the output gap (lags 0,1,2)[2]	0.0848	0.0345**
Dummy 1990 Q4[3]	0.9766	0.3041***
Dummy 1991 Q1	– 1.3333	0.3033***
Dummy 1999 Q1	– 0.4824	0.2721*
Long-run elasticities		
Unit labour costs	0.5662	0.1296
Landed import prices	0.4338	0.1296
Adjusted R2	0.8670	
Residual autocorrelation LM(4)		{0.3810}
Breusch-Pagan heteroscedasticity test		{0.1439}
Jarque-Bera normality test		{0.5399}
Linear homogeneity[4]		{0.1819}

[1] The equation is an updated version of that in Beechey et al (2000). ***, ** and * represent significance at the 1, 5 and 10% levels. Numbers in braces {} are p-values. All variables in log-levels are multiplied by 100 (so growth rates are in percentages). [2] The restriction that the coefficients on each lag are equal is accepted and imposed. [3] The dummies allow for large but short-lived spikes in oil prices. [4] Linear homogeneity implies that the sum of the coefficients of unit labour costs and landed imported prices is equal to the absolute value of the coefficient of consumer prices.

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Productivity growth and prices in Canada: what can we learn from the US experience?

Tiff Macklem and James Yetman[1,2]

Abstract

In recent years, there has been increasing discussion about the possible emergence of a “new economy”. In this paper we review recent developments in productivity growth and prices of final goods and services in the United States in an effort to identify early indicators of whether the Canadian economy is on a path to follow the United States to higher productivity growth. We put particular emphasis on the behaviour of prices, since monetary policy in Canada is directed towards maintaining low and stable inflation.

Although there is little evidence to date of a US-style acceleration in productivity growth in Canada, we suggest that there are several reasons to be cautiously optimistic that Canada will follow the US experience to some degree. We formalise one aspect of this hypothesis using estimated, expectations-augmented Phillips curves. We present evidence for the United States of changes in the relationship between prices and output that would be consistent with the emergence of the new economy, the effects of which have been largely concentrated in the provision of final goods. We then provide evidence of a similar break for Canada in 2000. However, with only two quarters of data for 2000, considerable uncertainty remains as to the timing, size and duration of any acceleration in productivity growth in Canada.

1. Introduction

In recent years, there has been increasing discussion about the possible emergence of a “new economy”.[3] In its extreme form, proponents claim that existing economic paradigms no longer apply due to recent technological innovations, and economic growth may remain at historically high levels indefinitely without stimulating inflation. They argue that increased globalisation has decreased or removed the potential for domestic firms to increase prices in the face of high demand. As a result, evidence of increased demand does not require a tightening in monetary policy.

While many economists reject this notion of the new economy, there are others who believe that recent technological innovation has substantially reduced the cost of doing business, either directly or by raising the productivity of workers, and this has had the effect of allowing higher trend growth in output without stimulating inflation.

One early source of evidence on the new economy came from the information technology sector itself: one need look no further than the market for personal computers to observe increasing demand being met with higher-quality products at a decreasing price over time. If such price declines were contained within the IT sector alone, the new economy would have few implications for monetary policy, as relative price changes on computers and related goods would have relatively minor direct effects on

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1 This paper was prepared for the BIS conference on “Empirical studies of structural change and inflation”. The views expressed here are those of the authors. No responsibility for them should be attributed to the Bank of Canada.

2 The authors thank Jennifer Glahs for providing the estimates for the Fillion and Léonard model, René Lalonde and Danielle Lecavalier for assistance with the US data and estimates, Maral Kichian, David Longworth and participants at the BIS conference on “Empirical studies of structural change and inflation” for many helpful comments, and Annie De Champlain and Geoff Wright for excellent research assistance.

3 See Nakamura (1999), Sharpe (2000), Stiroh (1999) or Triplett (1999) and the references contained therein for discussions of the emergence of a “new economy”.

the broader price indices that are the focus of monetary policy. In recent years, however, there is some evidence for the United States that the effects of the new economy have spread so that the behaviour of inflation for the economy as a whole is significantly affected. To date, however, other economies have not shared in this experience to an important degree.

In this paper we review developments in productivity growth and the prices of final goods and services in the United States in the 1990s in an effort to identify early indicators of whether the Canadian economy is on a path to follow the United States to higher productivity growth. We put particular emphasis on the behaviour of prices. This reflects both the view that there is important information about productivity growth in the behaviour of prices, and the recognition that monetary policy is directed towards maintaining low and stable inflation. Thus, for monetary policy, a key issue is how the new economy is affecting the behaviour of inflation.

The paper proceeds in two sections. The first of these, Section 2, compares the behaviour of productivity and prices in the United States and Canada in the 1990s and considers alternative views of the new economy and their implications for Canada. In Section 3 we attempt to formalise one aspect of the story that we develop in Section 2, namely the evidence of a structural break in the behaviour of inflation. In particular, we consider the effects of the new economy on inflation in the United States, and examine the extent to which the recent behaviour of inflation in Canada shows a similar pattern to developments in the United States with a lag.

2. Productivity growth and prices in the United States and Canada

2.1 Some stylised facts

The performance of the US economy over the past several years has been remarkable. From 1995 to 1999, growth in real output in the United States has averaged about 4% and inflation has remained low - indeed, until recently, it was declining. This has been accompanied by a marked pickup in labour productivity growth that has restrained costs. Output per person-hour in the business sector grew at an average rate of about 2.5% from 1995 to 1999, compared to about 1.4% from 1973 to 1995. In other words, labour productivity growth is about 1 percentage point higher in the recent period.

Canada, however, has not experienced such an acceleration in productivity growth. Output growth per person-hour averaged just below 1% from 1995 to 1999, which is slightly less than the average rate of growth from 1973 to 1995.

These very different experiences are highlighted in Figure 1 which compares output per person-hour in the United States and Canada since 1993. To smooth out high-frequency fluctuations, the data are annual; the dotted lines for 2000 are the average of the first two quarters of 2000 relative to the first two quarters of 1999.[4] As shown, labour productivity in the United States moved above its historical average in 1996, and has continued to accelerate, moving above 4% in the first half of 2000. In contrast, labour productivity growth in Canada has fluctuated between about 0 and 2.5% over the same period, with no obvious change in trend.

Figure 2 points out that what is remarkable about the US experience in the 1990s is not the rise in productivity growth, but its timing. The typical cyclical pattern is for productivity growth to rebound sharply early in a recovery (eg 1976, 1983 and 1992), and then to weaken as the expansion matures (eg 1977-80, 1987-90). In the most recent US expansion, productivity growth has increased late in the cycle and continued to accelerate.

With higher productivity growth, output growth also increased late in the expansion, but less than productivity growth. The result, until recently, has been falling inflation. As shown in Figure 3, underlying inflation of final goods and services prices in the United States (measured as the CPI

[4] Canada-US comparisons, as with any international comparison of productivity performance, are plagued by differences between the data definitions and the methodologies used by the different national statistical agencies. In particular, the treatment of software as investment in the United States but not in Canada increases measured US productivity growth relative to Canada's. However, with the continued widening of the Canada-US productivity gap, it has become clear that the gap cannot be dismissed as a figment of measurement.

excluding food, energy and tobacco) began to drift down starting in about 1996 - the same year productivity growth began to pick up.

The Figure also points out that the decline in underlying inflation is almost entirely due to final goods prices. While the rate of increase in the prices of services has remained relatively stable at about 3% since 1996, the rate of change of final goods prices has fallen by more than 4 percentage points, from about 1.5% at the start of 1996 to less than -2.5% mid-1999. Historically, goods prices have increased less rapidly than services prices because of the higher trend productivity growth in the goods sector. There are also a variety of factors that affect relative goods and services prices. In particular, the appreciation of the US dollar has had a larger effect on goods prices than on services prices. Nonetheless, the dramatic fall in the price of final goods relative to final services suggests that it is in the provision of final goods that the new economy is having its main impact.

There are a number of possible reasons why this might be the case. If the new economy is fundamentally about globalisation, the lower level of competition in the provision of final services across national boundaries relative to final goods could explain the divergence in goods and services prices. Alternatively, it may be that recent innovations have been concentrated in areas that affect final goods prices. This includes the direct effects of price declines in new economy goods, like consumer electronics, as well as indirect effects of cost reductions in intermediate services that are important inputs into final goods (but not final services), such as wholesale and retail trade. Another possibility is that, independent of the form that the new economy takes, for many services it is difficult to separate changes in the quality and quantity of the services provided from changes in the price of those services. Therefore it is possible that evidence of the new economy would first appear in published data for the goods sector.

Turning to Canada, the picture is very different. As Figure 4 makes clear, productivity growth in the recent cycle looks much the same as in previous cycles. Following a marked cyclical rebound immediately following the 1991 recession, productivity growth since then has shown no trend increase. Underlying inflation has also shown no trend movement since the mid-1990s. As shown in Figure 5, the year-over-year rate of increase in the CPI excluding food, energy, tobacco and alcohol has remained relatively stable at about 1.5% since 1996.[5] Perhaps more significantly, there is no obvious trend in final goods prices relative to final services prices in the 1990s. As in the United States, the rate of increase of goods prices has been systematically below that of services prices, but in marked contrast to the United States, goods and services prices have moved up and down together. The very recent period starting in mid-1999 is the exception - a point we will return to below.

2.2 Is Canada following the United States to higher productivity growth?

To speculate intelligently on this question first requires a clear understanding of the resurgence in US productivity growth. This has been a very active area of research, as well as debate, and we make no attempt to summarise it systematically. Rather we focus on a few issues that are particularly relevant to Canada.

The rise in productivity growth in the United States lagged an acceleration in business spending on machinery and equipment by about four years. Figure 6 plots investment in machinery and equipment as a share of GDP, and starting in 1992 there is a very obvious trend increase in this ratio that shows no signs of abating.

Two reasons are typically cited for the increase in business investment in machinery and equipment. First, investment has been spurred in the United States by high levels of economic activity. With firms pushing up against capacity limits and facing a tight labour market, there has been a strong incentive to invest to increase both capacity and labour productivity. By itself, however, this probably cannot account for the acceleration in labour productivity. As discussed above in the context of Figure 2, the typical cyclical pattern is for the growth of labour productivity to decline as the economy reaches high levels of economic activity late in the cycle. This points to a second factor, namely the acceleration in

5 The Bank of Canada's official measure of core inflation is the CPI excluding food, energy and the effects of indirect taxes. We use the alternative shown in Figure 5 because separate series for goods and services adjusted for the effects of indirect taxes are not available.

the rate of decline of computer prices since 1995 and the associated increase in investment in computers, or new information and communication technologies more generally.

While there is a considerable consensus that investment in computers has contributed to the acceleration in productivity growth, there is more debate about how it has done so. Gordon (2000) argues that the main source of higher trend productivity growth in the United States is improvements in the production of computers. He points out that much of the higher productivity growth in the United States is concentrated in two sectors - electrical and electronic products, and industrial machinery - and argues that there is little evidence that the use of computers has raised productivity in other sectors. Other research, however, has found a significant role for the use of computers. Oliner and Sichel (2000), Whelan (2000) and Jorgenson and Stiroh (2000) all find that while the production of computers is an important factor, the use of computers is more important.

The nature of the role of computers in the US productivity growth resurgence is important for Canada because the computer-producing sector in Canada is considerably smaller than in the United States. Thus if, as Gordon argues, most of the gains in the United States have come from the production of computers, the prospects for Canada to experience a US-style acceleration in productivity growth are limited. If, on the other hand, they are due to the use of computers, Canada is well positioned to benefit from the diffusion of information and communication technologies across a broad range of industries.

Looking at the US experience, there are several reasons to be optimistic that productivity growth will accelerate in Canada. First, starting in about 1996 business investment in machinery and equipment in Canada accelerated, leading to a rise in machinery and equipment as a share of GDP (Figure 6). In the United States, productivity growth increased about four years after investment in machinery and equipment began increasing as a share of GDP. If Canada were to experience a similar lag, this would imply that productivity growth should start to accelerate in 2000. Coincidentally, productivity growth has moved up in the first half of 2000, though it is clearly much too early to identify this movement as the start of a new trend.

Second, underlying inflation has been surprisingly weak. As shown in Figure 5, the year-over-year rate of increase of the CPI excluding food, energy, tobacco and alcohol has drifted down slightly since mid-1999 against a background of particularly strong output growth.[6] More significantly perhaps, the rate of increase in final goods prices has decelerated sharply since mid-1999 relative to the rate of increase in final services prices. Goods prices in Canada, as in the United States, are now falling on a year-over-year basis. Notice also that the lags line up roughly with the US experience, with surprises in final goods inflation in Canada following the acceleration in investment by about four years.

Third, the Canadian economy is now operating at a high level of activity with some signs that capacity pressures are emerging.

Fourth, in the 1990s Canadian firms went through a more intense period of restructuring (Kwan (2000)) as did the public sector. As markets tighten, the productivity gains from these changes may become more evident.

These signals all provide room for optimism. Needless to say, considerable uncertainty remains as to the timing, size and duration of any acceleration in productivity growth.

3. Structural change in the behaviour of inflation

In this section we put the focus squarely on prices and consider the evidence of structural change in the US economy based on Phillips curves for underlying inflation and its goods and services components. We then turn to Canada and examine whether there is any evidence of similar structural changes in the behaviour of final prices in this country that lags the experience in the United States. Relative to the graphical analysis in Section 2, Phillips curves have the attraction that they control for a

6 A similar pattern is present in the official measure of core inflation - the CPI excluding food, energy and the effects of indirect taxes.

variety of factors that affect prices. Structural change - or evidence of the new economy - only emerges if these other factors cannot explain the observed behaviour. Estimated Phillips curves also have the attraction that they allow us to bring standard statistical techniques to bear on the issues, from which we can make probabilistic statements.

Our main tool is the expectations-augmented Phillips curve. In its simplest form, it is given by

$$\pi_t = \pi_t^e + \beta \tilde{y}_{t-j} + \varepsilon_t ,$$

where π_t is inflation, π_t^e is a measure of inflation expectations which will be proxied below by lagged inflation and $\tilde{y}_{t-j}$ is a measure of the output gap or labour gap, lagged *j* quarters. For each of the definitions of the new economy described in the introduction above, estimates of the Phillips curve relationship would be fundamentally changed. For example, if increased global competition reduced the ability of domestic companies to respond to excess demand by raising prices, inflation shocks ($\in_t$) would be persistently negative. Alternatively, if the new economy resulted in an increase in trend productivity growth, measures of potential output or the NAIRU based on extrapolating historical trends would understate the true value. Either way, it would appear that there was a change in the Phillips curve relationship. Here we will investigate evidence of such a break, first using a Phillips curve model of the US economy, and then with a model of the Canadian economy.

We examine the relationship between output and inflation for the United States using a simple Phillips curve similar to that found in Gordon (1997), Brayton et al (1999) and Crary (2000). This takes the form

$$\pi_t = A(L)(\pi_{t-1}) + \beta \tilde{y}_t + B(L)(\pi_{t-1}^{rel}) + \delta \pi_t^{fe} + \varepsilon_t$$

where π_t is the growth rate in the all items CPI, $\tilde{y}_t$ is a measure of the labour gap, where for simplicity, the NAIRU is assumed to be constant and equal to 6.18%,[7] π_{t-1}^{rel} is the rate of change in the relative price of imports to the total CPI, and π_t^{fe} is the rate of change in the relative price of food and energy to the total CPI. Twenty-four lags of inflation are included in *A*(*L*), and parsimony is achieved through the use of successive four-quarter averages as in Gordon (1997), so that only six coefficients must be estimated. Further, the sum of these coefficients is constrained to equal 1.[8] Four lags on the relative inflation rate of imports are included.

The model was estimated over the 1975:1-1995:4 period, commencing shortly after the Nixon-era price controls and ending before evidence started to emerge of an apparent new economy in the United States. Dynamic out-of-sample forecasts were then constructed to 2000:2. Estimated parameters are given in Table 1, while the forecasts, together with bootstrap-based confidence bands, are given in Figure 7.[9]

From the dynamic forecasts, we see that realised inflation is only a little below the dynamic forecast for most of the period, although it crosses the 75% confidence level near the end of the sample. At this degree of aggregation, there is thus limited evidence of a change in the relationship between output and prices that is consistent with the new economy.

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7 Crary (2000) estimates a Phillips curve using a wide variety of different assumptions about the NAIRU, including this one, and obtains qualitatively similar results for them all.

8 Crary (2000) and Brayton et al (1999) also impose this restriction.

9 Note that only the lagged inflation terms are simulated out-of-sample in the construction of these confidence bands. All other independent variables are assumed to be known.

The estimation was then repeated, but with inflation for final goods (*g*) and final services (*s*) considered separately, as follows:

$$\pi_t^i = A^i(L)(\pi_{t-1}^i) + \beta^i \tilde{y}_t + B^i(L)(\pi_{t-1}^{reli}) + \delta^i \pi_t^{fei} + \varepsilon_t^i$$

for $i \in (g,s)$. Notice that the rate of change in the price of imports is now measured relative to the inflation rate of component *i*, as is the rate of change in the price of food and energy. Also, the relative inflation rate of food and energy was not significant in the services equation, so, in the results that follow, $\delta^s = 0$

The equations for both sectors can be estimated using Seemingly Unrelated Regression Estimation, taking advantage of the fact that inflation shocks will be correlated across sectors. Again, estimation is conducted using data from 1975:1 to 1995:4. Estimates are given in Table 2. Fitted values, along with dynamic out-of-sample forecasts and bootstrapped confidence bands to 2000:2, are given in Figure 8 for goods and Figure 9 for services.

The out-of-sample forecasts reveal that realised inflation is very close to its dynamic forecast for the services sector, but well below its dynamic forecast in the goods sector. As shown, the realised rate of change of goods prices has been largely below the 90% confidence band since mid-1999. This implies that, from a standard estimated Phillips curve for the US economy, evidence of a new economy is largely concentrated in the goods sector. Note that we also considered an estimated Phillips curve for the US economy incorporating the output gap, based on the Congressional Budget Office's measure of potential output projected forward from 1995:4 using its historical trend. Evidence of the new economy obtained using this measure was qualitatively very similar to that presented here, although less statistically significant.

Other robustness checks included the choice of the relative price of imports measure. The results for the goods sector are very robust to to this choice. For example, if we exclude petroleum and computers from our measure of import prices as in Brayton et al (1999),[10] the out-of-sample forecasts that result are given in Figure 10, and are qualitatively similar to those presented previously, with similar levels of statistical significance.

In contrast, the results for the estimated Phillips curve of services inflation were less robust. Examining the same alternative measure as above, the out-of-sample forecasts are given in Figure 11. Now the forecasts increasingly diverge from realised inflation, and reach statistically significant levels by the end of the sample. One result that remains clear, however, is evidence of a structural break in the relationship between prices and output in the goods sector for the United States.

We now examine similar relationships using estimated Phillips curves for the Canadian economy. As was argued in the previous section, if the path of events leading up to the change in inflation behaviour were similar to that for the United States, we would expect a break in the Phillips curve to have occurred very recently. We start with the Phillips curve model based on that estimated in Fillion and Léonard (1997), which is used for monitoring and short-term forecasting of inflation at the Bank of Canada.

The estimated Phillips curve is of the following form:

$$\pi_t = dummies + A(L)\pi_{t-1} + \beta\tilde{y}_{t-1} + B(L)(\Delta\pi_{t-1}^{imp}) + C(L)(\Delta ind_t)$$
$$+ D(L)(\Delta\pi_{t-1}^{oil}) + err_t$$

where π_t is the growth rate in the all items CPI less food, energy and indirect taxes. *dummies* is a set of intercepts combined with dummy variables to capture different inflation regimes in Canada,[11] $\tilde{y}_{t-1}$ is a measure of the output gap,[12] and $\Delta\pi_{t-1}^{imp}$ is the change in imported inflation, where π_{t-1}^{imp} is measured

[10] Brayton et al (1999) also exclude semiconductors using an unpublished series. Other measures of import prices examined here included import prices by sector (goods versus services).

[11] These dummies also interact with the lagged inflation terms in the initial version of the model considered here.

[12] The measure of potential used here is the internal Bank of Canada measure: see Butler (1996) for details of its construction.

as the growth rate of the value of the Canadian dollar (expressed as Canadian dollars per US dollar) plus the rate of growth in the all items CPI less food and energy in the United States, averaged over the previous three quarters. $\Delta\pi_{t-1}^{oil}$ is the first difference of the ratio of the growth rate of the price of crude oil to the US GDP deflator, and Δind_t is the first difference in the rate of indirect taxes on goods excluding food and energy.

We estimate equation (4) over the period 1970:1 to 1995:4 and, as for the US model above, construct out-of-sample dynamic forecasts to 2000:2. The forecasts and realised inflation are given in Figure 12. Over the early part of the forecasting period, forecast inflation is below realised inflation, while after the middle of 1998, realised inflation lies systematically below the inflation forecast.[13]

To further examine this relationship, the same analysis was repeated with the dependent variable being the inflation rate for final goods. Since there is no readily available measure of core inflation by sector in Canada, the measure used was final goods inflation excluding food, energy, tobacco and alcohol. These latter components remove a large portion of the indirect tax changes over the sample. A dummy variable is also added in the first quarter of 1991, to take account of the introduction of the Goods and Services Tax (GST).

Realised goods inflation lies systematically below the dynamic forecasts (given in Figure 13) starting in approximately 1998. In contrast, repeating the analysis on final services inflation (Figure 14) reveals no such systematic forecast bias. The model produces only small forecast errors all the way out to the end of the forecast period. These results suggest that negative aggregate surprises in Canadian inflation since 1998 can be largely explained by price changes in final goods.

This analysis of the Canadian economy has assumed that the same independent variables affect inflation for each sector. We will now consider generalising this model to allow for the propagation of inflation to differ across sectors. As for the US model before, we will use Seemingly Unrelated Regression Estimation to estimate both Phillips curves jointly, making use of the fact that inflation shocks are correlated across sectors.

Following a series of specification tests on the variables and lag lengths in the above Fillion and Léonard (1997) model, we arrived at an estimated Phillips curve of the form

$$\pi_t^i = \alpha^i + \delta^i D_t + A^i(L)(\pi_{t-1}^i - \delta^i D_{t-1}) + B^i(L)(\pi_{t-1}^j - \delta^j D_{t-1}) + \beta^i \tilde{y}_{t-1}$$
$$+ C^i(L)(\Delta\pi_{t-1}^{imp}) + E^i(L)(\Delta\pi_{t-1}^{oil}) + err_t^i$$

for $i \in (g,s)$, $j \in (g,s)$, $i \neq j$. D_t is a dummy variable equal to 1 in 1991:1 and 0 elsewhere to take account of the impact of the introduction of the GST. The inclusion of this dummy in the lagged inflation terms is consistent with the idea that the introduction of the GST had only a one-time effect on inflation, and did not fuel increased inflation expectations. Lags on services inflation provide little explanatory power for goods inflation so $B^g(L) = 0$. The other variables included in this equation are as described earlier.

There are now two equations, one for final goods inflation and one for final services inflation, that can both be estimated jointly, incorporating the cross-equation restriction in δ^i. The equations are estimated over the 1970:1-1995:4 period with out-of-sample forecasting and bootstrapped confidence bands constructed out to 2000:2. The results are given in Table 3, while graphs of the fitted values and forecasts for goods are in Figure 15, and for services in Figure 16.

Realised inflation in final goods has been consistently lower than forecast for most of the forecast period, but until the end of 1999 it was largely within the 90% confidence interval. In the first two quarters of 2000, however, realised goods inflation has fallen sharply, pushing it below the 90% confidence interval. Very similar results can also be obtained if one considers dynamic out-of-sample forecasts starting at a later date. In contrast, while realised inflation in the final services sector is slightly below its forecast on average since about 1998, the error is always within the 90% confidence band and in 2000 the forecast error has virtually disappeared. As with the earlier Canadian model, this

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[13] In a future version of this paper, we will construct bootstrapped confidence intervals around this dynamic forecast.

evidence is suggestive of a structural break in the relationship between output and prices that is concentrated in final goods.

4. Conclusions

The possible emergence of the "new economy" has important implications for the conduct of monetary policy, since it implies that economic growth above historically sustainable levels does not necessarily imply rising inflation, other things equal.

In this paper we have reviewed recent developments in productivity growth and prices in an effort to identify early indicators of whether the Canadian economy is following the United States to higher productivity growth. There are several reasons to be cautiously optimistic that Canada will follow the United States to higher productivity growth with a lag of approximately four years, although the acceleration may be less pronounced than in the United States. According to this view, we should now be starting to observe signs of the emergence of a new economy in terms of increased productivity growth and lower than expected inflation, as we have in 2000.

We then formalise one aspect of the story, namely the evidence of a structural break in the behaviour of inflation using estimated, expectations-augmented Phillips curves, first for the United States and then for Canada. We present evidence that, in the United States, changes in the relationship between prices and output that would be consistent with the emergence of the new economy have been largely concentrated in final goods.

We also identify evidence of a similar break in the relationship between output and prices for final goods in the Canadian economy, but it is concentrated in the two most recent quarters. Clearly with only these two observations fitting the new economy hypothesis as outlined here, we are in need of further observations to determine whether these residuals reflect a new direction for the economy or simply a short-term aberration due to some unmodelled factor or random shock.

Our econometric evidence of the emergence of a "new economy" in the United States and Canada is based on the properties of residuals. In particular, we ascribe the persistent overprediction in recent years of the US Phillips curve for final goods prices to the "new economy". And we make a similar inference with respect to the much more recent overprediction of the Canadian Phillips curve for final goods prices. While there are good reasons for the "new economy" to be the leading suspect, there are other developments that may account for at least part of this overprediction. In the United States, the changes in the way the CPI is calculated may explain as much as 0.5 percentage points of the unexplained decline in the CPI inflation. There may also be factors independent of the "new economy" that have lowered NAIRU in the latter half of the 1990s - for example, reductions in the coverage of welfare. These other factors may explain part of the overprediction of the aggregate Phillips curve in the United States, but it is less clear that they could explain the large drop in goods prices relative to services prices. Exchange rate pass-through, in contrast, does have the potential to explain this relative price change. Our estimated Phillips curves control for changes in import prices, and we consider alternative measures of import prices as a robustness check to ensure that we have adequately captured the the full effects of exchange-rate pass-through. We found that the results for the US Phillips curve for final goods prices are robust to alternative measures, while those for final services are less so.

More broadly, our analysis points towards a number of paths for future research. It would be interesting to apply our research to other countries, such as the United Kingdom, that have experienced strong investment in machinery and equipment together with declining final goods prices, but little acceleration to date in labour productivity growth. Another priority is to better understand why evidence of structural change is concentrated in the behaviour of final goods prices. Does this largely reflect difficulties in the measurement of quality improvements in services, productivity improvements in the production of final goods, or productivity improvements in intermediate services that are inputs into final goods production? There is some evidence to support all three hypotheses, but further work is required before we can draw any conclusions.

Table 1

US Phillips curve

Dependent variable: π_τ

Estimation: 1975:1-1995:4

Regressor	Coefficient	p-value
$\bar{\pi}_{t-1,t-4}$	0.39	0.049[1]
$\bar{\pi}_{t-5,t-8}$	0.27	0.168
$\bar{\pi}_{t-9,t-12}$	0.13	0.425
$\bar{\pi}_{t-13,t-16}$	– 0.030	0.849
$\bar{\pi}_{t-17,t-20}$	0.22	0.154
$\bar{\pi}_{t-21,t-24}$	0.011	0.910
$\tilde{y}_t$	0.65	0.004[2]
π_{t-1}^{rel}	0.083	0.026[2]
π_{t-2}^{rel}	0.055	0.134
π_{t-3}^{rel}	– 0.021	0.569
π_{t-4}^{rel}	0.011	0.748
π_t^{fe}	0.32	0.000[2]
$\bar{R}^2$	0.71	
S.E.E.	3.44	
S.S.R.	237.0	
D.W.	1.86	

[1,2] indicate significance at the 5% and 1% level respectively.

Table 2

US Phillips curve by sector

Dependent variable: $\overline{\pi}_t^g$ **Estimation: 1975:1-1995:4**			**Dependent variable:** $\overline{\pi}_t^s$ **Estimation: 1975:1-1995:4**		
Regressor	**Coefficient**	***p*-value**	**Regressor**	**Coefficient**	***p*-value**
$\overline{\pi}_{t-1,t-4}^g$	0.28	0.097	$\overline{\pi}_{t-1,t-4}^s$	0.40	0.014[1]
$\overline{\pi}_{t-5,t-8}^g$	0.22	0.168	$\overline{\pi}_{t-5,t-8}^s$	0.43	0.013[1]
$\overline{\pi}_{t-9,t-12}^g$	0.16	0.284	$\overline{\pi}_{t-9,t-12}^s$	– 0.053	0.746
$\overline{\pi}_{t-13,t-16}^g$	0.17	0.227	$\overline{\pi}_{t-13,t-16}^s$	0.042	0.775
$\overline{\pi}_{t-17,t-20}^g$	0.14	0.331	$\overline{\pi}_{t-17,t-20}^s$	0.25	0.054
$\overline{\pi}_{t-21,t-24}^g$	0.030	0.780	$\overline{\pi}_{t-21,t-24}^s$	– 0.071	0.538
$\tilde{y}_t$	1.10	0.000[2]	$\tilde{y}_t$	0.66	0.014[1]
π_{t-1}^{relg}	– 0.002	0.974	π_{t-1}^{rels}	0.15	0.000[2]
π_{t-2}^{relg}	0.080	0.088	π_{t-2}^{rels}	0.041	0.312
π_{t-3}^{relg}	– 0.095	0.048[1]	π_{t-3}^{rels}	0.018	0.653
π_{t-4}^{relg}	0.093	0.034[1]	π_{t-4}^{rels}	– 0.021	0.596
π_t^{feg}	0.82	0.000[2]	S.S.R	494.6	
S.S.R.	441.2		D.W.	1.94	
D.W.	1.84				

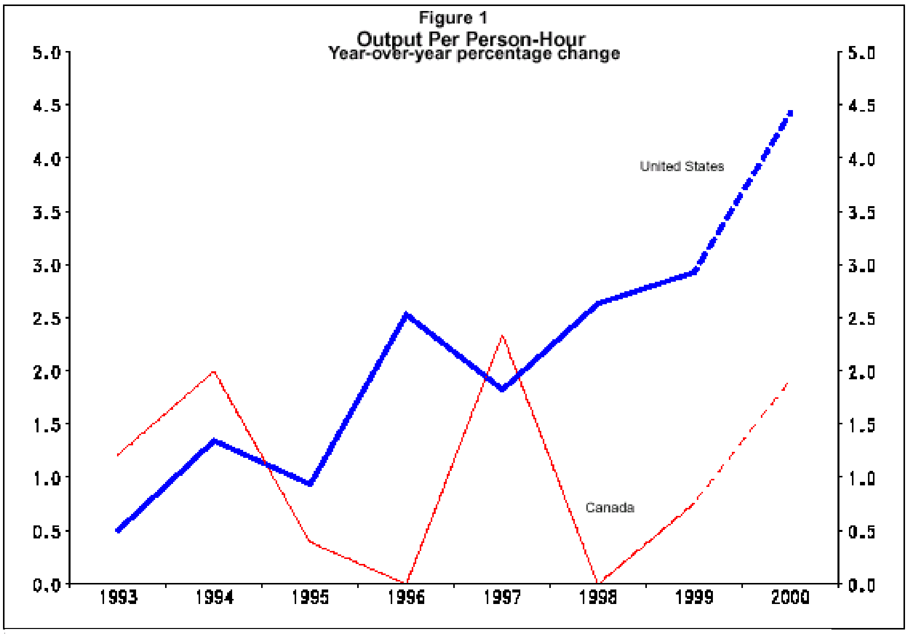
[1,2] indicate significance at the 5% and 1% level respectively.

Table 3

Canadian Phillips curve by sector

Dependent variable: π_t^g Estimation: 1975:1-1995:4			**Dependent variable: π_t^s Estimation: 1975:1-1995:4**		
Regressor	**Coefficient**	***p*-value**	**Regressor**	**Coefficient**	***p*-value**
Constant	0.82	0.032[1]	Constant	0.75	0.003[2]
$\pi_{t-1}^g - \delta^g D_{t-1}$	0.47	0.000[2]	$\pi_{t-1}^s - \delta^s D_{t-1}$	0.74	0.000[2]
$\pi_{t-2}^g - \delta^g D_{t-2}$	– 0.029	0.778	$\pi_{t-2}^s - \delta^s D_{t-2}$	– 0.18	0.090
$\pi_{t-3}^g - \delta^g D_{t-3}$	0.26	0.015[1]	$\pi_{t-3}^s - \delta^s D_{t-3}$	0.40	0.000[2]
$\pi_{t-4}^g - \delta^g D_{t-4}$	0.14	0.161	$\pi_{t-4}^s - \delta^s D_{t-4}$	– 0.24	0.012[1]
$\pi_{t-5}^g - \delta^g D_{t-5}$	– 0.091	0.374	$\pi_{t-5}^s - \delta^s D_{t-5}$	0.062	0.530
$\pi_{t-6}^g - \delta^g D_{t-6}$	0.11	0.225	$\pi_{t-6}^s - \delta^s D_{t-6}$	– 0.13	0.088
$\tilde{y}_{t-1}$	0.21	0.014[1]	$\pi_{t-1}^g - \delta^g D_{t-1}$	– 0.051	0.344
$\Delta\pi_{t-1}^{imp}$	0.18	0.080	$\pi_{t-2}^g - \delta^g D_{t-2}$	0.082	0.174
$\Delta\pi_{t-2}^{imp}$	0.16	0.141	$\pi_{t-3}^g - \delta^g D_{t-3}$	0.016	0.798
$\Delta\pi_{t-3}^{imp}$	0.17	0.120	$\pi_{t-4}^g - \delta^g D_{t-4}$	0.034	0.575
$\Delta\pi_{t-4}^{imp}$	0.14	0.214	$\pi_{t-5}^g - \delta^g D_{t-5}$	0.19	0.002[2]
$\Delta\pi_{t-5}^{imp}$	0.03	0.753	$\pi_{t-6}^g - \delta^g D_{t-6}$	0.054	0.337
$\Delta\pi_{t-6}^{imp}$	0.24	0.013[1]	$\tilde{y}_{t-1}$	0.19	0.001[2]
$\Delta\pi_{t-1}^{oil}$	0.000	0.795	$\Delta\pi_{t-1}^{imp}$	0.21	0.001[2]
$\Delta\pi_{t-2}^{oil}$	0.004	0.004[2]	$\Delta\pi_{t-2}^{imp}$	– 0.094	0.148
$\Delta\pi_{t-3}^{oil}$	0.004	0.000[2]	$\Delta\pi_{t-3}^{imp}$	0.060	0.372
$\Delta\pi_{t-4}^{oil}$	0.004	0.001[2]	$\Delta\pi_{t-4}^{imp}$	0.022	0.736
D_t	9.54	0.000[2]	$\Delta\pi_{t-5}^{imp}$	0.19	0.001[2]
S.S.R.	251.3		$\Delta\pi_{t-6}^{imp}$	– 0.185	0.003[2]
D.W.	2.05		$\Delta\pi_{t-1}^{oil}$	0.001	0.061
			$\Delta\pi_{t-2}^{oil}$	0.002	0.008[2]
			$\Delta\pi_{t-3}^{oil}$	– 0.001	0.355
			$\Delta\pi_{t-4}^{oil}$	0.001	0.418
			D_t	8.10	0.000[2]
			S.S.R.	81.5	
			D.W.	2.07	

[1,2] indicate significance at the 5% and 1% level respectively.



Note: Output per person-hour = Ratio of real gross domestic product at market prices to labour input (persons-hours)

Sources: US Department of Labor, Bureau of Labor Statistics, and US Department of Commerce, Bureau of Economic Analysis Statistics Canada, Aggregate Productivity Measures, and Income and Expenditure Accounts Division

Figure 2
Output Per Person-Hour and Real GDP Growth - United States
Year-over-year percentage change

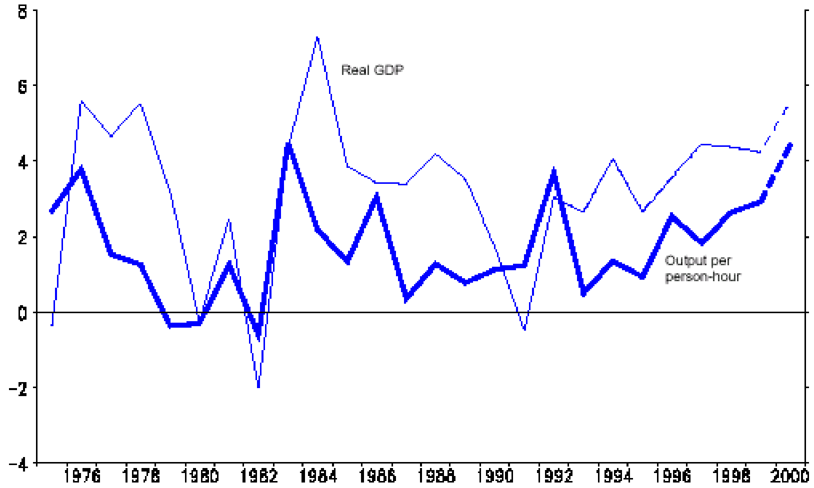
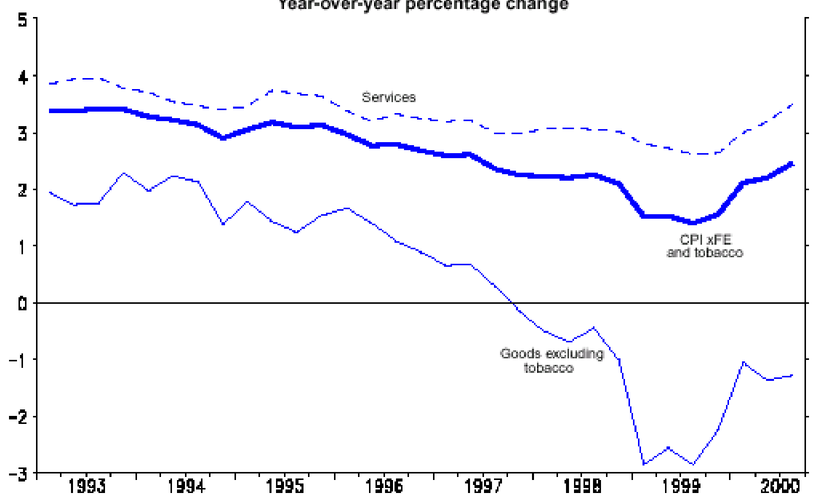


Figure 3
Rate of increase in CPI excluding food, energy and tobacco and goods and services components - United States
Year-over-year percentage change



Note: Output per person-hour = Ratio of real gross domestic product at market prices to labour input (persons-hours)

Sources: US Department of Labor, Bureau of Labor Statistics, and US Department of Commerce, Bureau of Economic Analysis

Figure 4
Output Per Person-Hour Real GDP Growth - Canada
Year-over-year percentage change

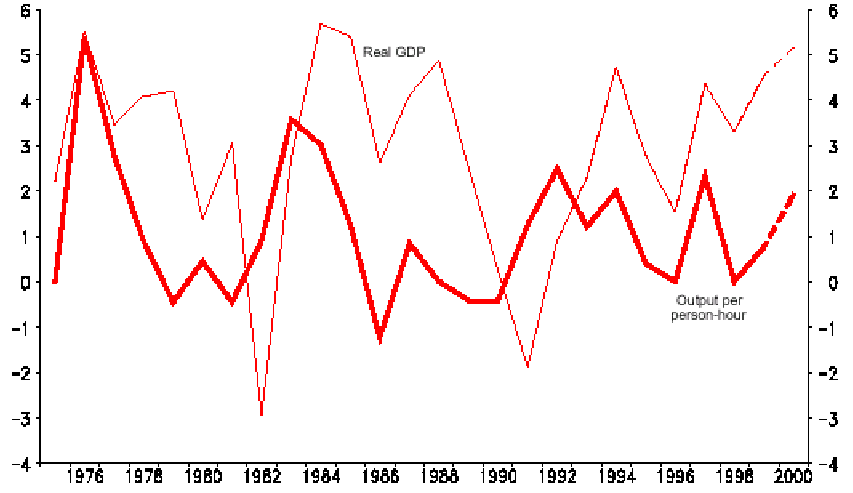
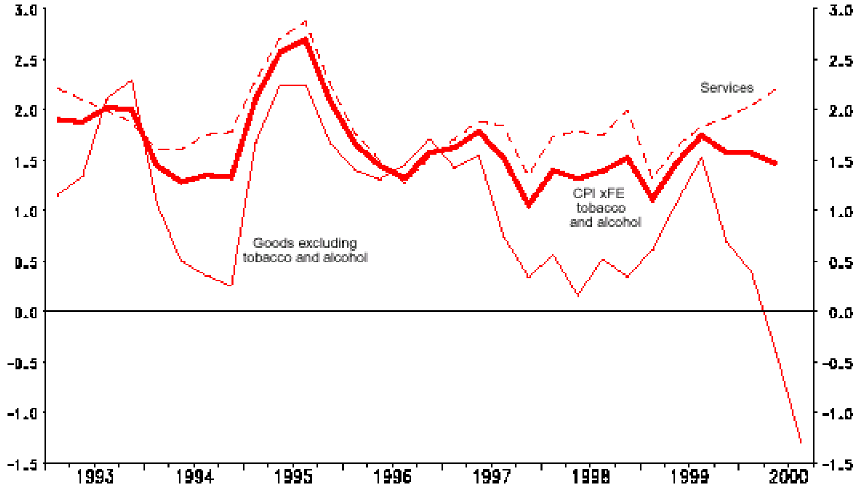
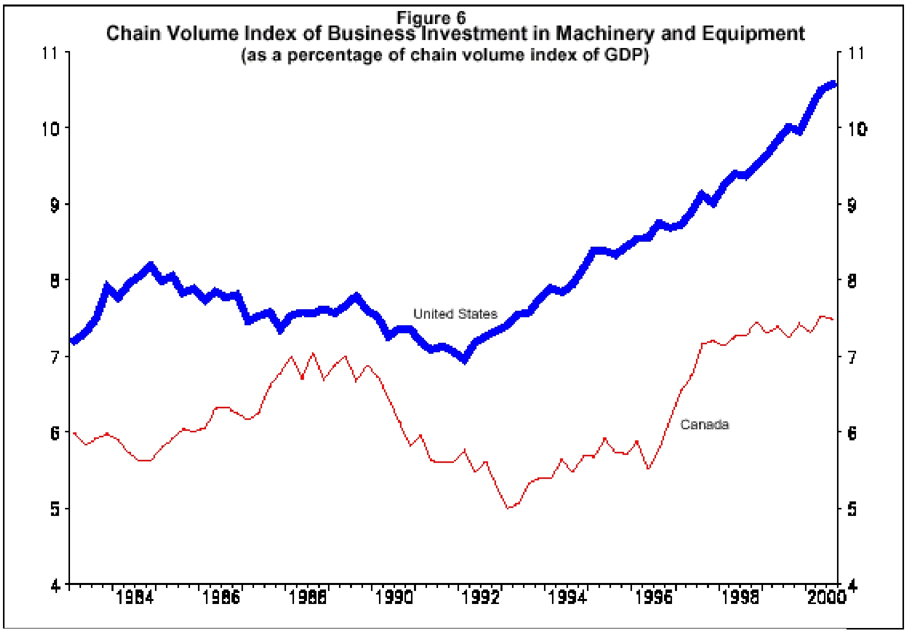


Figure 5
Rate of increase in CPI excluding food, energy, tobacco and alcohol and goods and services components - Canada
Year-over-year percentage change



Note: Output per person-hour = Ratio of real gross domestic product at market prices to labour input (persons-hours)

Sources: Statistics Canada, Aggregate Productivity Measures, and Income and Expenditure Accounts Division



Sources: US Department of Commerce, Bureau of Economic Analysis, Statistics Canada, Income and Expenditure Accounts Division

Figure 7
Rate of Increase in CPI - United States
Quarter-over-quarter percentage change
Fitted, actual and dynamic forecast

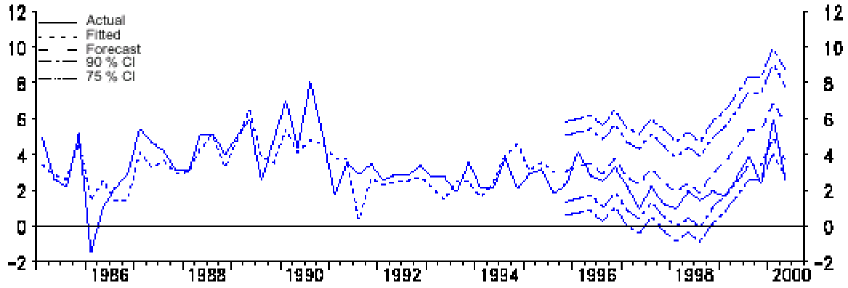


Figure 8
Rate of Increase in CPI goods components - United States
Quarter-over-quarter percentage change
Fitted, actual and dynamic forecast

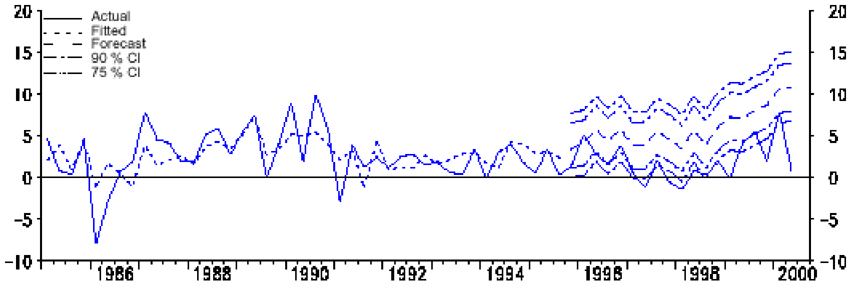


Figure 9
Rate of Increase in CPI services components - United States
Quarter-over-quarter percentage change
Fitted, actual and dynamic forecast

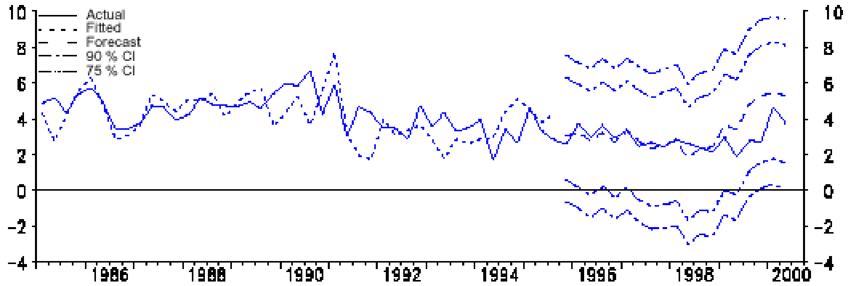


Figure 10
Rate of Increase in CPI Good Components - United States
Quarter-over-quarter percentage change
Alternative measure of imported inflation

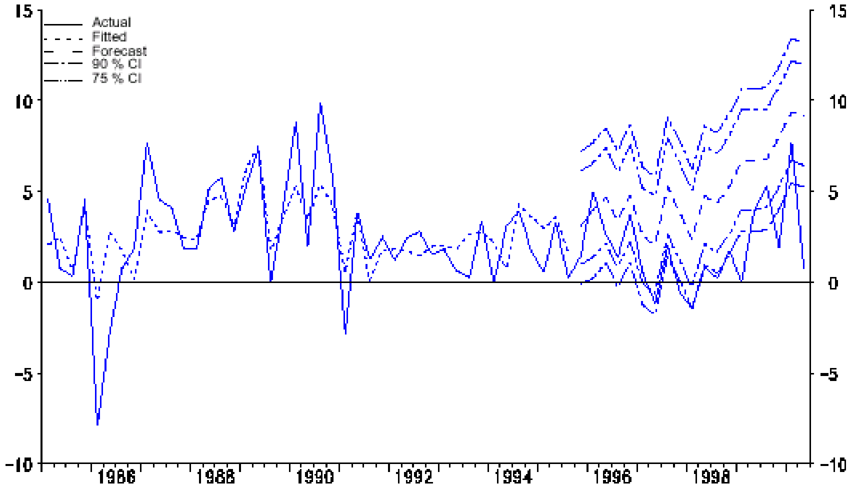


Figure 11
Rate of Increase in CPI services components - United States
Quarter-over-quarter percentage change
Alternative measures of imported inflation

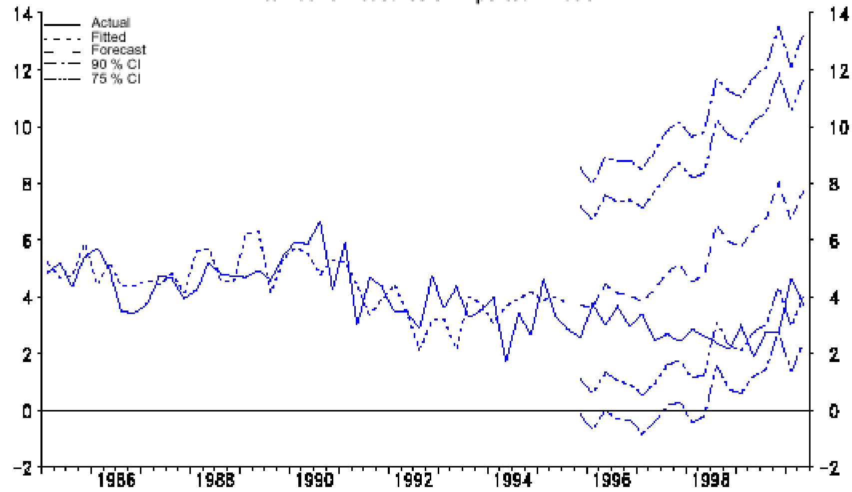


Figure 12
Rate of Increase in CPI excluding food, energy and indirect taxes - Canada
Quarter-over-quarter percentage change
Actual and dynamic forecast

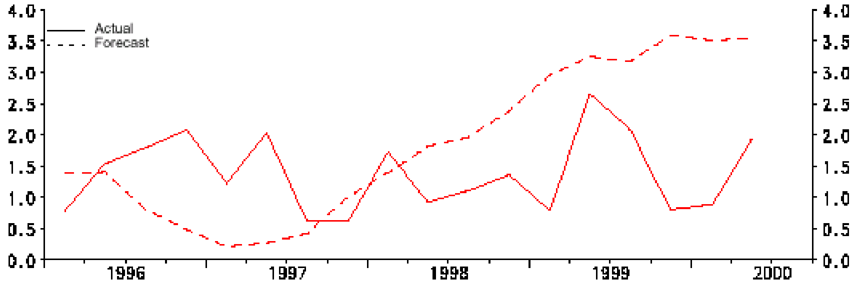


Figure 13
Rate of Increase in CPI good components excluding food, energy, alcohol and tobacco - Canada
Quarter-over-quarter percentage change
Actual and dynamic forecast

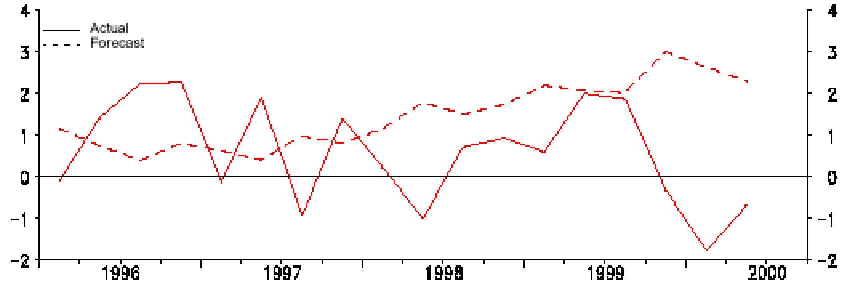


Figure 14
Rate of Increase in CPI services component - Canada
Quarter-over-quarter percentage change
Actual and dynamic forecast

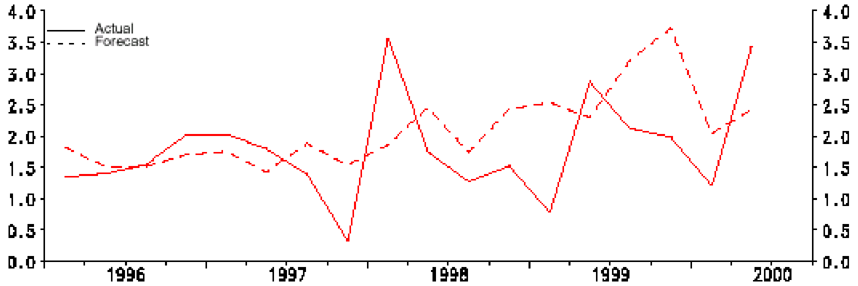


Figure 15
Rate of Increase in CPI good components excluding food, energy, alcohol and tobacco - Canada
Quarter-over-quarter percentage change
Fitted, actual and dynamic forecast

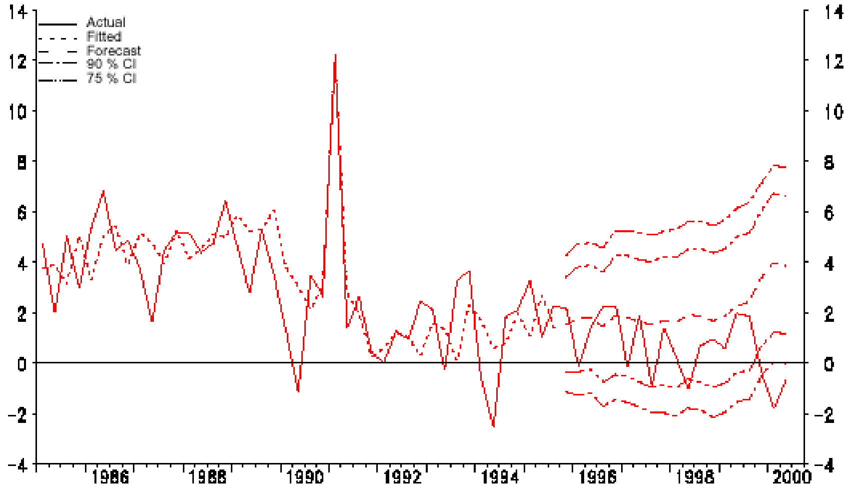
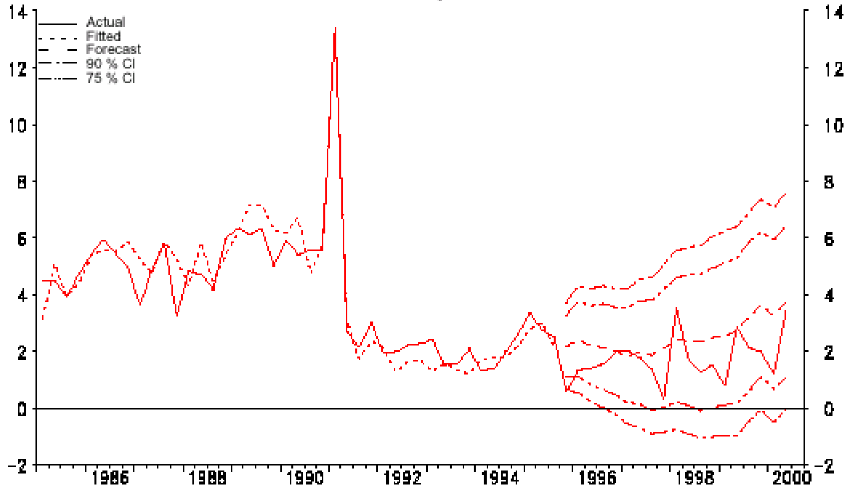


Figure 16
Rate of Increase in CPI services components - Canada
Quarter-over-quarter percentage change
Fitted, actual and dynamic forecast



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Investment-specific technological progress in the United Kingdom[1]

Hasan Bakhshi and Jens Larsen[2]

Abstract

This paper adapts the dynamic general equilibrium model of Greenwood et al (1997, 2000) to decompose labour productivity growth along the balanced growth path for the UK economy into investment-specific technological progress and sector neutral technological progress. We find that investment-specific technological progress in information and communication technology (ICT) assets might account for around 20-30% of labour productivity growth along the balanced growth path. But this conclusion depends crucially on how ICT prices are measured. We show that shocks to investment-specific technological progress can have very different macroeconomic implications from a "neutral shock" that applies to production of all goods. We demonstrate that a permanent increase in the growth rate of ICT-specific technological progress will increase the investment expenditure share but lower the aggregate depreciation rate, while an increase in the return to investment in ICT capital will increase both the expenditure share and the depreciation rate.

1. Introduction

A broad consensus appears to have emerged amongst academics and policymakers alike that there was some improvement in (at least medium-term) US trend productivity growth in the second half of the 1990s. Recent attempts to decompose US labour productivity growth into its main determinants report that information and communication technology (ICT) has made significant contributions through increases in both capital deepening and total factor productivity (TFP) growth over this period. Notable examples include the work by Oliner and Sichel (2000), Gordon (2000), Jorgenson and Stiroh (2000) and Whelan (2000). Kneller and Young (2000) and Oulton (2000) perform similar decompositions for the United Kingdom, though the data constraints are greater in this case.[3] In this paper, this approach is labelled "historical growth accounting". A separate literature using dynamic general equilibrium (DGE) models distinguishes between technological progress that is specific to production of capital goods and technological progress that is "neutral" in the sense that it applies to production of all goods (TFP).[4] The main reference here is Greenwood et al (1997), with Greenwood et al (2000) and Pakko (2000) being recent examples of application. These models do not attempt historical decompositions of labour productivity growth, but instead decompose productivity along the balanced growth path of the economy into investment-specific technological progress and neutral

1 Preliminary draft, not to be quoted without explicit permission. The views expressed are those of the authors and do not necessarily reflect those of the Bank of England. Thanks are due to John Butler for his help in the formative stages of this paper. We are grateful to Charlie Bean, Ian Bond, Roy Cromb, Jo Cutler, Simon Gilchrist, DeAnne Julius, Tiff Macklem, Steve Millard, Steve Nickell, Katharine Neiss, Mike Pakko, Alison Stuart and seminar participants at a BIS workshop on "Structural change and inflation" for comments on earlier drafts of this paper. Thanks also to Morten Ravn for letting us use some of his software and to Nick Oulton for help with constructing and interpreting the data and the results.

2 Structural Economic Analysis and Monetary Assessment and Strategy Divisions, Monetary Analysis, Bank of England, Threadneedle Street, London EC2R 8AH. E-mail: hasan.bakhshi@bankofengland.co.uk, jens.larsen@bankofengland.co.uk.

3 One of the issues for these papers is that it is not at all clear that there has yet been any increase in trend productivity growth in the United Kingdom, despite strong increases in ICT investment. That is not of course to rule out the possibility that such productivity improvements might be on the horizon.

4 This relates directly to the Solow (1960) and Jorgenson (1966) debate on whether technological progress is "embodied" or "disembodied". Hercowitz (1998) argues that this language is imprecise and instead uses the distinction "sector-specific" and "neutral" technological progress that we also use in this paper.

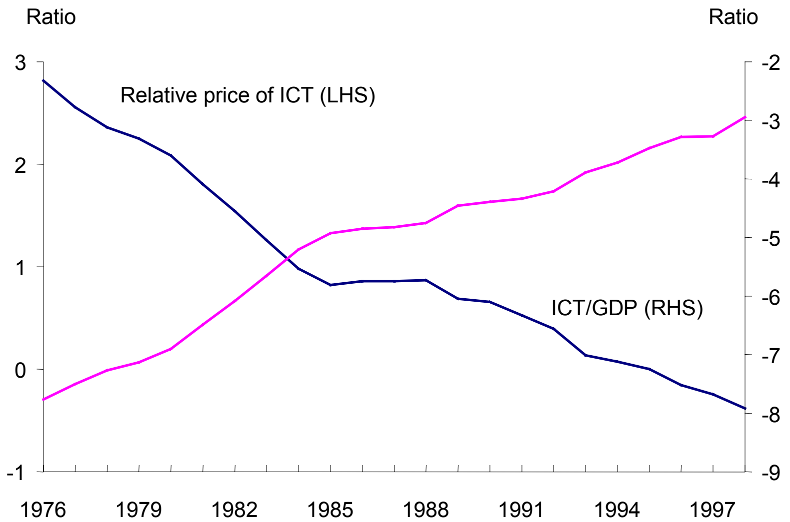
technological progress. This approach emphasises the importance of substitution effects: rapid technological progress in production of capital goods leads to declining prices and hence to increasing capital intensity.

In this paper, we adapt the model of Greenwood et al (1997) to quantify the contribution of ICT-specific technological progress to productivity growth along the balanced growth path for the UK economy, drawing heavily on the efforts of our colleague Nick Oulton at the Bank of England to derive ICT investment data for the United Kingdom. Like Greenwood et al (1997), our motivation is the observation that rapid declines in the relative price of ICT goods have been accompanied by an increase in the ratio of real ICT investment, measured in units of ICT, to (non-housing) output (see Figure 1).[5] We identify technological progress in production of ICT goods as inversely related to the relative price of ICT goods. Using this information and the model's balanced growth path relations, we can calculate the contribution of ICT-specific technological progress to labour productivity growth along the balanced growth path. We find that despite the fact that ICT is a relatively small component of the overall capital stock, ICT-specific technological progress contributes significantly to labour productivity growth along the balanced growth path for the UK economy, accounting for around 20-30% of labour productivity growth.

The key advantage of the DGE approach over the growth accounting is that it permits forward-looking analysis: the short-run macroeconomic implications of a shock to investment-specific technological progress or TFP can be simulated, even if such shocks have not yet hit the economy. This is a particularly useful tool in our context, as it provides a macroeconomic guide for policymakers who wish to incorporate such shocks into their forecasts. We present impulse responses for temporary shocks to both ICT-specific technological progress and neutral technological progress. Shocks to ICT-specific technological progress have very different implications for investment, depreciation, the capital stock and labour productivity than shocks to neutral technological progress. The main driver of these differences is that where an increase in sector neutral technological progress has an immediate “free lunch” effect on final output - final output increases for a given level of factor inputs - technical progress that is specific to production of ICT investment goods requires that investment is undertaken. We describe these effects using a simple baseline model, but also consider extensions and variations that arguably bring the model closer into line with certain empirical regularities. In particular, we consider modifications to the labour supply specification, capital adjustment costs, variable utilisation of capital, and also modify the specification of the stochastic processes driving the shocks.

Figure 1

Relative price of ICT goods and the ICT-output ratio



Note: (1) All series are in logs; (2) ICT is measured in real quantities.

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5 The details of how these series are derived are discussed at length in Section 3.1.

The main disadvantage of this approach is that it necessarily loses some of the empirical richness of the historical growth accounts. In particular, the balanced growth decompositions of Greenwood et al (1997) ignore the contribution that ICT makes to labour productivity through the direct effect of TFP improvements in the ICT-producing sector on economy-wide TFP. As such, this would understate ICT's contribution to long-run growth. Against this though, Hercowitz (1998) notes that the treatment of investment-specific technological progress in Greenwood et al (1997) implicitly assumes there are no resource costs to the economy when enjoying investment-specific technological progress. This is likely to overstate the contribution of ICT to long-run economic growth. In the following, we spell out in more detail the relation between the two approaches to growth accounting.

1.1 Balanced growth and "historical" growth accounting

The balanced growth accounting exercise differs from "historical" growth accounting by focusing on the long-run, or steady state, growth path. Growth accounting is about attributing growth at a particular point in time to growth in factor inputs and total factor productivity, taking prices and quantities as given. Take a typical but stylised growth accounting equation:

$$\Delta \ln Y_t = \alpha_t \Delta \ln K_t + (1 - \alpha_t)(\Delta \ln N_t + \Delta \ln H_t) + \Delta \ln TFP_t, \text{ or} \quad (1)$$

$$\Delta \ln Y_t - (\Delta \ln N_t + \Delta \ln H_t) = \alpha_t (\Delta \ln K_t - \Delta \ln N_t - \Delta \ln H_t) + \Delta \ln TFP_t \quad (2)$$

In (1), output growth $\Delta \ln Y_t$ is attributed to growth in capital inputs $\Delta \ln K_t$, labour inputs in heads and hours ($\Delta \ln N_t + \Delta \ln H_t$), weighted by their (possibly time-varying) income shares, and to growth in total factor productivity, $\Delta \ln TFP_t$. (2) is a simple rearrangement that attributes growth in labour productivity, measured per hour, to capital deepening, that is an increase in the capital-labour ratio, and to total factor productivity. Ignoring statistical issues, this is an accounting identity: indeed, total factor productivity growth is calculated to make these equations hold with equality.

These equations are obviously useful tools for providing a historical account of output or productivity growth. But they are less useful as a tool for forward-looking analysis: by taking factor inputs as given, growth accounting does not provide us with a tool for making projections for future growth, because it is conditional on the behaviour of factor demand. The DGE approach differs by characterising a steady state balanced growth path of a dynamic general equilibrium model that imposes constraints on factor inputs. Specifically, the steady state balanced growth path is characterised by constant growth rates. Growth in capital inputs is related to growth in its economic determinants, neutral technological progress and investment-specific technological progress. Employment grows at a constant rate, that is the rate of population, and hours per worker are constant. Income shares are constant. In other words, along the balanced growth path:

$$\Delta \ln Y = \alpha (\Delta \ln Y + \Delta \ln Q) + (1 - \alpha)(\Delta \ln N) + \Delta \ln TFP. \quad (3)$$

where no subscript indicate that the variable is time-invariant. Here, capital growth is characterised as the growth in production of final goods $\Delta \ln Y$ (as this is a homogeneous good model) and the growth that is specific to production of investment goods, $\Delta \ln Q$. This equation is useful because, unlike (1) and (2), it characterises the long run.[6] In the following, we describe Q as sector-specific while TFP is described as sector neutral technological progress; notation-wise, we use the term Z to describe TFP.

Greenwood et al (1997) offer two alternative interpretations of the index, Q. First, in this homogeneous good model, Q can be seen as denoting the amount of capital that can be purchased in efficiency units for one unit of final output. This increases over time with investment-specific technological progress. A second interpretation is that Q represents the vintage of a capital good: each period a new vintage is produced that is successively more productive - of "higher quality" - than the previous one. The empirical counterpart of Q is identical in both interpretations: it equals the inverse of the price of investment goods, adjusted for quality, relative to some measure of the price of the homogeneous good (this must be a consumption deflator as the homogeneous good enters agents' utility functions).

[6] As mentioned, the disadvantage of this framework is that it is necessarily less rich than a growth accounting framework a la Jorgenson: in this example, and in our balanced growth accounting, we do not take account of factors such as labour quality that are obviously important in providing an account of economic growth.

In the growth accounting literature, the expenditure measure of GDP growth includes a measure of investment that allows for the "quality" of capital goods having improved over time. The empirical implication is that left hand side of (3) should be deflated by a quality-adjusted deflator to reflect the quality improvement in the investment component of aggregate demand. In the homogeneous good framework of Greenwood et al (1997), no such allowance is made. In this literature, output is expressed in units of the homogeneous good and so the empirical counterpart is that output should be deflated by a consumption deflator.[7] Hercowitz (1998) sets out a framework that he argues nests the positions of both these traditions. In particular, he shows that the homogenous good model embedded in Greenwood et al (1997) assumes there are no resource costs to the economy from investment-specific technological progress, while arguing, following Hulten (1992), that quality-adjusting the left hand side of (3) is a way of incorporating such resource costs: an increase in quality requires a reduction in another expenditure component for a given level of aggregate output. In a one-sector model, this has undesirable implications; in particular, the relative price of investment goods is constant, inconsistent with the empirical evidence, and the difference between investment-specific and sector neutral progress can no longer be identified. Hercowitz's (1998) essay implies that a more general model that allows for *some* form of resource cost would be superior. In the absence of such a model, we follow Greenwood et al (1997, 2000), implicitly assuming there are no resource costs of investment-specific technological progress.[8]

The remainder of the paper is organised as follows. In Section 2 we set out the baseline model, characterising the equilibrium of our dynamic economy and its balanced growth path. In Section 3, we calibrate the baseline model to the UK economy and decompose labour productivity growth along the balanced growth path into investment-specific technological progress and neutral technological progress. Section 4 presents the dynamic analysis of the baseline model, drawing out the key differences in the macroeconomic effects of investment-specific shocks and neutral shocks to technological progress. Section 5 presents extensions of the baseline model. We choose those extensions from the existing theoretical literature as these address some obvious shortcomings of the baseline model. Section 6 considers some "scenarios for structural change": more specifically, we consider the dynamic implications of permanent rather than temporary shocks to the level of technology, and draw out some implications of changing the growth rate of technological progress and the return to investment in some comparative statistics exercises. Finally, Section 7 concludes.

2. The baseline model

In the following, we describe the baseline model and characterise equilibrium and the balanced growth path. The model follows Greenwood et al (1997) closely, with the main differences being that we split the capital stock into ICT (indexed by *e* for exciting) and non-ICT (indexed *d* for dull) capital rather than equipment and structures, and we allow for investment-specific technological growth in both types of capital.[9] This latter distinction makes the analysis more relevant to the current UK policy debate. But

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7 This assumes that the economy is closed. In an open economy the empirical counterpart should, strictly speaking, be the domestically produced component of the consumption deflator. This is consistent with the homogeneous good assumption if we assume that countries specialise in production and that all imports are final goods.

8 Jorgenson and Stiroh (2000) further argue that the investment-specific technological progress identified by Greenwood et al (1997) as accounting for the major component of postwar US economic growth in fact reflects disembodied technological progress in the production of semiconductors used as intermediate inputs. We do not comment on this, except to note that in our homogeneous good model such a distinction cannot be made.

9 The non-stationarity of the quality-adjusted equipment investment-to-GDP ratio and the stationarity of the structures investment-to-GDP ratio in the United States is used by Greenwood et al (1997) to motivate their assumption that there is sector-specific technological progress in equipment but not in structures. But the structures investment data are not quality-adjusted in the same way as the equipment data in the United States: certainly no hedonic adjustments are made. Even with sector-specific technological progress in structures, the ratio of non-quality adjusted structures to GDP would be stationary along the balanced growth path. So this is not in fact a good motivation for their assumption of no sector-specific technological progress in structures. Our series for the quality-adjusted ICT ratio with respect to GDP is non-stationary in the United Kingdom too, so we assume that investment-specific technological progress occurs in that sector. As with the structures data in the United States, however, our non-ICT data are not hedonically adjusted. In the absence of such data for non-ICT investment, we follow Greenwood et al (1997) and use the stationarity properties of the non-quality adjusted data to justify our characterisation of sector-specific technological progress in the non-ICT sector. In particular, we allow for

recognising the particularly severe data constraints we face for quality-adjusted non-ICT prices in the United Kingdom, we also present balanced growth accounting estimates where it is assumed that only ICT is subject to investment-specific technological progress.

The key characteristic that distinguishes this model from a standard one-sector growth model is the capital accumulation equation. In the current model, the stock of capital of type $i = d, e$ at time $t + 1$, K_{t+1}^i, is related to the stock of capital and investment at time t, K_t^i through:

$$K_{t+1}^i = (1-\delta_i)K_t^i + Q_t^i X_t^i, \tag{4}$$

where δ_i is a parametric depreciation rate.[10]

The factor Q_t^i determines the amount of capital of type i that can be purchased for one unit of final output; in the standard neoclassical growth model $Q_t^i \equiv 1$ but here we allow Q to increase over time. Notice that investment X_t^i is measured in units of final goods, so aggregate investment X_t is given by $X_t = \Sigma X_t^i$. Here, we interpret Q_t^i as a measure of technological change specific to the production of investment good i: a rise in Q_t lowers the marginal cost of producing investment goods measured in units of final goods, and so Q_t^i is inversely related to the relative price of capital good i. One simple way to spell out this relationship and to outline the sectoral interpretation of the model is the following: capital goods are produced by firms, using materials M_t^i as the only input in the production process, charging a price P_t^i for their output in a perfectly competitive market. Such a firm maximises profits $P_t^i\left(Q_t^i M_t^i\right) - M_t^i$ where $\left(Q_t^i M_t^i\right)$ is the firm's output and the price of materials, in the form of final goods, is normalised at one. The first-order condition for this problem, where the firm determines its output levels taking prices and technology as given, obviously implies that $P_t^i = 1/Q_t^i$. We use this relationship in the calibration exercise, where the growth rate of Q_t^i is calibrated using series on relative prices of capital goods. As emphasised in Section 1.1, technological progress that is "embodied" in capital can be interpreted as "disembodied" technological progress in the capital-producing sector. In describing the model in the following, we follow a convention whereby capital letters denote trended variables and lower case letters indicate stationary variables. All quantity variables are measured in per capita terms.

2.1 The agents

The economy is inhabited by an infinitely-lived, representative agent who has time-separable preferences U defined over consumption C_t of final goods and leisure L_t. The agent chooses C_t, L_t and investment X_t to maximise the expected present value of contemporaneous utility, using a discount factor β, subject to the budget constraint:

$$C_t + X_t = (1-\tau_K)(r_t^d K_t^d + r_t^e K_t^e) + (1-\tau_l)W_t h_t + T_t. \tag{5}$$

Here, consumption and investment cannot exceed the sum of labour and capital rental income net of taxes and lump sum transfer, T_t; wages and hours worked are W_t and h_t respectively, and τ_l is the tax rate on labour income. Rental income has two components: there is rental income from capital of

sector-specific technological progress in the non-ICT sector too. So we implicitly assume that there is some form of quality adjustment in the non-ICT data even if that adjustment is not hedonic. This characterisation of sector-specific technological progress in the United Kingdom is consistent with Greenwood et al's analysis for the United States insofar as non-ICT investment contains non-ICT elements of equipment that Greenwood et al (1997) assume is subject to sector-specific technological progress. Gort et al (1999) use a panel data set on rental values to estimate sector-specific technological progress in US structures investment too.

[10] Fraumeni (1997) reports that geometric depreciation is in general a good approximation to the decline of asset prices with age.

type *d* at rate r_t^d and type *e* at rate r_t^e, with quantities at K_t^d and K_t^e respectively. The tax rate on rental income is τ_κ.

Agents' capital holdings of type $i = d$, e evolve according to (4), reported below as (6) for convenience:

$$K_{t+1}^i = (1-\delta_i)K_t^i + Q_t^i X_t^i, \tag{6}$$

where δ_i is the depreciation rate for capital of type *i*.

The agents maximise their expected lifetime utility subject to the budget constraint (5) and the accumulation equations (6) by choosing C_t, L_t and X_t^i. The first-order conditions for this problem are:

$$U_l(C_t,1-h_t) = U_c(C_t,1-h_t)(1-\tau_l)W_t$$
$$\lambda_t^e = \lambda_t^d = U_c(C_t,1-h_t)$$
$$\lambda_t^i / Q_t^i = \beta E_t \lambda_{t+1}^i \left((1-\tau_\kappa)r_{t+1}^i + \beta(1-\delta_i)/Q_{t+1}^i\right), i = d,e \tag{7}$$

The first condition equates the marginal disutility from an additional hour of work with the marginal return to working, adjusted for taxes and measured in utility terms. The second condition describes the marginal utility of an additional unit of capital of type *i*: as there are no additional resource costs associated with changing capital from one type to the other, the marginal utilities of an additional unit of the capital goods are equal. And as capital goods can be transformed into consumption goods at no cost, the marginal utility of an additional unit of capital equals the marginal utility of consumption. The third condition is the standard Euler equation, equating the marginal cost of acquiring an additional unit of capital today in utility terms with the discounted expected return to this investment, consisting of expected after-tax rental income and the value of having this unit next period, adjusted for depreciation and possible capital losses.

2.2 Firms

In the baseline model, Q_t^i is assumed to capture all differences between production of final and investment goods: apart from technological progress, the production process is identical across goods. So a characterisation of firms producing final goods is sufficient. The firms in this economy have access to a production technology for final goods that uses capital of both types and labour:

$$Y_t = F(K_t^e, K_t^d, Z_t h_t), \tag{8}$$

where Y_t is output and Z_t is labour augmenting technological progress that applies to production of all goods. *F* is assumed to be continuous and concave in each of the inputs, and homogenous of order one. Goods and factor markets are assumed to be perfectly competitive, so that firms in their production decisions take output and factor prices as given. Firms rent capital and labour on a period by period basis - the workers hold the capital stock - so the firms' dynamic optimisation problem is identical to a sequence of the following static optimisation problems:

$$\max \Pi_t = F(K_t^e, K_t^d, Z_t h_t) - r_t^e K_t^e - r_t^d K_t^d - W_t h_t. \tag{9}$$

The first-order conditions for this problem are:

$$F_{K^i}(K_t^e, K_t^d, Z_t h_t) = r_t^i;\ i = d,e \tag{10}$$

$$F_h(K_t^e, K_t^d, Z_t h_t) = W_t. \tag{11}$$

There are no dynamic aspects to the firms' decisions, so the conditions describing factor demand simply state that marginal cost, given by real rental rates and real wages, equals marginal factor products, given by the marginal products of capital and labour.

2.3 Government

We incorporate a tax-levying government in the model because of the potentially important effects that distortionary taxes have on capital accumulation, and hence on the decomposition exercise. We are not analysing the use of taxation in demand management in this paper, and simply assume that the government balances its budget period by period by returning revenues from distortionary taxes to the agents via lump sum transfer. The government's budget constraint is then:

$$T_t = \tau_k (r_t^e K_t^e + r_t^s K_t^s) + \tau_l W_t h_t. \tag{12}$$

This completes the description of the baseline model. In the following, we characterise equilibrium and the balanced growth path.

2.4 Equilibrium and balanced growth

To facilitate our exposition of the steady state, we make assumptions about particular functional forms here. We assume a Cobb-Douglas production function[11] and a logarithmic specification for the instantaneous utility function:

$$Y_t = Z_t (K_t^e)^{\alpha_e} (K_t^d)^{\alpha_d} (h_t)^{1-\alpha_e-\alpha_d} \tag{13}$$

$$U(C_t, L_t) = \theta \ln (C_t) + (1-\theta) \ln (1-h_t). \tag{14}$$

Prior to characterising the balanced growth path, we describe the equilibrium of this economy. Equilibrium is characterised by a set of time-invariant decision rules for C_t, X_t^i and h_t, pricing functions for W_t, r_t^i, a balanced budget rule, and laws of motion for the aggregate capital stock that solve the agents' and firms' optimisation problem and satisfy the economy's resource constraint. These conditions are summarised by the following set of equations:

$$\frac{h_t}{(1-h_t)} = \frac{\theta}{1-\theta}(1-\tau_l)(1-\alpha_e-\alpha_d)\frac{Y_t}{C_t} \tag{15}$$

$$\lambda_t^i / Q_t^i = \beta E_t \lambda_{t+1}^i \left((1-\tau_K)\alpha_i \frac{Y_{t+1}}{K_{t+1}^i} + (1-\delta_i)/Q_{t+1}^i \right), i = d, e \tag{16}$$

$$\lambda_t^e = \lambda_t^d = \frac{\theta}{C_t} \tag{17}$$

$$\gamma_{t+1}^L K_{t+1}^i / Q_t^i = (1-\delta_i) K_t^i / Q_t^i + X_t^i, i = d, e, \tag{18}$$

$$C_t + X_t^e + X_t^d = Z_t (K_t^e)^{\alpha_e} (K_t^d)^{\alpha_d} (h_t)^{1-\alpha_e-\alpha_d}. \tag{19}$$

The first three conditions, (15)-(17), come straightforwardly from combining the first-order conditions characterising the agent's problem with those characterising the firms' and hence need no further comment. (18) characterises the economy's accumulation of capital of type *i*, where the term γ_{t+1}^L is the gross growth rate of population. The resource constraint, (19), is obtained from combining the budget constraint of the worker with the government budget constraint, using the homogeneity properties of the production function.

We can now characterise the non-stochastic, steady state balanced growth path of this model as an equilibrium satisfying conditions (15)-(19) where all variables grow at a constant rate. Denote the *gross growth rate* of output per capita, Y_t, along the balanced growth path with g and of capital per capita, K_t^i, with g_i.[12]

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[11] Notice that we have detached the technology variable Z_t from labour inputs here, so we have not written Z_t as labour augmenting. This is purely for convenience and ease of comparison with Greenwood et al (1997): with a Cobb-Douglas production, labour augmenting and factor neutral technological progress are identical up to a constant.

[12] So, for example, a growth rate of 2% is a gross growth rate of 1.02.

A balanced growth path obviously requires that hours per worker do not grow (otherwise they will hit their upper or lower bound). Combined with the fact that this is a full employment economy, this implies that total hours grow at the rate of population: the only contribution from hours worked to output growth comes from growth in labour force, and ultimately, as participation rates along a balanced growth path are constant, from population growth. In the model, we assume no population growth along the balanced growth path, to ease the description and facilitate comparison with Greenwood et al (1997), that is assuming that $\gamma_{t+1}^{L} = 1$. This has no implications for the growth accounting exercise as we are accounting for labour productivity growth, which by nature is independent of the size of the population, but would obviously affect an estimate of the growth rate of aggregate output along a balanced growth path.

From (19), balanced growth requires that the demand components of the model, that is C_t, X_t^d and X_t^e, grow at the same gross rate as output Y_t, g. Furthermore, let γ_e, γ_d and γ_z describe the steady state gross growth rates of Q_t^e, Q_t^d and Z_t. Using the production function, this implies that:

$$g = \gamma_z g_e^{\alpha_e} g_d^{\alpha_d}. \tag{20}$$

From (20), in the long run, increases in output can be accounted for by neutral technological progress or, equivalently because the production function is Cobb-Douglas, by labour augmenting technological progress, γ_z, and by increases in the capital stock per capita, equivalent to capital deepening, $g_d^{\alpha_d} g_e^{\alpha_e}$. But growth in the capital stock depends on technological progress in production of capital goods, *in addition to* neutral technological progress. The dependence stands out from the capital accumulation equations, where by (18), $g_i = g\gamma_i$. Combining this with (20), the growth rates can be expressed as functions of the exogenous growth rates of the production technologies:

$$\begin{aligned}
g &= \gamma_z^{1/(1-\alpha_e-\alpha_d)} \gamma_e^{\alpha_e/(1-\alpha_e-\alpha_d)} \gamma_d^{\alpha_d/(1-\alpha_e-\alpha_d)}, \\
g_d &= \gamma_z^{1/(1-\alpha_e-\alpha_d)} \gamma_e^{\alpha_e/(1-\alpha_e-\alpha_d)} \gamma_d^{(1-\alpha_e)/(1-\alpha_e-\alpha_d)}, \\
g_e &= \gamma_z^{1/(1-\alpha_e-\alpha_d)} \gamma_e^{(1-\alpha_d)/(1-\alpha_e-\alpha_d)} \gamma_d^{\alpha_d/(1-\alpha_e-\alpha_d)}.
\end{aligned} \tag{21}$$

The equilibrium conditions (15)-(19) can now be transformed by expressing them in terms of the following variables, where lower case indicates stationary variables:

$$\begin{aligned}
&y_t = Y_t/g^t; c_t = C_t/g^t; x_t^e = X_t^e/g^t; x_t^d = X_t^d/g^t; k_t^d = K_t^d/g_d^t; k_t^e = K_t^e/g_e^t; \\
&q_t^e = Q_t^e/\gamma_e^t; q_t^d = Q_t^d/\gamma_d^t; z_t = Z_t/\gamma_z^t; \widetilde{\lambda}_t^e = \lambda_t^e g^t; \widetilde{\lambda}_t^d = \lambda_t^d g^t.
\end{aligned} \tag{22}$$

These variables are stationary, so a balanced growth path with constant growth in the non-normalised variables can be characterised as a stationary state with no growth in these transformed variables. Let no time subscript indicate stationary state values. Then the balanced growth path is characterised by the following set of equations:

$$\frac{1-\alpha_d-\alpha_e}{(1-\tau_l)} \frac{1-\theta}{\theta} \frac{y}{c} = \frac{1-h}{h} \tag{23}$$

$$\frac{\beta}{g\gamma_i}\left((1-\tau_k)\alpha_i \frac{y}{k^i} + (1-\delta_i) \right) = 1, \; i = d,e \tag{24}$$

$$\frac{k^i}{y}(g\gamma_i - (1-\delta_i)) = \frac{x^i}{y}, \; i = d,e \tag{25}$$

$$\widetilde{\lambda}^e = \widetilde{\lambda}^d = \frac{\theta}{c} \tag{26}$$

$$\frac{c}{y} + \frac{x^e}{y} + \frac{x^d}{y} = 1 \tag{27}$$

Before moving on to assessing the importance of investment-specific technological progress in accounting for long-run growth, it is worth characterising the steady state growth path in words. Along the steady state path, productivity in the production of capital goods is increasing faster than productivity in production of consumption goods, so the relative price of capital goods is falling at a constant rate. Along this path, capital-labour ratios are increasing faster than labour productivity, so capital deepening is faster than output growth. Investment in capital increases in line with the capital stock and hence faster than output but, due to falling prices, investment expenditure grows in line with output, so the investment expenditure share of GDP stays constant.

3. Characterising the balanced growth path

To assess the contribution of investment-specific technological progress to long-term growth, the parameters of the model must be assigned values. We follow the calibration approach advocated by Kydland and Prescott (1982). According to this approach, parameter values are set either according to related empirical evidence or, in the absence of such evidence, to ensure that the model's balanced growth path is consistent with averages observed in UK aggregate data over the sample period. Consistency with the balanced growth path is an important feature of this approach - the parameter values must be set consistently such that for the chosen set of parameters, the equations characterising the balanced growth path, (23)-(27), are satisfied. In this sense, the model guides our interpretation of the data.

3.1 Calibration

The parameters of the model are

$\{\theta, \beta, \alpha_e, \alpha_d, \delta_d, \delta_e, \gamma_d, \gamma_e, \gamma_z, \tau_l, \tau_k\}$.

The growth rates γ_d and γ_e are calibrated directly using deflators for non-ICT and ICT investment goods.[13]

Reliable hedonic deflators for ICT goods that attempt to control for quality improvements are not available in the United Kingdom. In the absence of such data, we follow Broadbent and Walton (2000), Kneller and Young (2000) and Oulton (2000a) in employing a law of one price-type argument and use deflators from the United States, converted to GBP using the USD/GBP exchange rate.[14,15] In particular, we use estimates of nominal investment expenditure on computers, software and telecommunications in the United Kingdom derived from input-output tables (see Oulton (2000a)[16]), to weight together computer, software and telecommunications deflators from the US NIPA.[17] We treat the resulting chain-weighted Fisher price indices as our ICT investment deflator series.

According to Moulton et al (1999) and Parker and Grimm (2000), only prices for prepackaged software in the US NIPA are calculated from constant-quality price deflators based on hedonic methods. Prices for firms' own-account software in the NIPA are based on input cost indices that implicitly assume no increase in the productivity of programmers. Custom software prices are assumed to be a weighted average of prepackaged software prices and own-account software (with an arbitrary weight of 75% on own-account software). But it is implausible to assume that the productivity of programmers has not improved over time. This might lead to a significant understatement in the decline in the relative price of software and hence in our ICT deflator. To investigate the implications of this possible

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13 K_d, while representing "dull" capital, is productive capital, so excludes housing capital. This is appropriate because our measure of output, Y_t, excludes housing services.

14 Gust and Marquez (2000) discuss how Australia, Denmark and Sweden all officially use US hedonic computer deflators, exchange rate-adjusted, to proxy quality-adjusted computer prices in their respective countries.

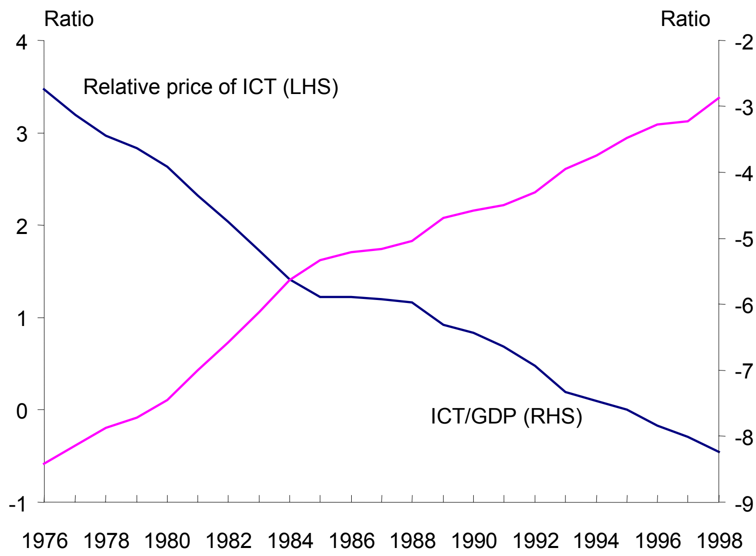
15 Because ICT products are traded on a global market, it seems likely that the rate at which quality-adjusted prices are falling over time should be the same in the United Kingdom and the United States. The *level* of prices may differ, say because of market discrimination by suppliers who possess monopoly power. But even changes in the degree of monopoly power are likely to be swamped by the huge falls in US prices related to investment-specific technological progress.

16 Oulton (2000a) notes that while the growth rates of software investment in nominal terms have been similar in the United States and the United Kingdom in the official data, the level of UK software relative to computer investment is much smaller in the United Kingdom. Oulton suggests that an upward adjustment be made to the UK data to control for this.

17 There are currently no official data available in the United Kingdom for our definition of ICT investment.

mismeasurement for assessing the importance of ICT investment-specific technological progress, we also present balanced growth accounting estimates calculated on the assumption that prepackaged software prices capture price trends for all types of software (we refer to this variant as the "high software" case as distinct from the "low software" case consistent with NIPA data).[18] The "high software" relative price and quantity-output ratio are reported in Figure 2 while the "low software" is the data underlying Figure 1.

Figure 2
Relative price of ICT goods and the ICT-output ratio.
High software.



Note: (1) All series are in logs; (2) ICT is measured in real quantities.

Of course, ICT goods are not the only types of investment good that have been subject to quality improvement (see Gordon (1990)). Hedonic price measurement by the Bureau of Economic Analysis in the United States is restricted to ICT goods. We assume for illustrative purposes that their adjustment for quality improvement for non-ICT (excluding housing) goods using methods other than hedonic regressions is again a good proxy for the quality-adjusted price of non-ICT goods in the United Kingdom. Again relying on a weak law of one price-type argument, we construct a chain-weighted Fisher price series for non-ICT goods (excluding housing) using deflators from the US NIPA. This time, as the nominal investment shares corresponding to the NIPA breakdown for non-ICT goods are not readily available for the United Kingdom, we have used US expenditure data to construct the weights. This is an assumption we will revisit in future drafts of this paper, once we have derived non-ICT investment and the corresponding deflators for the United Kingdom. Given, however, the particularly severe data constraints we face in deriving a plausible quality-adjusted non-ICT deflator for the United Kingdom, we also present balanced growth decompositions for the case where we assume that there is investment-specific technological progress for ICT investment goods only.

The growth rate g is calibrated by estimating average labour productivity growth over the sample. The within-sample properties of hours per capita and labour force participation differ from those of a balanced growth path: it is well known that since 1976, average hours per worker have declined and participation rates in the United Kingdom have increased. The correct way to estimate output/productivity growth along a balanced growth path where such changes are not possible is to

[18] Jorgenson and Stiroh (2000) go further still and report traditional growth accounting estimates under the assumption that software prices fall at the even more rapid rate reported by Brynjolfsson and Kemerer (1996) for microcomputer spreadsheets in 1987-92.

control for these factors within sample: we hence measure output growth per hour, and infer the long-run output growth by combining this measure with the balanced growth requirement that hours per worker and participation rates are constant.

The depreciation parameters δ_d and δ_e are key parameters in the construction of the ICT and non-ICT capital stocks using (6). For δ_e, we use the time series for constant price capital stock of computers, software and telecommunications in Oulton (2000a)[19] to weight together the depreciation rates for computers, software and telecommunications in Jorgenson and Stiroh (2000).[20] The sample average (1976-98) of the resulting weighted average depreciation rate series is 0.22 assuming software low and 0.20 assuming software high. The depreciation rate for non-ICT capital, δ^d, is derived using the depreciation rate for ICT capital together with a series for the implied aggregate depreciation rate. For the aggregate rate, δ_t, we use estimates of the constant price capital stock for buildings (excluding dwellings), vehicles, plant, intangible fixed assets and costs of ownership transfer from Oulton (2000b) to weight together depreciation rates taken from Fraumeni (1997). The formula we use for the implied depreciation rate is:

$$\delta_t = \frac{X_t - \Delta K_{t+1}}{K_t} \tag{28}$$

where no superscript indicates aggregate values and the capital stock is measured at the beginning of period t. From this, we derive a series for δ_t^d as a weighted average of the depreciation rate of each type of asset, where the weights are each asset's share of the aggregate capital stock. From this economy-wide depreciation rate (excluding housing) we subtract the share of ICT capital in the total non-dwelling capital stock multiplied by our estimate of the ICT depreciation rate, δ_e. The sample average of the resulting series is 0.059 (to three decimal points on both low software and high software assumptions).[21]

With these parameters determined, the balanced growth path investment-capital ratios can be determined from the capital accumulation equations (25). We then measure the ratios x^j/y using the data from Oulton (2000a,b). Given that we use the same deflator for both investment and output, these can be measured in nominal or real terms. From these we can infer the consumption-output ratio $c/y = 1 - \Sigma x^j/y$.[22]

From the income side of National Accounts, a steady state labour share of 70% is estimated. A marginal tax rate on labour income of 42.7% is used, τ_t, based on the work by Millard et al (1999). This

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19 These capital stock series are constructed by applying the perpetual inventory method to UK nominal investment data deflated by US deflators. In principle, we could have used these series for our measure of the ICT capital stock. We construct our own estimates using the perpetual inventory method in equation (6) because we wish to identify q separately.

20 Specifically, we assume depreciation rates of 31.5% per year for computers and software and 11% per year for telecommunications.

21 This method of calculating ICT and non-ICT capital stocks produces estimates of the real wealth stock at replacement value. The economic depreciation rates, δ_t^j, denote the decline in the replacement value of a unit of capital (relative to the price of new capital) that occurs as the unit ages. But it is the real productive capital stock that enters into the production function in (13). So the appropriate depreciation rate is actually a physical decay rate: the rate at which a unit of capital of a given vintage becomes less capable of producing output as it ages. In a simple model of vintage capital with investment-specific technological progress, Whelan (2000) shows that the real wealth stock backed out using quality-adjusted real investment and geometric, quality-adjusted economic depreciation rates is identical to the productive capital stock. This reflects the fact that the quality-adjusted economic depreciation rate in the simple model equals the rate of physical decay. But Whelan (2000) notes that the simple model does not allow for the technological obsolescence we observe in the real world: firms sometimes retire productive capital when the marginal product falls below some fixed "IT support cost". (Whelan quotes research in the United States by the Gartner Group (1999) that for every $1 spent on computers in 1998, there was another $2.4 spent on wages of IT workers and consultants.) Whelan shows that allowing for such technological obsolescence in the vintage capital model leads to a breakdown of the equivalence between real wealth measures of the capital stock and the productive capital stock. In particular, the economic depreciation rate now exceeds the physical decay rate that should be used in derivation of the productive capital stock. The depreciation rates we use in our study are economic depreciation rates based on studies underlying the US NIPA measures of the real wealth stock. So on Whelan's arguments they may be too high for growth accounting purposes.

22 Note that ICT and non-ICT investment includes government investment in these assets respectively. And our measure of the consumption-output ratio includes government consumption.

is the average value of the marginal tax rate faced by a worker on average earnings over the period 1976-98. Specifically, it is the basic rate of income tax plus the marginal national insurance contribution faced by such a worker, divided by one plus the marginal national insurance contribution faced by their employer. With Cobb-Douglas and perfect competition, the labour share is equal to 1 – α_d – α_e. We also determine h, the proportion of hours available used for work, as 0.26. This is the average portion of non-sleeping time spent in work reported in two "use of time" studies in the United Kingdom discussed by Jenkins and O'Leary (1997). This is very similar to the 0.24 used by Greenwood et al (1997) for the United States. With these estimates at hand, the first-order condition for labour characterising the balanced growth path determines the utility parameter θ, (23).

Finally, to determine the remaining parameters, β, α_d, α_e and τ_κ, we estimate the average after-tax real rate of return on capital. We assume that this equals 5.3% as in Bakhshi et al (1999). This is computed using estimates of the "effective" marginal tax rate on savings in the United Kingdom (which is based on estimates for the average marginal income tax rate on capital income following King and Fullerton (1984) and estimates of the effective tax rate on capital gains). This ties down the ratio β/g. This obviously ties down β for a given estimate of g, but also the three remaining parameters as the solution to the two steady state Euler equations, (24), and the restriction that (1 – α_d – α_e) is equal to labour share of income. The resulting values are α_d = 0.2616 and α_e = 0.0305 for the "low software" case, and α_d = 0:2618 and α_e = 0:0303 in the "high software" case.

Table 1 summarises the baseline calibration.

Table 1

Calibration of baseline model

	Low	High		Low	High		Low	High		
γ_d	1.02	1.02	δ_d	0.059	0.059	α_d	0.262	0.262	τ_l	0.427
γ_e	1.15	1.19	δ_e	0.190	0.212	α_e	0.031	0.030	h	0.26
γ_z	1.01	1.01	δ	0.065	0.065	τ_κ	0.320	0.280	β	0.972
									x^d/y	0.137
									x^e/y	0.019

Note: "Low"/"high" refers to the case where productivity growth in software production is assumed to be low/high.

3.2 Accounting for growth

We use our 1976-98 sample period, for which we have a complete data set, to estimate γ_d and γ_e. Given our estimates of α_d and α_e, we use the production function in (13) to back out a series for Z_t. The annual percentage change in Z_t gives us our estimate of γ_z. With our estimates of γ_z, γ_d, γ_e, α_d and α_e we can use equation (20) to decompose long-run growth into contributions from investment-specific technological progress for ICT and non-ICT separately and for neutral technological progress. The derived series for Z_t is illustrated in Figure 3. Two points can be noted. First, Z_t fell at the beginning of the 1990s, having peaked in 1988, and only recovered to this level in 1997. Second, this period of weak sector neutral technological progress coincides with the period where investment-specific technological progress for ICT takes off. So when changes in investment-specific technological progress are allowed for, the weakness of TFP in the early 1990s becomes even more pronounced. Of course, movements in Z and Q^e will reflect cyclical as well as trend movements in technological progress.

Table 2 summarises the results for both the low software and high software cases. This shows that ICT investment-specific technological progress contributes between 0.66 and 0.78 percentage points to labour productivity growth along the balanced growth path; non-ICT investment-specific technological progress contributes 0.85 percentage points and the remaining 1.57-1.59 percentage points is explained by TFP.

Figure 3

ICT investment-specific and neutral technological progress

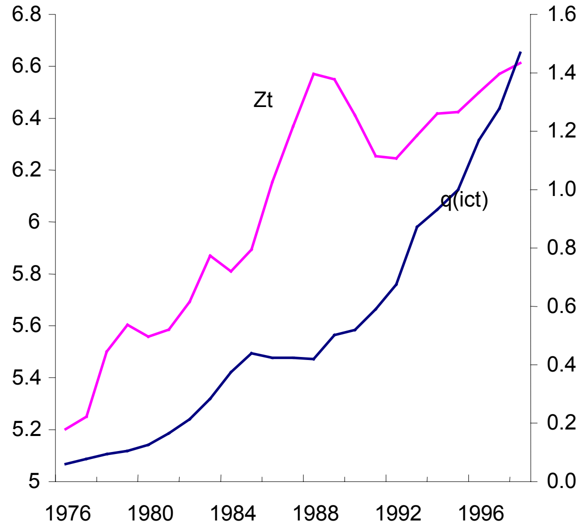


Table 2

Decomposing labour productivity growth

	TFP	ICT-specific	Non-ICT specific	Implied total
"Low software"	1.59%	0.66%	0.85%	3.12%
"High software"	1.57%	0.78%	0.85%	3.23%

Note: The implied total does not equal actual average labour productivity growth over the 1976-98 sample period. The error reflects differences between the sample average and the balanced growth path.

The particularly severe data constraints we face for quality-adjusted non-ICT prices for the United Kingdom were discussed in Section 3.1. Due to these constraints, we compute a balanced growth decomposition on the assumption that investment-specific technological progress occurs for ICT only (ie $\gamma_d = 1$ at all times). Table 3 summarises the results from this exercise. In this case, ICT investment-specific technological progress of course still contributes 0.66-0.78 percentage points to labour productivity growth along the balanced growth path, while TFP contributes the remaining 1.50-1.52 percentage points.

Table 3

Decomposing labour productivity growth

	TFP	ICT-specific	Implied total
"Low software"	1.52%	0.66%	2.18%
"High software"	1.50%	0.78%	2.29%

Note: The implied total does not equal actual average labour productivity growth over the 1976-98 sample period. The error reflects differences between the sample average and the balanced growth path.

These contributions from ICT-specific technological progress appear very large (around 20-30% of total labour productivity growth). They reflect the dual assumptions of very sharply falling relative prices of ICT investment goods and the fact that the ICT capital stock as a percentage of GDP in the United Kingdom appears to have been at near-US levels over our sample period. To the extent that the significant contribution of ICT to long-run growth is predicated on sustained falls in the relative price of ICT goods, this echoes the conclusions of Jorgenson and Stiroh (2000), Oliner and Sichel (2000), Gordon (2000), Bosworth and Triplett (2000) and others. They have argued that sustained high productivity growth rates in the United States will in part depend on continued sharp falls in the relative price of computers. This is an important lesson to come out from our balanced growth accounting exercise too.

4. Dynamic aspects of the baseline model

In the previous section, we characterised the balanced growth path of the model. In the following, we will analyse fluctuations around this steady state path, caused by temporary but persistent shocks to technology. This analysis is based on a log-linearised approximation to the economy characterised by (15)-(19), solved using the techniques described in King et al (1988). Using this approximation, we can describe the dynamics of the variables of interest as percentage deviations from the steady state path described above. Notice that, as before, we assume a constant population so variations in labour inputs are caused by variations in hours. In an economy with deterministic population growth, these variables should be interpreted in per capita terms. The details of these derivations are omitted here, but a technical appendix setting out the details is available on request.

To analyse the effects of shocks to technological progress, a stochastic process for the exogenous shocks must be specified. For that purpose we write:

$$Q_t^i = X_t^i q_t^i,$$

$$Z_t = X_t^z z_t$$

where capital letters indicate the trend component and lower case letters denote the cyclical component. The baseline case that we have used in the growth accounting exercise assumes a deterministic trend so that:

$$\ln\left(X_t^i\right) = \gamma_0^i + t\ln\left(\gamma^i\right). \tag{29}$$

To characterise business cycle fluctuations around this trend, we specify that:

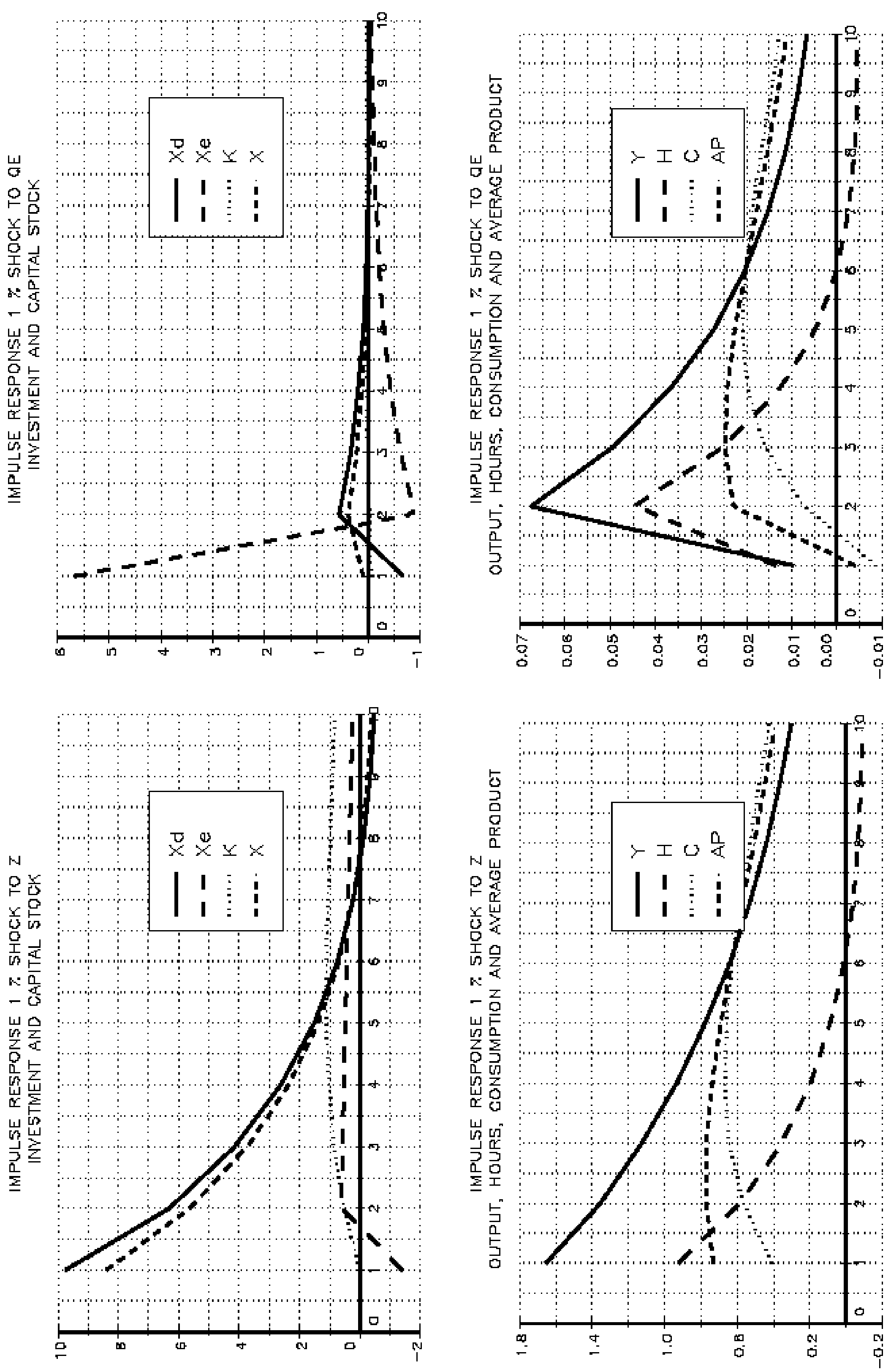
$$q_t^i = \exp\left(a_t^i\right);\ a_t^i = \rho_i a_{t-1}^i + \varepsilon_t^i,\ i = d,e$$

$$z_t = \exp\left(a_{zt}\right);\ a_{zt} = \rho_z a_{t-1}^z + \varepsilon_t^z \tag{30}$$

We focus solely on impulse response functions, so the only parameters of interest are the persistence parameters ρ_i, i = d, e, z. We estimate ρ_i by fitting an AR(1) with a constant and a linear trend to the series for (the natural logs of) Q_t^d, Q_t^e and Z_t derived previously. Depending on the exact measures (low or high software), this exercise suggests that ρ_d = ρ_e = 0.7 and ρ_z = 0.8 are reasonable values.

Here, we compare the dynamic response to shocks to z_t and to q_t^e. Given the specification chosen, the shocks we are considering are temporary increases beyond the deterministic trend in productivity: these shocks are persistent, but in both cases the productivity variable returns to trend. We will later discuss the implication of non-stationary shocks, that is, one-off shocks that permanently raise the level of productivity of the economy (though not the growth rate). There are crucial differences in the dynamic responses to these different shocks, but the economic mechanisms are essentially the same.

Figure 4
Impulse responses - baseline model



The impulse responses of the baseline model are illustrated in Figure 4. The *x*-axis of these charts is time, where each period is one year. Shocks occur in period 1. The *y*-axis is the percentage deviation from the trend path: in the baseline specification, the variables are trend stationary. Both shocks increase investment in capital of type *e* by increasing the expected marginal product of this type of capital - but while a shock to z_t increases the marginal product of capital on both types of capital, a shock to q_t^e only raises the marginal product of type *e*. This difference in productivity of capital leads to an immediate reallocation of capital from production of *d* to production of *e* capital: a shock to q_t^e initially causes substitution from investment in *d* to investment in type *e*. But the subsequently high *e* capital stock raises the marginal product of capital on *d*-type capital, leading to a subsequent counterflow in investment of type *d*: so the initial substitution effect of a shift in relative prices from investment of type *d* to *e* is offset in the following periods by a "complementarity effect" that shifts resources back towards *d* capital.

To study the response of the aggregate capital stock, the aggregate capital stock is defined as the weighted sum of the two types of capital, where the weights are the relative prices of capital goods to output:

$$K_t = P_t^d K_t^d + P_t^e K_t^e = K_t^d \big/ Q_t^d + K_t^e \big/ Q_t^e,$$

$$k_t = k_t^d \big/ q_t^d + k_t^e \big/ q_t^e. \tag{31}$$

The aggregate capital stock is hence measured in units of final output - within this one-sector model, this is equivalent to the Office for National Statistics' measure of the capital stock at replacement value, cf the discussion of this issue above. So the capital stock K_t grows at the same rate as output, and the output-capital ratio, Y_t/K_t, is stationary. Importantly, K_t is not a state variable: a positive shock to q_t^e lowers the relative price of a component of the capital stock, and hence the replacement value of the entire stock. A shock to z_t, on the other hand, has no such direct effect on the capital stock.

In addition to these differences in the investment response, shocks to q_t^e and to z_t differ in terms of their output implications. A shock to z_t raises output on impact, as more output is produced for given factor inputs. Hours worked also increase as the return to working increases, raising output further; but due to the direct effect of z_t on output, average labour productivity increases on impact. A shock to q_t^e, on the other hand, has no immediate direct effect on output - the effect comes from an increased return to investment, and hence an increase in the capital stock. Output is increased on impact through an increase in hours worked, but this implies a negative rather than a positive effect on average labour productivity. Note how long it takes for labour productivity to settle back to its balanced growth path in both cases. Also, unlike the shock to z_t, the initial effect of a shock to q_t^e on consumption is negative, as resources for extra investment are brought about by a decrease not only in consumption of leisure but also in consumption of goods.

The quantitative effects of the two shocks obviously differ: a shock to q_t^e affects only a small proportion of production and a shock to z_t is obviously more "powerful" in the sense that it applies to all production. Yet it is noteworthy that a shock to q_t^e has a stronger effect on output than its share of production would suggest: the peak effect of a 1% shock to ICT-specific technological progress is 0.07%. This suggests that if fluctuations in q_t^e are relatively large, ICT-specific technological progress may account for a large proportion of business cycle fluctuations, despite a relatively small output share. This is in line with Greenwood et al (2000), who make a similar inference based on technological progress specific to investment in equipment.

5. Extending the baseline model

Above, we provided a brief characterisation of the baseline model. In this section, we highlight shortcomings of the baseline model as a tool for business cycle analysis. To address these, we modify the model and add features to bring the model more into line with well known empirical regularities. These do tend to obscure the basic mechanisms discussed in the section above, but the gain is a richer dynamic structure. The features we build in are drawn largely from the existing literature: the main purpose of the exercise is not to provide new theoretical insights, but to analyse the issue at hand, sector-specific technological progress, in a model with these features.

One striking feature of the baseline model is that a sector-specific shock causes negative co-movements between sectoral inputs and outputs: a shock to q_t^e leads to an increase in investment of type *e* but a fall in inputs into production of consumption and *d*-type investment goods. Similarly, a shock to z_t shifts resources, in the form of hours worked, away from production of consumption goods into production of investment goods (though the net effect on consumption is positive, unlike a shock to investment-specific technological progress). The DGE literature on multisector models, reviewed by Greenwood et al (2000), addresses this issue by including materials (Hornstein and Praschnik (1997)) or intrasectoral adjustment costs (Huffman and Wynne (1999)). The home production model by Benhabib et al (1991) provides a different mechanism to address this issue that is easily implementable in the model considered here: by introducing a home sector to which workers can allocate hours, labour supply to market activities becomes more responsive. In this model, a positive shock to "market activities", whether investment neutral or sector neutral technological progress, implies that workers shift hours from the home sector in addition to lowering leisure. This issue is analysed in detail in Greenwood et al (1995).

One aspect of the baseline model that might appear implausible is the rapid reallocation of resources from investment in one type of capital to another or, equivalently, the speed with which the capital stock adjusts in response to shocks. The obvious solution in this context is to implement costs to adjusting the capital stock - this, in addition to slowing down the response of the capital stock, affects the response of the price of capital stock by effectively inserting a wedge between Q_t^i and P_t^i. This is explored in detail in Christiano and Fisher (1995) (who also include habits in consumption). In addition, inclusion of adjustment costs tends to strengthen the propagation mechanism, thus addressing a fundamental weakness of the standard real business cycle model.

The final aspect we look at is variable utilisation rates of capital. Effective capital input then consists of the stock of capital, utilised at a variable rate, with utilisation being costly in the form of increased depreciation. This is important for at least two reasons. First, variable utilisation rates imply that effective capital inputs into production can be increased immediately in response to shocks, making output more responsive to shocks and strengthening the propagation mechanism. The implications of this are explored in the literature associated with, amongst others, Burnside and Eichenbaum (1996). Second, a shock to Q_t^i that tends to lower the price of capital of type *i* implies a loss in value for existing capital holders. And a lower price of the capital stock implies a lower cost, measured in consumption units, of depreciation. This price effect makes it less costly to increase utilisation rates in response to sector-specific shock. This will tend to amplify the output response of a sector-specific shock relative to a neutral shock.

In the following, we provide the details of these extensions to the model. The extensions are implemented in such a way that the steady state growth path is identical to that of the baseline model. A general property of these extensions is that Q_t^i no longer corresponds directly to the inverse of the deflators. As with the baseline model, we characterise the model by looking at impulse response functions.

5.1 Home production

We introduce home production in the simplest possible way by assuming a home production technology without capital that is linear in hours worked:

$$Y_t^H = Z_t^H h_t^H, \tag{32}$$

where Y_t^H is production of home-produced goods, h_t^H is labour input into home production and Z_t^H is labour productivity in the home sector. Home-produced goods are distinct from market goods in that home-produced goods cannot be saved, so consumption of home-produced goods necessarily equals production, that is $C_t^H = Y_t^H$. The agent's time constraint is modified to include hours worked at home such that:

$$h_t + h_t^H + l_t = 1. \tag{33}$$

As mentioned in the previous section, the model extensions are formulated in such a way that the extended model nests the baseline model. To do so here, we assume the existence of a consumption aggregate $\zeta_t = \zeta(C_t, C_t^H)$, where ζ is a convex and homogenous aggregator, and write the utility function as $U(\zeta_t, L_t)$: the baseline specification then simply requires that $\zeta_t = C_t$.

This modification alters the agent's dynamic maximisation problem, adding a first-order condition for hours worked in production at home, and modifying the first-order condition for hours worked in market activities:

$$h_t^H : Z_t^H U_\zeta(\zeta_t, l_t)\zeta_{C^H}(C_t, C_t^H) = U_l(\zeta_t, l_t), \tag{34}$$

$$h_t : U_l(\zeta_t, l_t) = U_\zeta(\zeta_t, l_t)\zeta_C(C_t, C_t^H)W_t(1-\tau_l). \tag{35}$$

The first condition balances the marginal disutility of an extra hour worked with the return to working an additional hour at home, Z_t^H, measured in utility terms, while the second relates the marginal disutility of an extra hour worked with the returns to market activities. These conditions describe how home production alters labour supply: an increase in the real wage now affects labour supply through two channels: it represents a decrease not only in the relative price of market consumption goods relative to leisure but also in that of market consumption goods relative to the price of home-produced goods. So in this sense, introduction of home production strengthens the substitution effect of an increase in real wages.

To parameterise this extension, only a consumption aggregator is needed. We specify ζ as a CES aggregator:

$$\zeta_t = \{(1-\theta^H)(C_t)^e + \theta^H(C_t^H)^e\}^{\frac{1}{e}} \tag{36}$$

which implies that home and market goods are imperfect substitutes with an elasticity of 1/(1 – e), with θ^H measuring the "bias" towards home-produced goods. Existence of a steady state growth path requires that productivity in the home sector Z_t^H grows at the same rate as market output, ie g: this assumption also ensures that the extended model has the same steady state path as the baseline model. To calibrate the remaining parameters, observe that the first-order condition for allocation of labour implies the following steady relationship:

$$\left(\frac{c}{c^H}\right)^{-e}\frac{c}{y}\frac{h}{h^H} = (1-\alpha_d-\alpha_e)(1-\tau_l)\frac{(1-\theta^H)}{\theta^H} \tag{37}$$

We follow Greenwood et al (1995) and set $h^H = 0.25$ and $e = 0$, implying a unit elasticity of substitution between home-produced and market goods. The baseline model's calibration of the remaining parameters and steady state ratios then implies a value for θ^H.

5.2 Capital

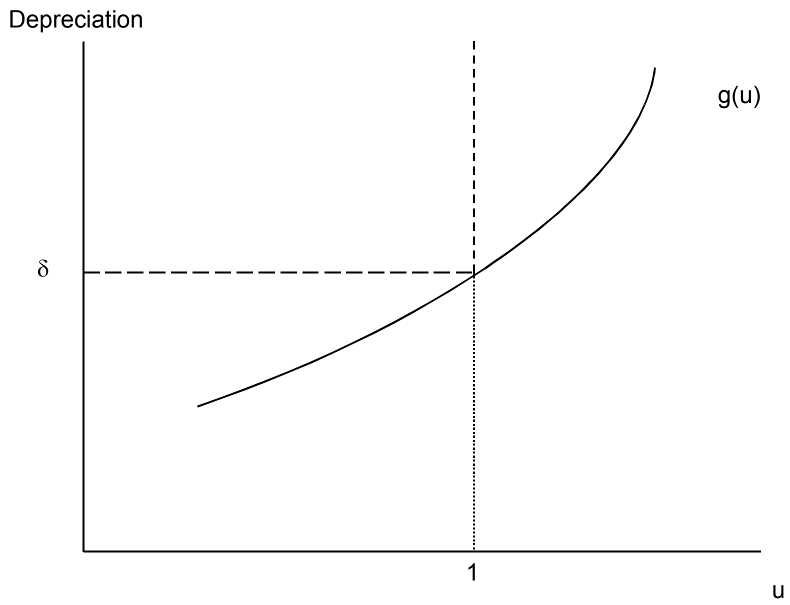
As in the baseline model, we assume that the agents own the capital stock and rent it to firms on a period by period basis. The rental contract specifies an amount of *effective capital input* $K_t^{i*} = u_t^i K_t^i$ that the agent will provide to the firm at a fixed price r_t, but the agents determine the composition of the input between utilisation u_t^i and quantities K_t^i. The agent is assumed to determine the capital stock prior to observing the shocks but utilisation after observing the shocks. Increasing utilisation is costly: if the agent decides to increase effective capital supply by increasing utilisation, this results in a higher depreciation rate. Depreciation of capital good i at t is given by:

$$\delta_{it} = g_i(u_t^i), i = d, e \tag{38}$$

where g_i is a continuous and convex function $g_i'(.) > 0$ and $g_i''(.) > 0$: increased utilisation of capital increases depreciation at an increasing rate. The properties of the depreciation function are illustrated in Figure 5. In characterising the deviations from steady state, it is the derivative and the elasticity of the derivative that are important, that is, how much increases in utilisation translate into increases in depreciation and the elasticity of this response. The baseline case emerges when the elasticity $g_i''(1)u_i / g_i'(1) \to \infty$ (illustrated with the dashed line). In that case, the returns to changing utilisation are becoming infinitely small. This will not affect steady state utilisation, as this is related to the levels of *g*, not the derivatives.

Figure 5

The depreciation function $g(u_t^i)$



In addition to variable utilisation, we introduce a cost of adjusting the capital stock. In particular, we assume the existence of a wedge between investment expenditure measured in units of capital goods, $Q_t^i X_t^i$, and the increase in the capital stock, given by:

$$\psi_i\left(\frac{Q_t^i X_t^i}{K_t^i}\right)K_t^i,\ i = d,e.$$

The adjustment costs are assumed to be convex by assuming that ψ is concave in its arguments, $\psi_j'(.) > 0$ and $\psi_j''(.) < 0$.

These extensions add an additional first-order condition to the agent's problem, characterising utilisation, and alter the equations that characterise the marginal value of an additional unit of capital and the asset Euler equation. The first-order condition for utilisation dictates that the marginal product of additional utilisation, adjusted for tax and measured in utility terms, equals the marginal cost in the form of increased depreciation:

$$\lambda_t(1-\tau_k)r_t^i K_t^i = \lambda_t^i g_i'(u_t^i)\frac{K_t^i}{Q_t^i},\ i = d,e \qquad (39)$$

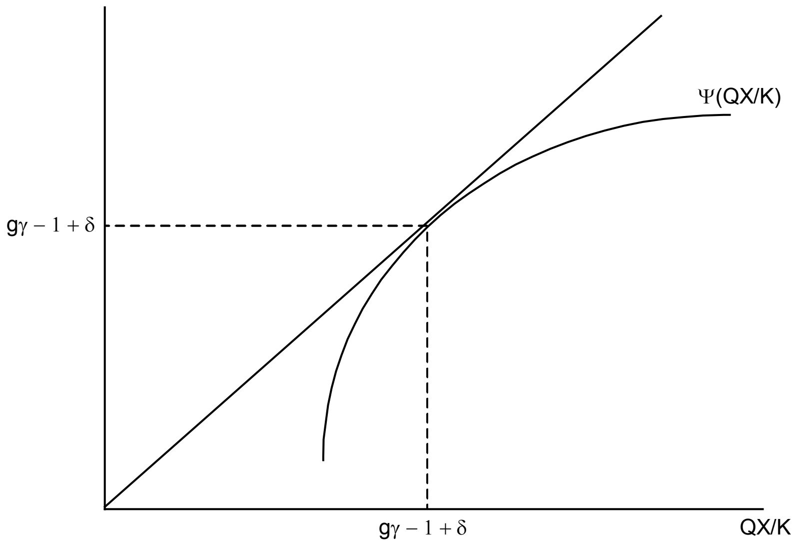
where λ_t is the marginal utility of consumption at time *t*. Here, $g_i'(u_t^i)$ is the marginal increase in the rate of depreciation of the capital stock K_t^i. The presence of adjustment costs implies that out of steady state, there is a wedge between the marginal values of capital stock and the marginal utility:

$$\lambda_t = \lambda_t^d \psi_{dt}' = \lambda_t^e \psi_{et}'. \qquad (40)$$

Hence the ratio $1/\psi'_{it}$ measures the marginal value in output terms of an additional unit of capital and can thus be interpreted as a measure of Tobin's marginal q[23] (not to be confused with q_i!): if the derivative of the adjustment cost function is less than 1, this suggests firms should increase investment, see Figure 6; in the absence of adjustment costs, q is always 1. Notice that the baseline specification requires that the elasticity of ψ' in steady state is 0, while values smaller than 0 indicate more curvature.

Figure 6

Adjustment cost function



Variable utilisation and adjustment costs obviously also modify the Euler asset price equation:

$$\frac{\lambda_t^i}{Q_t^i} = \beta i_t \left(1 - g_i\left(u_t^i\right) + \psi_{it+1} - \psi'_{it+1} \frac{Q_{t+1}^i X_{t+1}^i}{K_{t+1}^i} \right) \frac{\lambda_{t+1}^i}{Q_{t+1}^i}$$

$$+ \beta i_t \lambda_{t+1} (1 - \tau_k) r_{t+1}^i u_{t+1}^i . \qquad (41)$$

Finally, the accumulation equation for individuals' holding of capital is altered to reflect utilisation and adjustment costs:

$$K_{t+1}^i = \left(1 - g_i\left(u_t^i\right)\right) K_t^i - \psi_i \left(\frac{Q_t^i X_t^i}{K_t^i} \right) K_t^i ,\ i = d,e. \qquad (42)$$

We calibrate the extended model to ensure that the steady state path is identical to that of the baseline model. To illustrate the restrictions we impose on the adjustment cost function, we return to the sectoral interpretation used previously in Section 2. A capital-producing firm makes output decisions by choosing expenditure on materials M_t, conditional on Q_t^i and K_t^i and given prices P_t^i, to maximise profits $P_t^i \psi_i (Q_t^i M_t / K_t^i) K_{it} - M_t$. The first-order condition for this problem implies that:

$$P_t^i Q_t^i \psi'_i \left(\frac{Q_t^i X_t^i}{K_t^i} \right) = 1. \qquad (43)$$

[23] See Hayashi (1982).

In the baseline model, the inverse relationship between P_t^i and Q_t^i holds in all equilibria, whether these are on or off the steady state path. To establish the same relationship on the steady state path for the extended model, we specify and calibrate the functional form such that $\psi_i'(g\gamma_i - 1 + \delta_i) = 1$ - this implies a steady state value of one for Tobin's marginal *q*. Notice that in the extended model the inverse relationship between P_t^i and Q_t^i holds only in steady state.

The accumulation equation function (42) imposes an additional restriction on ψ_i: for this accumulation equation to reproduce (18) in steady state, we impose that:

$$\psi\,(g\gamma_i - 1 + \delta_i) = g\gamma_i - 1 + \delta_i, \tag{44}$$

where $g\gamma_i - 1 + \delta_i$ is the investment/capital ratio in the baseline steady state.

In the log-linearised economy, the only additional parameter in ψ_i that needs calibration is the elasticity of ψ_i' in steady state - recall that we have already tied down the level and first derivative in steady state, so we effectively only need to determine the curvature of ψ in the vicinity of steady state. There is no readily available empirical evidence on these two parameters, so we calibrate this parameter by looking at the model's adjustment path when the capital stock is away from steady state. In practice, we set the convergence rate to steady state at 25% a year, implying a half-life of capital stock deviations from steady state of approximately 2.4 years. This is roughly equivalent to the values in Basu et al (2000).

For the utilisation function, we impose the restriction that:

$$g_i\,(u^i) = \delta_i,\ i = d, e, \tag{45}$$

that is, in steady state, the depreciation rate in the extended model equals that of the baseline model. Notice also that from the first-order condition for utilisation, in steady state:

$$g_i'(u^i)u^i = (1 - \tau_k)\alpha_d \frac{y}{k^i}. \tag{46}$$

By restricting the depreciation function to be a CES function, (45) and (46) are sufficient to tie down the necessary parameters.

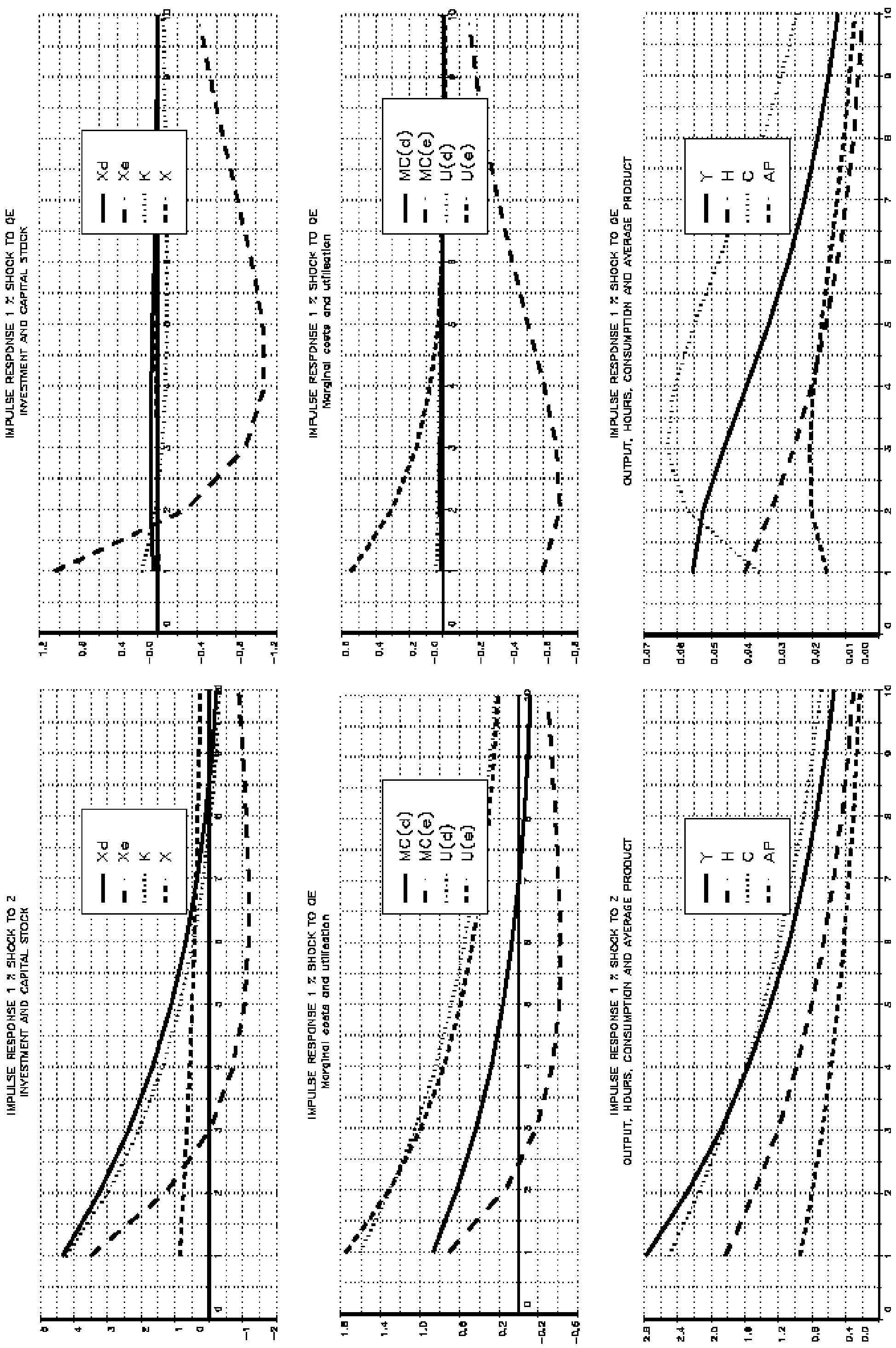
5.3 Dynamic aspects of the extended model

As already noted, the extended model is set up in such a way that the steady state growth path is exactly identical to that of the baseline model - so it only remains to characterise the differences in dynamics around this unchanged steady state path. As before, we characterise the model by looking at impulse response functions. The impulse responses are illustrated in Figure 7, where the left-hand set of charts show responses to a 1% shock to z_t, while the right-hand set show responses to a 1% shock to q_t^e.

As suggested earlier, the presence of adjustment costs implies that there is a wedge between p_t^i and $1/q_t^i$. Prices of capital goods are less responsive to sector-specific shocks because the marginal costs of producing capital goods are sluggish. To illustrate the mechanics of this, recall that marginal costs of producing capital goods are $(q_t^i \psi_t')^{-1}$ and that $\psi'' < 0$. A positive shock to q_t^i directly lowers marginal costs of producing new capital goods, but an increase in production of these goods implies a decrease in ψ_t', offsetting the direct cost effect. This tends to dampen the strong "substitution effect" seen in the baseline model that leads to a reallocation of resources from production of *d* to production of *e*. There is still a "complementarity effect": a large capital stock of type *e* raises the marginal product of capital of type *d*. With a weakened "substitution effect", this complementarity effect combined with the incentive to smooth investment provided by the adjustment costs implies that investment in capital of type *d* increases in response to a shock to q_t^e where in the baseline model the "substitution effect" dominated (though the effect is quantitatively small). The presence of a home sector reinforces this co-movement: a shock to q_t^e raises the return to market activities relative to home, and this tends to raise production of all market goods. But there are still differences compared with the response of investment in the two types to a sector neutral z_t shock: the positive co-movement between investment into the two sectors is still much stronger in that case.

Figure 7

Impulse responses - extended model



The inclusion of adjustment costs also affects the output and consumption responses, primarily by dampening the responses. Importantly, variable utilisation of capital implies that effective capital inputs can be raised immediately in response to shocks - this implies that output can be increased on impact by both increasing hours and utilisation. The return to utilisation increases in response to shocks to both z_t and q_t^e, but a shock to q_t^e has the added effect that the expected future capital loss on existing capital stock, coming from future lower prices, decreases the cost of increased depreciation measured in output terms. The outcome is that in response to a shock to q_t^e, output now increases by more than hours, increasing average labour productivity (unlike in the baseline model).

6. Scenarios for structural change

In the preceding analysis, the maintained assumption has been that a non-stochastic trend is a good description of the economy's steady state growth path. In this section, we change and relax this assumption in a number of ways. In doing this, we are essentially trying to use the model as a tool for "scenario analysis" of different contemporary examples of structural change. The exercises we consider include temporary and permanent changes to the growth rate of technological progress, as opposed to the temporary changes to the *level* studied in the previous sections. We also look at the implications of changing the technical coefficient α_e on expenditure shares and the aggregate depreciation rate.

6.1 Permanent shocks to technology

The extensions to the model discussed in Section 5 alter the dynamics around the deterministic path, but maintain the stationary trend assumption. An obvious question is what difference a change in the stochastic properties of the shock would make: Rotemberg and Woodford (1996), for instance, argue in favour of permanent rather than temporary shocks to technology. In the UK context, Ravn (1997) shows that the distinction is important when explaining UK data, but argues that assuming non-stationary shocks alone is insufficient when explaining business cycle facts. While being somewhat agnostic on this issue, we want to consider the implications of permanent shocks to technological progress in our model. Arguably, such a shock is a better characterisation of the views of proponents of the "new economy" hypothesis: they argue that the US economy may have experienced an increase in medium-term productivity growth, but that it is still too early to conclude anything about long-run growth. And on this view, a temporary shock to the growth rate of productivity might be a more pertinent simulation for policymakers in the United Kingdom who wish to embed a "new economy" shock into their macroeconomic forecasts. We do this by modifying (29) so that:

$$\ln\left(X_t^i\right) = \ln\left(\gamma^i\right) + \ln\left(X_{t-1}^i\right) + \varepsilon_t^i,\ i = d, e, z \qquad (47)$$

We set the drift parameter such that the average growth rates of the model with non-stationary shocks are identical to those of the baseline model, so that in the absence of shocks the two economies would follow the same growth path. Furthermore, we assume that there are no temporary shocks.[24] So a shock in this new economy shifts the level of productivity permanently, whereas in the baseline model, a shock only has a temporary (though persistent) effect. We analyse this issue using the baseline specification of the model.

This change in the stochastic properties of the shocks changes the normalisation of variables. We replace the terms g^t, g_d^t and g_e^t that characterise the non-stochastic steady state path with three stochastic terms:

$$N_t = Z_t^{\frac{1}{\alpha_l}} \left(Q_t^d\right)^{\frac{\alpha_d}{\alpha_l}} \left(Q_t^e\right)^{\frac{\alpha_e}{\alpha_l}};\ N_t^d = Q_t^d N_t;\ N_t^e = Q_t^e N_t, \qquad (48)$$

where $\alpha_l = 1 - \alpha_e - \alpha_d$. The variables are now normalised as follows:[25]

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[24] By assuming that there are only permanent shocks, we avoid a potential signal extraction problem: if there were both permanent and temporary shocks, then the agents would have to separately identify the shocks.

[25] Notice that the growth rates γ_t^d, γ_t^e and γ_t^z are now stochastic. Moreover, to accommodate a stochastic growth rate, we have changed the timing convention on the capital stock normalisation.

$$y_t = Y_t / N_t \,;\; c_t = C_t / N_t \,;\; x_t^e = X_t^e / N_t \,;\; x_t^d = X_t^d / N_t \,;\; k_t^d = K_t^d / N_{t-1}^d \,;\; k_t^e = K_t^e / N_{t-1}^e \,;$$

$$\gamma_t^d = Q_t^d / Q_{t-1}^d \,;\; \gamma_t^e = Q_t^e / Q_{t-1}^e \,;\; \gamma_t^z = Z_t / Z_{t-1} \,;\; \tilde{\lambda}_t^e = \lambda_t^e N_t \,;\; \tilde{\lambda}_t^d = \lambda_t^d N_t . \tag{49}$$

The stationary system is then characterised by the following sets of equations:

$$\frac{h_t}{1-h_t} = \frac{\theta}{1-\theta}(1-\tau_l)(1-\alpha_e-\alpha_d)\frac{y_t}{c_t}$$

$$\tilde{\lambda}_t^e = \tilde{\lambda}_t^d = \frac{\theta}{\tilde{C}_t}$$

$$c_t + x_t^e + x_t^d = \left(\frac{1}{\gamma_t^N \gamma_t^d}\right)^{\alpha_d} \left(\frac{1}{\gamma_t^N \gamma_t^e}\right)^{\alpha_e} \left(k_t^e\right)^{\alpha_e} \left(k_t^d\right)^{\alpha_d} h_t^{1-\alpha_e-\alpha_d}$$

$$\tilde{\lambda}_t^i = \beta \tilde{\lambda}_{t+1}^i (1-\tau_k)\alpha_i \frac{y_{t+1}}{k_{t+1}^i} + \beta \tilde{\lambda}_{t+1}^i (1-\delta_i) \frac{1}{\gamma_{t+1}^N \gamma_{t+1}^i}$$

$$k_{t+1}^i = (1-\delta_i) k_t^i \frac{1}{\gamma_t^N \gamma_t^i} + x_t^i ,\; i = d, e \tag{50}$$

where

$$\gamma_t^N = \left(\gamma_t^z\right)^{\frac{1}{\alpha_l}} \left(\gamma_t^d\right)^{\frac{\alpha_d}{\alpha_l}} \left(\gamma_t^e\right)^{\frac{\alpha_e}{\alpha_l}} . \tag{51}$$

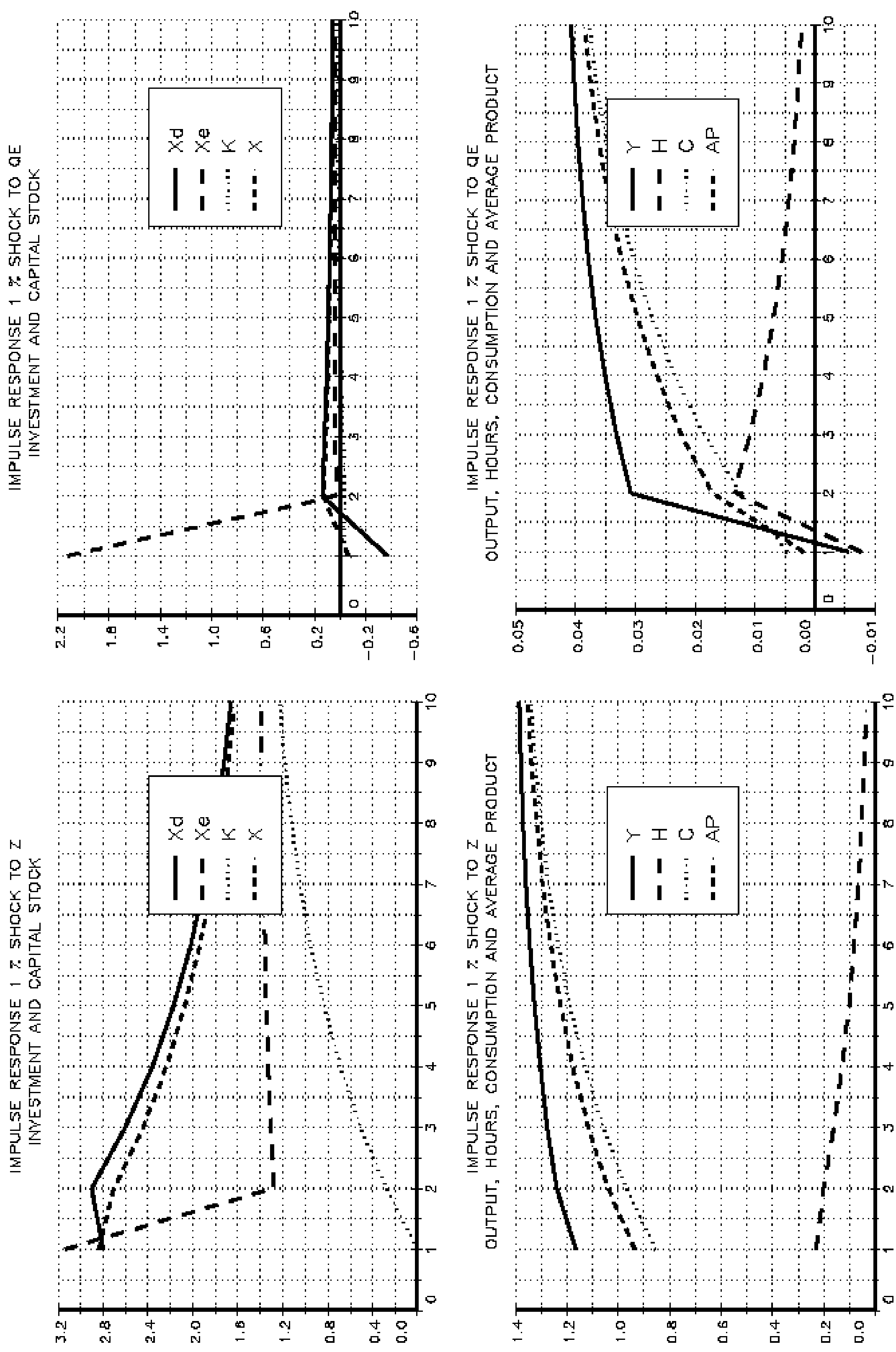
As mentioned, the shocks now permanently change the steady state level of output. From (48), a 1% permanent increase in the level of z_t permanently raises the steady state path of output by $1/\alpha_l$%, whereas a similar shock to Q_t^e shifts the steady state path by α_e/α_l. The dynamics of the adjustment paths are illustrated in Figure 8 - the economic mechanisms discussed at length in Section 4 are the same, but the dynamics differ. Unlike a neutral shock, a permanent increase in Q_t^e initially decreases output as hours worked fall. We ascribe this to the income effect dominating the substitution effect: having observed a permanent shock to technology, whether sector-specific or neutral, agents will know that long-run income levels have increased. This tends to lower labour supply. In the case of a sector neutral shock, there is a strong offsetting substitution effect from an immediate increase in wages (or equivalently, an increase in the cost of leisure). With a sector-specific shock, there is no such effect in the first period because increases in Q_t^e do not affect output on impact. Productivity and hence wages only increase in subsequent periods, which then increases labour supply.

The income/substitution effects also distinguish the investment/consumption responses in the two cases. Here, the counterbalancing is between a falling price of investment goods or an increasing return to investment on the one hand (substitution effect), and a permanent increase in income which tends to increase consumption at the expense of investment on the other (income effect). With a neutral shock, the return to investment increases for both types of capital good. This dominates the income effect, so aggregate investment overshoots its long-run levels and the consumption-output ratio decreases. A shock that is specific to production of investment goods of type *e* only raises the return to investment in capital of this type: it shifts resources from production of type *d* goods, but aggregate investment undershoots its long-run level as the income effect dominates the substitution effect and the consumption-output ratio increases.

6.2 ICT investment expenditure share

Even with permanent shocks to productivity growth, the balanced growth path is characterised by constant expenditure shares: production becomes increasingly ICT-intensive but the price of this capital good is falling, leaving the investment expenditure share constant. Arguably, one feature of the recent US experience is a sharp increase in the ICT investment expenditure share-certainly, in the United Kingdom the investment expenditure share rose sharply over the period, with the ICT share increasing from 0.7% in 1976 to 3.6% in 1998.

Figure 8
Impulse responses - permanent shocks



Accounting for this phenomenon poses a challenge to the model we are using. To some extent, the model can account for this as a *temporary* phenomenon: in the baseline model, a fall in the price of ICT capital goods leads to a large temporary increase in investment that exceeds the drop in prices, so that the ICT investment expenditure share temporarily increases. But with very rapid adjustments of factor inputs, the steady state expenditure share is quickly restored. The extensions of the baseline model dampen and slow down this adjustment, implying a smaller but more persistent response of the investment expenditure share. The baseline model cannot account for this as a *permanent* phenomenon: along the steady state growth path where growth is balanced, the expenditure shares are constant. To analyse *permanent* changes to the investment expenditure share, we need to consider changes in structural parameters. In the following, we perform some comparative static exercises and characterise how changes in some structural parameters change the balanced growth path, holding all other parameters at their steady state values.

The obvious first candidate to change is the growth rate of sector-specific technological progress, that is, to consider changes to γ^e in (47), similar to the exercise in Pakko (2000). From (51), an increase in γ^e also increases the aggregate growth rate γ^N. Such a change has two offsetting effects on the investment expenditure share. To see this, consider the steady state version of the capital accumulation and the Euler equations from (50):[26]

$$(1-\tau_k)\alpha_e \frac{y}{k^e} + \frac{(1-\delta_e)}{\gamma^N \gamma^e} = \frac{1}{\beta},$$

$$1 - \frac{(1-\delta_e)}{\gamma^N \gamma^e} = \frac{x^e}{k^e} \qquad (52)$$

An increase in the growth rate γ^e leads to an increase in the y/k_e ratio through a negative "capitalisation effect": the return to investing in one unit of capital is the after-tax marginal product of capital, plus the value of the capital stock next period, $(1 - \delta_e)/\gamma^N\gamma^e$. An increase in γ^e lowers the value of the capital, because the intertemporal price of capital good *e* is falling faster. For a given discount factor, this will require an increase in the return to capital, ie an increase in the y/k^e ratio to increase the marginal product of capital. On the other hand, there is an "accumulation effect": an increase in growth rate will require an increase in the investment-capital ratio, x^e/k^e, to maintain balanced growth. In combination, the ratio x^e/y is given by:

$$\frac{x^e}{y} = \frac{x^e}{k^e}\frac{k^e}{y} = \frac{\gamma^N\gamma^e - (1-\delta_e)}{\gamma^N\gamma^e - \beta(1-\delta_e)}\beta(1-\tau_k)\alpha_e. \qquad (53)$$

It is straightforward to establish that, provided $\beta < 1$, x^e/y is increasing in γ^e, so in other words, the accumulation effect dominates. Figure 9 depicts this relationship: notice that even substantial changes in γ^e (the *x*-axis) lead to fairly small changes in expenditure share (the *y*-axis). Hence, an increase in γ^e to match the increased ICT investment expenditure ratios would require the growth rate γ^e to increase substantially, implying in turn a substantial increase in the steady state growth rate.[27]

Figure 9 also shows the effect on the aggregate depreciation rate of varying γ^e: an increase in the growth rate of ICT-specific technological progress would imply a decrease in the aggregate depreciation rate. So despite the fact that an increase in γ^e leads to higher growth in intensity of a capital good with a relatively higher depreciation rate, the aggregate depreciation rate falls. This, essentially, is caused by the capitalisation effect. To see this, we define the aggregate depreciation rate as

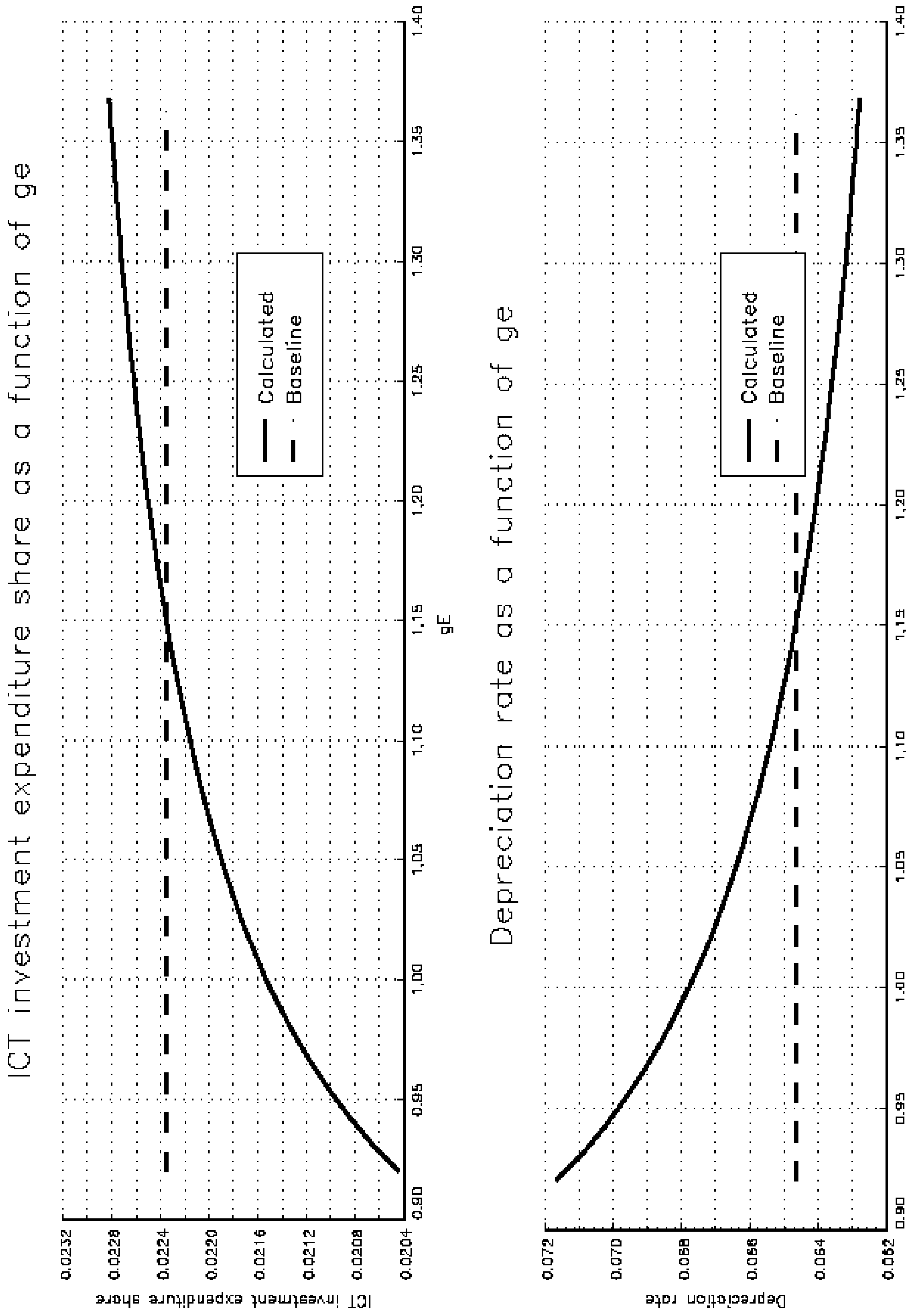
$$\delta_t = \omega_{dt}\delta_d + \omega_{et}\delta_d \qquad (54)$$

26 Recall that the capital stock of type *i* is normalised on $N_{t-1}Q^i_{t-1}$.

27 Notice that changes in x^i/y that lead to changes in c/y will affect the hours worked *h*. First, $\frac{c}{y} = 1 - \sum_i \frac{x^i}{y}$; using this, $h = \left(\frac{1-\tau_t}{\alpha_l}\frac{\theta}{1-\theta}\frac{c}{y}\right) / \left(1 + \frac{1-\tau_t}{\alpha_l}\frac{\theta}{1-\theta}\frac{c}{y}\right)$.

Figure 9

Effects of variations in γ^e



where the weights ω_{it} are shares in aggregate capital stock. This we can write as:

$$\delta_t = \frac{K_t^d / Q_t^d}{K_t}\delta_d + \frac{K_t^e / Q_t^e}{K_t}\delta_e$$

$$= \frac{k_t^d / y_t}{k_t / y_t}\frac{1}{\gamma_t^d \gamma_t^N}\delta_d + \frac{k_t^e / y_t}{k_t / y_t}\frac{1}{\gamma_t^e \gamma_t^N}\delta_e \qquad (55)$$

where the aggregate capital stock and capital-output ratios are defined as:[28]

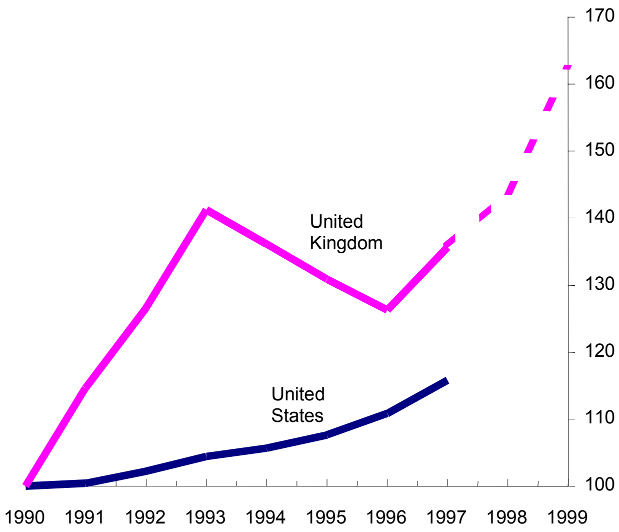
$$K_t = P_t^d K_t^d + P_t^e K_t^e,$$

$$\frac{k_t}{y_t} = \frac{k_t^d}{y_t}\frac{1}{\gamma_t^d \gamma_t^N} + \frac{k_t^e}{y_t}\frac{1}{\gamma_t^e \gamma_t^N}$$

From (55), an increase in γ^e lowers the weight on δ^e, implying a lower aggregate depreciation rate. This means that an increase of γ^e is inconsistent with the empirical evidence on depreciation rates. Official investment and capital stock data at the plant and machinery level are available for both the United Kingdom and the United States.[29] These can be used to back out implied depreciation rates as in (28). Figure 10 shows that the implied depreciation rates for both the United Kingdom and the United States have increased since 1990.

Figure 10

Implied depreciation rates for plant and machinery. United States and United Kingdom



In summary, an increase in γ^e can increase the investment expenditure share, but accounting for the observed increase would require a substantial increase in γ^e. In addition, such an increase lowers the aggregate depreciation rate, which is at odds with the empirical evidence.

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28 Notice that while K_t^d and K_t^e are state variables, the aggregate capital stock K_t is not: the fact that K_t is measured in units of final goods means that K_t can change instantaneously in response to shocks. For this reason, K_t is normalised on N_t rather than N_{t-1}.

29 We are grateful to Stacey Tevlin for providing us with the US data. The implied rates are calculated using a fixed-weight measure of the capital stock. These data include computers and communications equipment, but exclude software.

A direct change in the technical parameter α_e also increases the investment expenditure share and, contrary to the previous experiment, the aggregate depreciation rate. In the experiment we consider here, we increase α_e but hold $\alpha_e + \alpha_d$ constant - that is, an increase in α_e is offset by a decrease in α_d. By calculating the derivative of γ^N with respect to α_e under this assumption, it is straightforward to establish that provided $\gamma^e > \gamma^d$, the steady state growth rate γ^N increases with an increase in α_e. So while there are still capitalisation and accumulation effects, stemming from increases in growth rates, the capitalisation effect is now offset by a direct increase in the return to investment. Figure 11 draws out the change in steady state investment expenditure ratios and depreciation rates, as a function of a change in α_e, holding $\alpha_d + \alpha_e$ constant. To increase the ICT investment share of output to match the last observation in our data set, α_e should be increased to 0.054, from a benchmark value of 0.031. This implies an increase in the depreciation rate from the steady state value of 6.45% to 6.9%, or an approximately 7% increase. This increases the growth rate of output to 2.6%.[30]

7. Conclusion

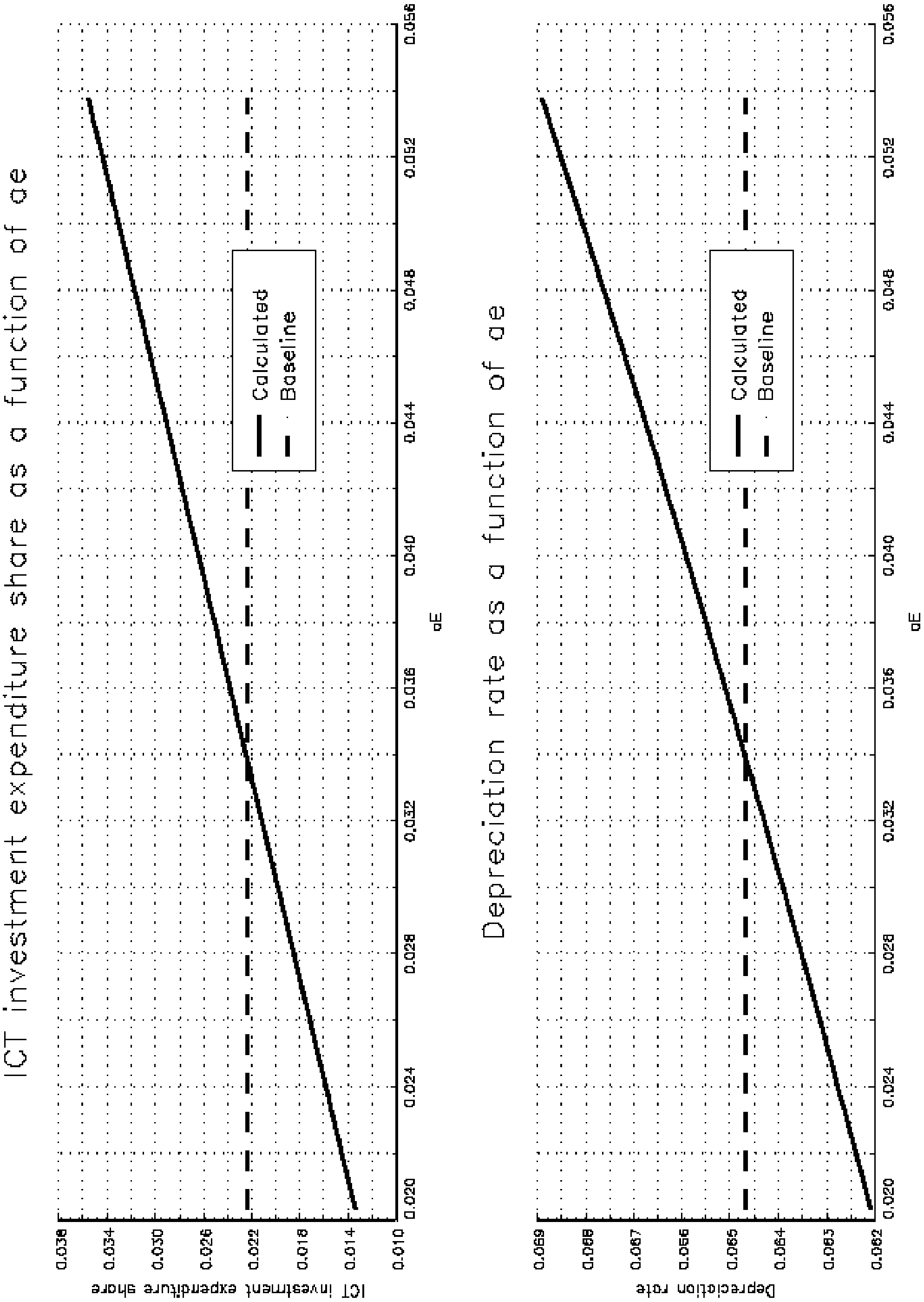
In this paper, we have decomposed labour productivity growth along the balanced growth path of the UK economy into investment-specific and sector neutral technological progress. Using US hedonic deflators for ICT investment goods, we find that ICT investment-specific technological progress makes a significant contribution to productivity growth along the balanced growth path, explaining as much as 20-30% of labour productivity growth. One obvious conclusion is that sustained improvements in labour productivity growth from this source will rely on continued sharp declines in the relative price of ICT goods.

We have drawn out the different implications of shocks to investment-specific technological progress on the one hand, and sector neutral technological progress on the other. Such differences are important for policymakers who wish to incorporate future "new economy" productivity shocks into their macroeconomic forecasts. In addition to this dynamic analysis, we have also performed some comparative static exercises, characterising how the balanced growth path is affected by changes in underlying parameters. We have not, in this paper, considered the exact dynamics of how the economy might move from one balanced growth path to another, although the model can obviously be used for such an exercise.

[30] One could obviously also consider changing the capital stock aggregator - a CES rather than a Cobb-Douglas aggregator could give rise to changes in the investment expenditure share without changing the parameters. An increase in the ICT share of the aggregate capital stock would then require that the elasticity of substitution between the two types of capital was *greater* than one.

Figure 11

Effects of variations in α_e



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A multi-country trend indicator for euro area inflation: computation and properties[1]

Elena Angelini, Jérôme Henry and Ricardo Mestre

1. Introduction

A crucial issue when analysing developments in the euro area is that of data availability, especially regarding the length of time series for the area as a whole. For example, the currently employed HICP - harmonised index of consumer prices - is available for the euro area only as of 1990 and the private consumption deflator only as of 1991. However, country data, although not available at the same frequency or with the same starting and ending date for all of the countries constituting the area,[2] offer a larger variety of data to pick from as well as a longer tradition of data collection. On the other hand, the need to deal with information collected for each individual country would significantly increase the size of the datasets to be employed. To the extent that new and ambitious techniques based on factor analysis (see, for example, Stock and Watson (1998) and Forni et al (1998)) are now available to extract summary information from very large datasets, it seems appropriate to use such techniques to analyse disaggregated multi-country data for the euro area. In this paper, we try to describe and analyse inflation on the basis of common factors underlying a large set of nominal variables for all the euro area countries.

One option to overcome the lack of long area-wide time series is to use explicit weighted-average formulas to aggregate country figures with a well defined weighting scheme, which requires having data on a homogenous and complete basis for all countries, a requirement not easily matched, if at all. Such an approach has a number of drawbacks, related in particular to interpolation and retropolation issues (as documented in Fagan et al (2001)) but also to the discussion of the respective relevance of various aggregation methods (see Winder (1997) or Fagan and Henry (1998)). In addition, such measures by construction ignore the information contained in cross-country variability.

Another option is to construct an "implicit" rather than an "explicit" average, in other words to employ statistical methods to derive the common trend in inflation for the euro area countries, using all of the information in the series for individual countries, without imposing ex ante some well defined weighting scheme. The objective is then to uncover the inflation common to a relatively large number of time series of inflation at the country level, with a view to identifying the latter as the underlying past trends for inflation in the countries now comprising the euro area.

Such an "implicit" approach is in fact very similar to that employed by Cecchetti (1997) (albeit using dynamic factors) in the case of the CPI in a single country, according to which some implicit trend is searched in the inflation numbers for the various sub-items entering the CPI. In both cases, be it multi-product or multi-country, the aim is to identify a summary statistic for inflation on the basis of a number of measures. The suggestion is to combine a multi-country approach with a multi-measure one, analysing a dataset comprising quarterly inflation measures based on national account deflators, consumer and producer price indices, and unit labour costs for all of the euro area countries over the period 1977 to 1999.

In one sense, such a multi-country-based indicator could, moreover, be viewed as an additional measure of underlying or "core" inflation in the euro area (see the review by Wynne (1999), on a

1 Opinions expressed in the paper are those of the authors and do not necessarily reflect those of the European Central Bank. We greatly benefited from discussions with J Stock at various stages of this work and from initial suggestions by S Cecchetti, as well as from input from colleagues at the ECB. Comments from participants in the CEPR European Summer Seminar on International Macroeconomics and in the BIS workshop on Empirical Studies of Structural Changes and Inflation are gratefully acknowledged, in particular from W Buiter, J Ihrig and L Reichlin, as well as from an anonymous referee. Remaining errors are the sole responsibility of the authors.

2 This paper refers to the euro area comprising those countries which adopted the euro on 1 January 1999.

number of standard alternative measures). Such an indicator should reflect some common level of inflation, filtered from the country-specific or measure-specific idiosyncratic component. In any event, it is worth checking the extent to which implicit aggregate inflation appears sensible in relation to simpler explicit measures, such as the weighted average of HICPs/CPIs and/or national account consumption deflators. Such investigation may eventually support an interpretation of the resulting trend inflation in terms of "underlying inflation". In turn, there is also a need to assess the forecasting properties of such implicit aggregate inflation measures in terms of predicting the more standard explicit aggregate measures.

Technically, a number of possibilities can be envisaged to find out what the implicit common inflationary trend has been for those countries now comprising the euro area. As already mentioned, the approach taken here is the factor analysis suggested by Stock and Watson (1998), which offers a number of clear advantages. First, alternative options based on multivariate cointegration analysis (see, for example, Warne (1993) on the basis of Johansen (1991)) are hardly feasible when dealing with a number of series as high as the one envisaged. Second, standard VARs deliver results on orders of integration that are very much lag-structure-dependent (as shown in Hall (1991)) whereas such techniques as factor analysis do not involve a specific lag structure. Third, the number of parameters to be estimated when taking such a statistical approach is much more parsimonious than within a VAR setting, which is hardly feasible when the number of series is large and the sample small (see also Forni and Reichlin (1996) on related issues). Fourth, issues of stationarity do not appear ex ante as crucial as when VAR techniques are employed, although such issues have not been clearly dealt with yet in the context of factor-based forecasting techniques. Ex post, the variance decomposition is expected to deliver some information on the non-stationary and therefore dominant components, as is the case, for instance, for standard principal component analysis (see Stock and Watson (1988) in the time domain or Phillips and Ouliaris (1988) in the frequency domain, at the zero frequency).

The technique employed can also outperform standard principal component analysis. First, the suggested approach goes beyond the principal component analysis to the extent that some time variability can be accommodated, first through additional factors and also through the loading terms; in other words, the extent to which any given series is affected by the common factors can vary slightly over time. Such a feature makes it easier to, for example, take due account of the structural change expected to have occurred prior to monetary union, when countries arguably converged towards a common level of inflation. The extent to which the latter could have changed can also be assessed by estimating the factors recursively. Second, the technique employed allows the econometrician to use series for which observations are only partially available over the sample (ie resorting to so-called "unbalanced" samples). This is clearly of interest in a situation where, as for the euro area, there is a lack of comprehensive back data. The robustness of results to non-available observations can be assessed by a straightforward comparison between factors computed with balanced and unbalanced samples, respectively.

Before going into further details, a summary view of the results can be provided. To begin with, the estimated factors appear to be fairly stable over time. Three to four factors appear to be sufficient to explain a large amount of the variability of the 100 or so series that are used. Moreover, standard "explicit" measures of euro area inflation, based on HICPs/CPIs and consumption deflators, are cointegrated with the first factor - which is clearly non-stationary - whereas further factors - the stationary ones - seem to account for dispersion of inflation across countries. Assuming further that the first factor is an implicit measure of common euro area inflation, it can be observed that that factor has remained extremely stable since the late 1980s, and slightly more stable than actual "explicit" standard measures of inflation. Moreover, on the basis of standard Granger (1988) causality tests in an ECM setting, "implicit" trend inflation seems to help to predict the more standard "explicit" measures, although results are not clear-cut in that respect.

The remainder of the paper is structured as follows. Section 2 describes the data collected. The third section documents the results of the dynamic factor analysis. Section 4 presents the causality analysis findings. Section 5 concludes and suggests further developments, mostly related to forecasting.

2. The data

The main criterion chosen for selecting among the different data sources was first of all to obtain the longest possible span of data for all of the countries considered; moreover, series were favoured that were readily available on a quarterly basis and seasonally adjusted directly by the corresponding source (see the table in Appendix 2 for the details). It was deemed appropriate to adjust the data as little as possible, with the exception of breaks clearly unrelated to economic factors, such as those arising from a change in methodology or coverage. However, for some countries all of these elements could not be fully satisfied. When non-seasonally adjusted series were the only ones available, we seasonally adjusted them applying the Seasonal Adjustment, Bell Labs method (SABL). Annual series (the only case is that of Ireland) were interpolated in order to recreate quarterly series using a simple linear interpolation filter. This procedure greatly simplified the calculations while not affecting the final results. Another exception, of course, was Germany, for which series for unified Germany exist only as of 1990 or 1991. In order to have historical data over a longer sample, series for West Germany prior to unification were used. The two series (pan-German and West German) were joined after the "old historical" data were rescaled to the "new" German series.[3]

For the national account deflators (for private consumption, exports, imports and GDP), the Quarterly National Accounts database published by the OECD was used. It is worth noting that trade deflators are inclusive of intra-area trade flows, to the extent that these trade series are not available on a consolidated basis. CPI, PPI and WPI series were taken from the OECD Main Economic Indicators database. Since PPI and WPI series were available only as monthly series, they were converted into quarterly ones.

In addition, due to the recent changeover to ESA95, it was necessary to backdate the national account series. The "old" series were rebased and joined to the "new" series, applying the same method used to overcome the German unification problem. Such a technique was used for all of the countries, the only exceptions being Belgium and the Netherlands - for which data were readily available over a large sample - and Ireland, for which, for the time being, only annual data are available, as already mentioned. In the latter case, we used the BIS annual data and interpolated the series in order to obtain quarterly data. The HICP and the consumer price deflator for the euro area as a whole were taken from the area-wide model database developed at the ECB (see Fagan et al (2001)).[4]

Once these data were compiled, the need for a "balanced panel" imposed restrictions on the series to be used and, as a consequence, on the countries covered, to the extent that series could be used only when they fully covered the preferred sample. In the case at hand, the balanced panel includes national account deflators for six of the ten countries considered and CPIs for all of the countries. The first analysis was run over the longest and most complete sample possible, ie starting in 1977 Q1 and ending in 1999 Q2. Therefore some countries were dropped altogether, either because their series ended too early or started too late (as in the case of Belgium and Portugal), or similarly some of the series were dropped for all countries, such as WPI (for which only recent data are available). Using an "unbalanced panel", in turn, imposes no availability restriction, so that all countries and all variables can be taken into consideration, provided that at least any given series is partially available over the sample.[5]

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3 In practice, it is not strictly necessary to make such adjustments to the extent that one of the interests of Stock and Watson (1998) lies precisely in the ability to deal with series with breaks and missing observations. However, such manipulation allowed the so-called "balanced panel" - ie series without missing observations - to also include series for Germany over the longer horizon. The other option, namely excluding all series for Germany, would have somewhat limited the relevance of the "balanced panel" analysis for the euro area. At a later stage, however, some sensitivity analysis could be run on the basis of the "unbalanced panel" approach, where the availability constraint is not a binding one.

4 The euro area HICP series published by Eurostat starts in 1990. This series has been backdated using aggregated national CPIs going as far back as 1970.

5 In the case of the euro area countries, quite a high number of the series needed for the analysis are either not available for some countries or do not cover the whole sample - because of lack of sufficient back data or lesser frequency of the observations. All in all, if we compute an attrition ratio as the number of missing observations over TxNxS, where T is the size of the quarterly sample, N the number of countries and S the number of series, it appears that only two thirds of the data are available, which is markedly less than what happens, for example, for the United States.

Prior to factor analysis, all of the above-mentioned price series were differentiated to generate inflation measures, and univariate stationarity tests were systematically conducted on the various resulting inflation rates. Both the standard Dickey-Fuller (1981) tests and the Perron and Vogelsang (1992) tests were employed, the latter allowing for a structural break in the underlying process (recursive testing is conducted, whereby no specific assumption is made ex ante on the date at which the break, if any, could have occurred). Such tests were also carried out for a number of different lag lengths, to assess further the robustness of the findings.

A striking feature of the results, which holds irrespective of the number of lags employed (ranging from two to eight for the various series), is that the null of non-stationarity can never be rejected, even when the alternative considered incorporates breaks in the average inflation rate, a hypothesis which was tested for break points located between 1982q4 and 1993q4 (ie dropping the end and the beginning of the sample as potential break points).

Table 1

Tests for the null of non-stationarity of two measures of euro area inflation

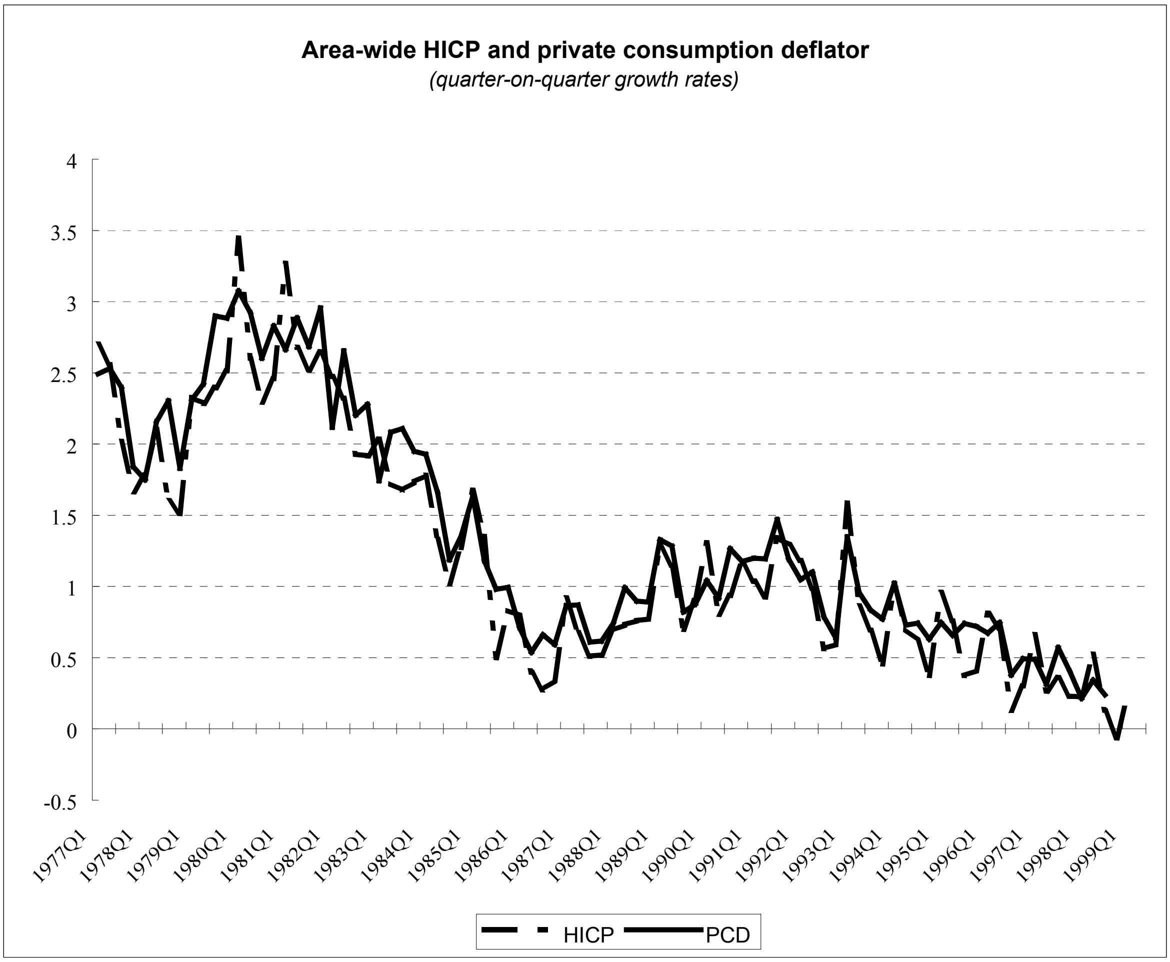
HICP 1977 Q1 – 1999 Q1 shift in mean model, break in 1986 Q4, DF(4) = –2.2
HICP 1977 Q1 – 1999 Q1 breaking trend model, break in 1985 Q4, DF(4) = –3.2
PCD 1977 Q1 – 1998 Q3 shift in mean model, break in 1986 Q4, DF(4) = –2.1
PCD 1977 Q1 – 1998 Q3 breaking trend model, break in 1985 Q4, DF(4) = –3.8
HICP: harmonised index of consumer prices
PCD: private consumption deflator

The results in Table 1 are provided for illustration. In all cases, the resulting *t*-stat for the Dickey-Fuller test never goes beyond –2.2, ie far from any sensible threshold of significance. The statistics are, however, much higher - beyond –3 - for models involving a breaking trend, but still quite far from the relevant critical values, ie under the ex ante assumption of an unknown break point.[6]

On strictly statistical grounds, inflation in the various euro area countries appears therefore as a non-stationary process (see Graph 1), albeit with a structural break in the mean or in the trend most likely in the mid-1980s, which may be related to the effect of the counter oil price shock or to the (then) EEC-wide convergence process. The resulting feature - namely an ever growing variance for inflation around its deterministic components - does not, however, seem to be a wholly acceptable picture, as opposed to the idea of inflation being brought progressively under control, with the successful convergence observed prior to monetary union taking place. Such considerations are to some extent related to the never-ending debate on the stationarity of interest rates (see Watson (1999) for a recent related methodological contribution). Irrespective of such issues, the major conclusion is that at least some of the factors should appear as non-stationary too, more specifically those explaining the largest share of the multi-country and temporal variance. It would then be appropriate in such a case to also investigate the cointegration properties of the estimated factors in relation to both the country and "explicit" aggregate measures of inflation. Although the factor technique allows in principle for non-stationary analysis, this in turn raises a number of questions not directly dealt with in this paper or in the literature, ie in connection with the asymptotic nature of implicit distributions. The approach followed here is a pragmatic one: although nothing explicit is stated on asymptotic distributional behaviour from a theoretical viewpoint, it is empirically the case that non-stationary variables will, as the sample increases in the time and cross-section dimensions, dominate the cross-moment matrix. There is therefore an increasing probability that the first factors will be linked to stochastic trends as N and T increase, provided that the number of trends is relatively small and stable as N increases.

[6] This is not the case for the private consumption deflator PCD (see Table 1), but this conclusion would hold only under the less conservative assumption of an exogenously given break point, which is not really an appropriate hypothesis.

Graph 1



3. An "implicit" measure of trend inflation for the euro area

The framework employed is one where factor analysis is carried out to uncover the common "driving forces" underlying the joint behaviour of the above-mentioned time series of inflation for the countries constituting the euro area. In the fully-fledged Stock and Watson (1999) approach, an additional element is used, whereby some time-varying combination of the above-mentioned factors is a predictor of some variable of interest. In the case at hand, one might for example at a later stage envisage applying the full analysis to predict euro area inflation, but in such a case the coverage of the dataset should be extended to variables measuring not only inflation.

3.1 Specification and estimation of the model

The model proposed by Stock and Watson (1998) is a specification in terms of dynamic factors. At each point in time some "driving forces" - namely the *r* factors summarising the variance of the panel - affect the *N* various series in the panel of time dimension *T* with weights that can vary over time, albeit asymptotically constant (the so-called "loadings"). More specifically, the model reads as follows:

$X_t = \Lambda_t F_t + e_t$ with dimensions $[N \times 1] = [N \times r]\ [r \times 1] + [N \times 1]$

where X_t is at each point in time the vector comprising the observations for all of the *N* series, F_t the *r* common factors driving the process, each of the *N* series being generated by the *r* factors, Λ_t the time-varying loadings, and e_t a stochastic disturbance, assumed to be stationary, with room for some correlation across series and over time (see Stock and Watson (1998) for the specific technical requirements).

The rank of the matrix F is r, ie the true number of factors driving the system (namely the data generating process or DGP). In the estimated model, however, since r is not known, k factors are estimated, and this number may of course differ from that driving the DGP.

Stock and Watson (1998) suggest using a least-squares approach to estimate the factors, in the simpler case where the loadings are constant over time.[7] The programme to be solved is then the following:

$$\text{Min}_F\, E(F) \;\text{ where } E(F) = Min_{\lambda_i} \frac{1}{NT}\sum_{i=1}^{i=N}(\overline{X}_i - F\lambda_i)'(\overline{X}_i - F\lambda_i)$$

where $\overline{X}_i$ is the $[T \times 1]$ vector comprising stacked observations for the i-th of the N variables, F the stacked $[T \times k]$ matrix with all observations for the k factors (stacking and transposing F_t) *and* λ_i the $[k \times 1]$ vector of loadings for the i-th of the N variables (similar to a row in Λ_t).

There are two possible ways of solving the above-mentioned optimisation problem. First, it can be shown that the loadings will coincide in a balanced panel - ie without any missing observations - with the eigenvectors associated with the k-th largest eigenvalues of the $[N\text{x}N]$ variance-covariance matrix of the stacked observations, namely:

$$\frac{1}{\sqrt{N}}X'X$$

where X corresponds to the $T\text{x}N$ matrix collecting all data information, pooling together the various $\overline{X}_i$. This result is standard, based on principal component analysis (see, for example, Anderson (1984)), and the approach is moreover similar to what is found when resorting to rank reduction techniques, such as the one employed in the Johansen (1991) multivariate cointegration framework. Factors can then be estimated by a simple projection (ie $\hat{F} = X\Lambda$ under the appropriate normalisation). Alternatively, the problem can be solved directly in terms of the F matrix. The time-varying factors would then correspond to the eigenvectors associated with the k largest eigenvalues of the matrix:

$$\frac{1}{\sqrt{T}}XX'$$

This second approach entails solving for the eigenvalues of a $T\text{x}T$ matrix, yielding the same results as the previous one - up to a rotation factor - but numerically more efficient when $N>T$. The latter approach is the one followed in this paper. To complete the computation, an identification scheme is also needed, namely a normalisation of the factors whereby $F'F/T$ equals the identity matrix of order k.

In the case of an unbalanced panel, however, an iterative procedure has to be employed, for which initial estimates of the factors are taken from a balanced panel of series covering the same sample. The intuition underlying each iteration is simple, ie series with missing observations are first projected over the initial set of factors so as to obtain the appropriate loadings, then artificial data are computed to fill the missing observations, and finally factors are recomputed on this artificially obtained balanced sample. The procedure should then converge, delivering the non-linear least-squares (NLLS) estimate for the factors.

In fact, experiments conducted with unbalanced panels suggest a relatively high degree of distortion in the final calculation of the factors in those observations for which a large portion of the variables are missing. The initial fitted values of the out-of-sample portion of some of the variables with missing observations were found to be poor enough to very probably downgrade the quality of the subsequently estimated factors. This problem in all likelihood arose because of the relatively large number of missing variables for some observations, a feature inherent in the very different data collecting procedures of the 11 countries. The problem was mitigated when the number of factors at

[7] The proposed methodology is robust, under assumptions specified in Stock and Watson (1998), to mild levels of time variation in the loadings, as expressed, for example, in the following specification: $\Lambda_t = \Lambda_{t-1} + \frac{h}{T}\varepsilon_t$ where h is a scalar and ε_t a wide-sense stationary disturbance, the contribution of which disappears asymptotically.

each iteration was kept low, in which case the convergence of the algorithm was fairly quick and the number of iterations correspondingly low. This problem compounds any interpretation of the unbalanced-panel factors, and in particular blurs the impact of the unbalanced-panel variables. An example of this impact, particularly relevant for the purpose in question, is the appearance of further non-stationary factors linked to trends present in the unbalanced-panel dataset but not in the balanced-panel one.

For both types of panel, the cross-country and cross-indicator dimension will be summarised at each point in time by the value of the factors for this given observation (the whole set of *NT* observations is taken into account in the maximisation programme solved). The approach can therefore be viewed as a proxy to the dynamic factor one, to the extent that finite lag structure in the process underlying the factors would indeed be captured by some of the *k* factors. Although infinite lag structure - such as that resulting from a factor following an AR(1) - will then necessitate an infinite number of factors, it may be equivalent from an observational viewpoint to truncate the lag distribution so that the variance explained would be comparable to that given by a dynamic factor model.

In addition, contrary to the dynamic factor approach, where some restrictions such as stationarity are generally imposed on the factors, factors estimated using this procedure will capture the dominant dynamic properties of the initial series, including non-stationarity. For example, in the event that some strong autocorrelation or even unit roots are empirically present in the panel, these features would also be reflected in the estimated factors (as in Stock and Watson (1989)). Presumably, if some of the variables in *X* were non-stationary, the first factors - ie those corresponding to the largest eigenvalues - would by construction end up sharing the same integration properties; moreover, they would be cointegrated with those *X* components that are non-stationary.

3.2 The estimated factors: time-series properties

Factors were first estimated on a sample covering the period 1977 Q1 to 1999 Q2. Both balanced and unbalanced panels were used, the latter also including data for Belgium, Ireland and Portugal, all countries for which series have missing observations either prior to 1985 Q2, 1988 Q2 or after 1997 Q4. On the basis of the variance decomposition, irrespective of the type of panel employed, two or three factors seem to be enough to capture most of the common variation in the cross-country and cross-indicator dimensions of the various inflation measures employed. Thereafter, further factors contribute only marginally to the variance of the panel (see Table 2). Some work could be envisaged with a view to employing a selection criterion for the number of factors instead of using such a heuristic approach. Furthermore, the proportion of the variance explained by the most important factors is fairly robust to changes in the sample size.

The high proportion of variance explained by the first few factors is a clear indication that the number of forces underlying movements in prices is relatively small.

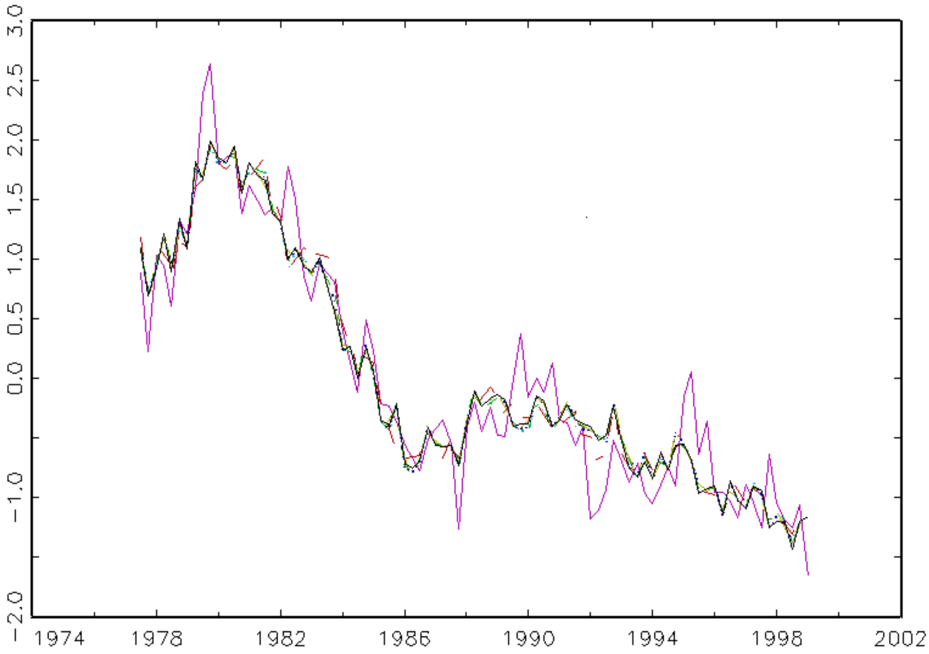
Table 2

Contributions to the explanation of the panel variance, marginal and cumulated

	Marginal	Cumulated
Eigenvalue 1	59%	59%
Eigenvalue 2	10%	69%
Eigenvalue 3	5%	72%
Eigenvalue 4	3%	75%
Eigenvalue 5	3%	78%

Graph 2

Variable 40 across iters., balanced panel

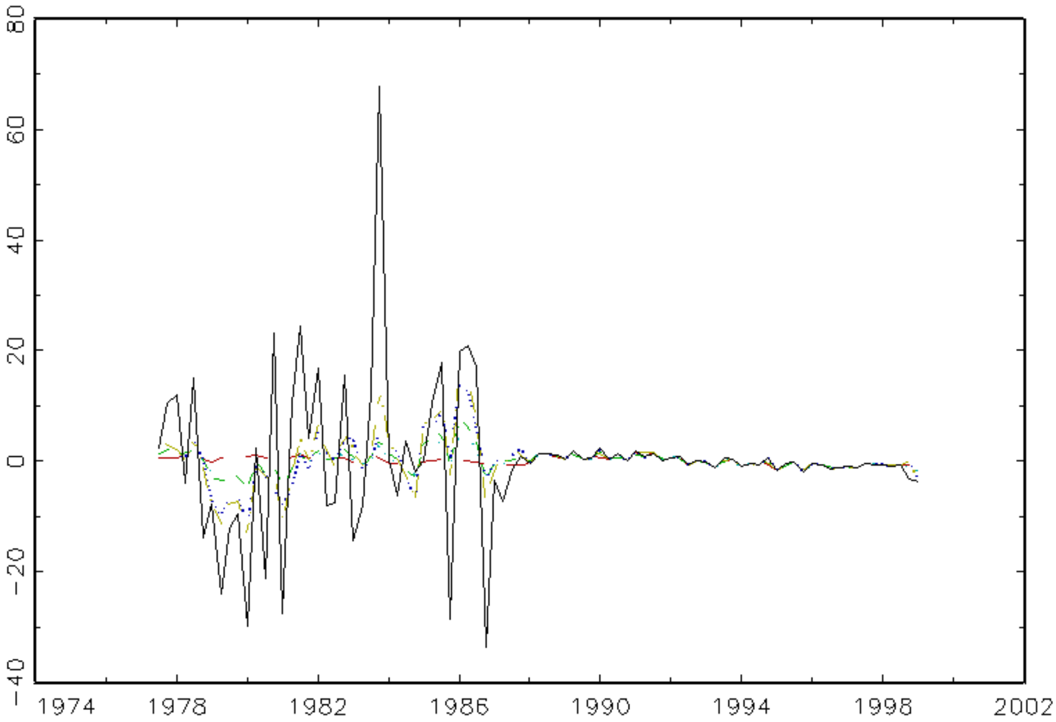


It is worth remembering that the results with the unbalanced panel are slightly puzzling, which calls for cautiousness when interpreting them. As already mentioned, the estimates drift away as the number of iterations increases, although eventually they do not differ drastically from the balanced-panel results. For illustration, Graphs 2 and 3 show estimated series (ie projections of the estimated series on the computed factors) as obtained at successive iterations of the unbalanced-panel procedure.[8] For series belonging to the balanced panel, iterations do not change the estimated value by much, whereas for series with missing values the backdated values do change a lot across iterations before convergence is reached, thereby reflecting the growing importance of the new series in the estimated factors.

[8] In the given case, the number of factors extracted at each iteration was relatively high (5), in order to better illustrate the distortion.

Graph 3

Variable 30 across iters., unbalanced panel



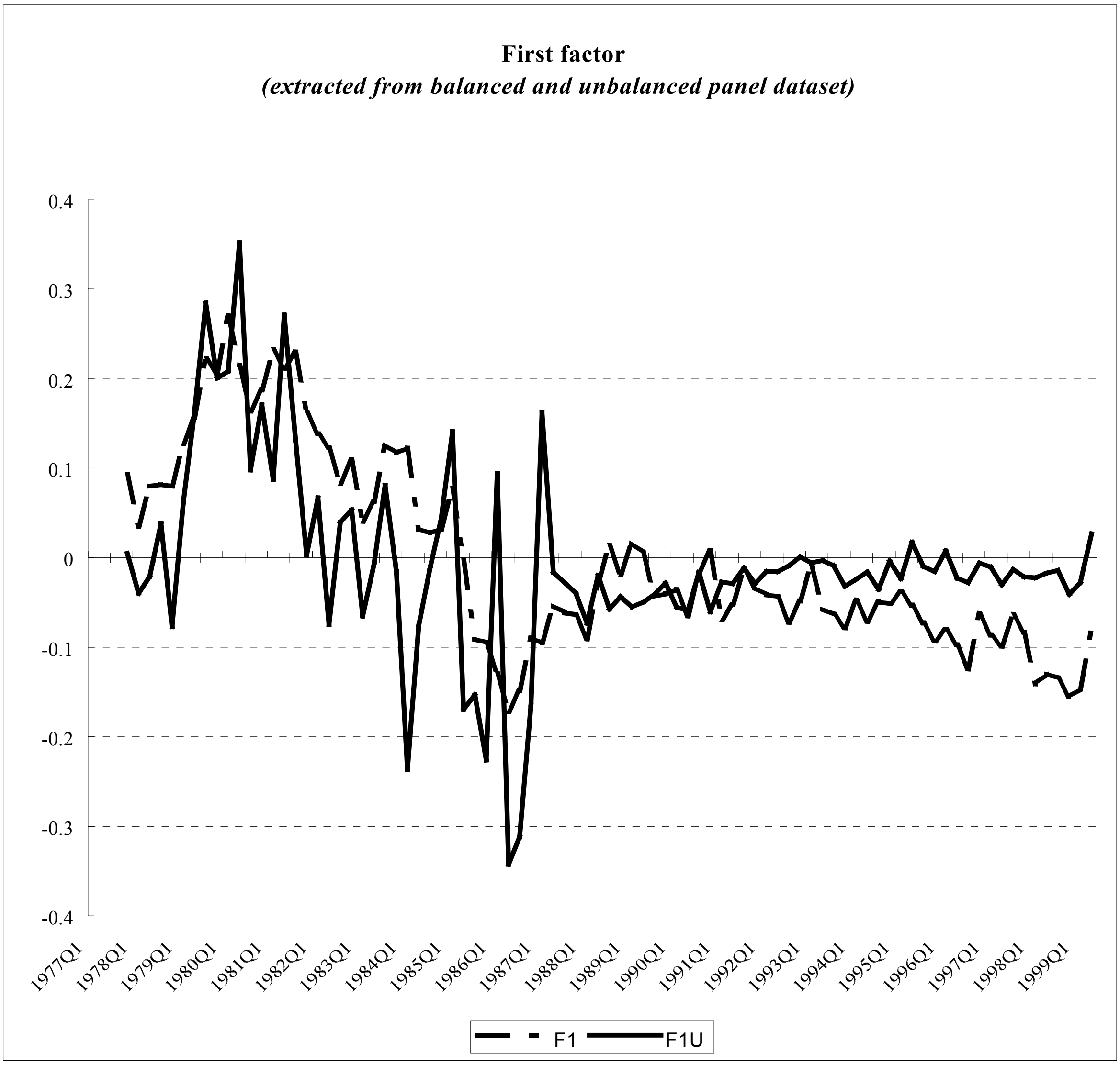
Furthermore, where the new series introduced also contain a seemingly non-stationary or highly volatile factor, the end result could be that the variance would be spread over a larger number of factors. In other words, extending the sample to variables with missing observations may lead to the introduction of a new and independent stochastic trend in the dataset, which would probably be reflected in an additional non-stationary factor. In such a case, the comparison across the two types of panels would not be relevant on a factor by factor basis but should focus on the space spanned by whatever number of factors is deemed relevant.

In the case concerned, although far more volatile in the earlier part of the sample, the first factor for the unbalanced sample - denoted F1U - is pretty similar to the one based on a balanced panel - denoted F1 - as can be seen in Graph 4a. The second factors - F2 and F2U - seem to differ basically only because of the arbitrary normalisation, so that essentially they are opposites (see Graph 4b).

Additional computations were carried out over the balanced sample, based on a recursive approach. All samples start in 1977 Q1. Graph 5 shows on the same plot the superimposition of the various estimates for each of the four factors, thereby providing a sort of visual illustration of the stability interval surrounding the various estimated factors. The interpretation is straightforward for each of the factors: the thicker the distribution of lines, the less constancy over time. This exercise therefore demonstrates that at least the first four factors seem to be quite robust and very stable over time, although some slight instability can be observed over the period prior to the mid-1980s. A quick overview seems also to indicate that the first two factors have a non-constant mean, some structural break taking place presumably at some point in the late 1980s.

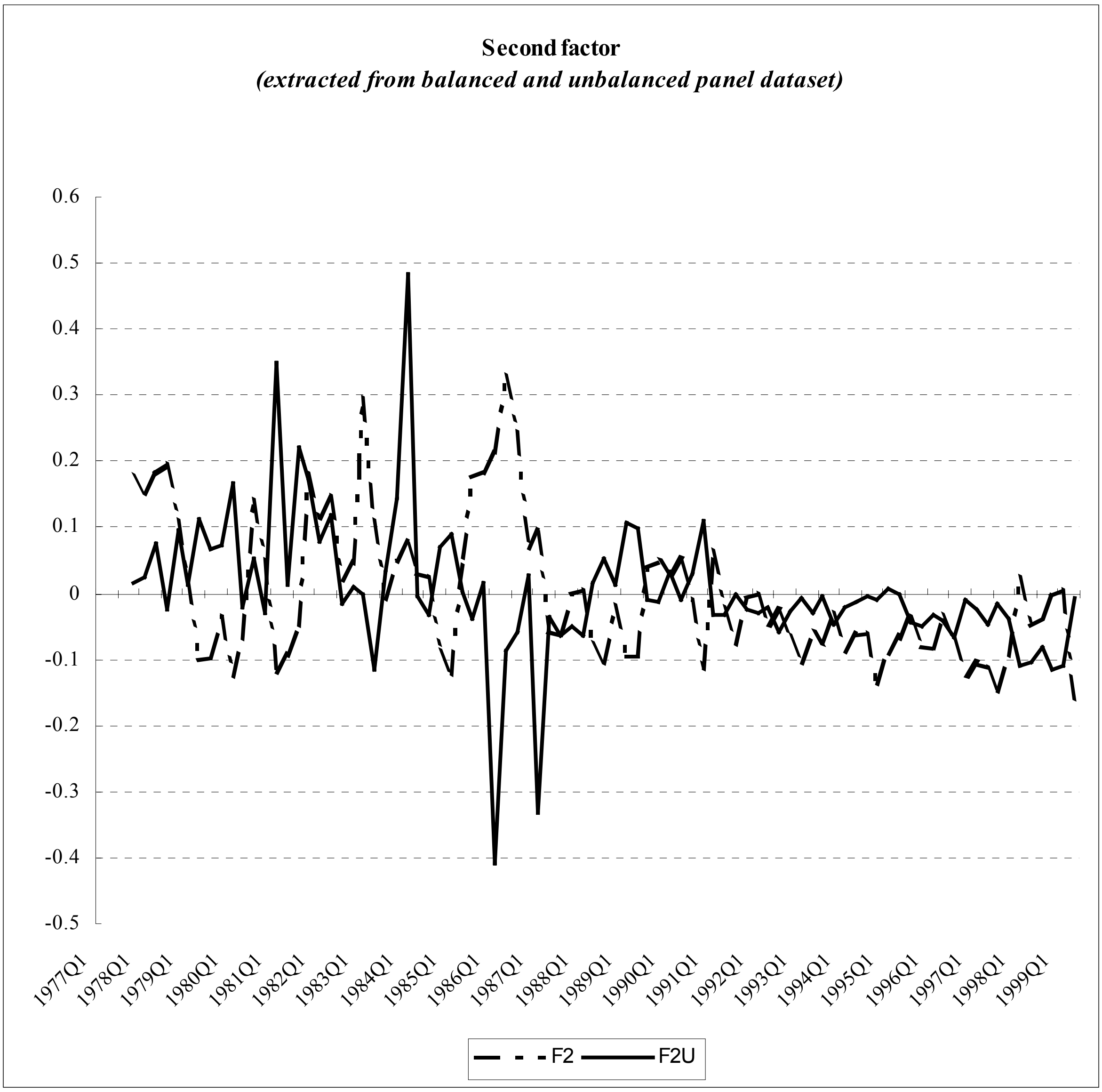
Graph 4a

Balanced and unbalanced panel, first factor



Graph 4b

Balanced and unbalanced panel, second factor



As a matter of fact, standard Dickey-Fuller (1981) and also Perron and Vogelsang (1992) stationarity tests confirm the “eyeball econometrics” intuition, namely that only the first factor is found to be I(1), whereas all subsequent factors - tested up to rank 4 - appear to be stationary (see Table 3). Such findings are consistent with the ranking of the factor not being neutral, with, for example, the first factor corresponding to the highest eigenvalues of the analysed variance-covariance matrix, thus capturing the component that has the strongest volatility. A by-product of this basic stationarity analysis is that the various indicators of country inflation analysed share one single common stochastic trend, which could be viewed as some underlying measure of euro area inflation. It should be noted in this respect that the first factor appears smoother than the otherwise standard measures of inflation for the euro area, thus coming closer to a “core” or “trend” indicator of underlying inflation.

Graph 5

Recursive estimates of the first four factors extracted from balanced panel

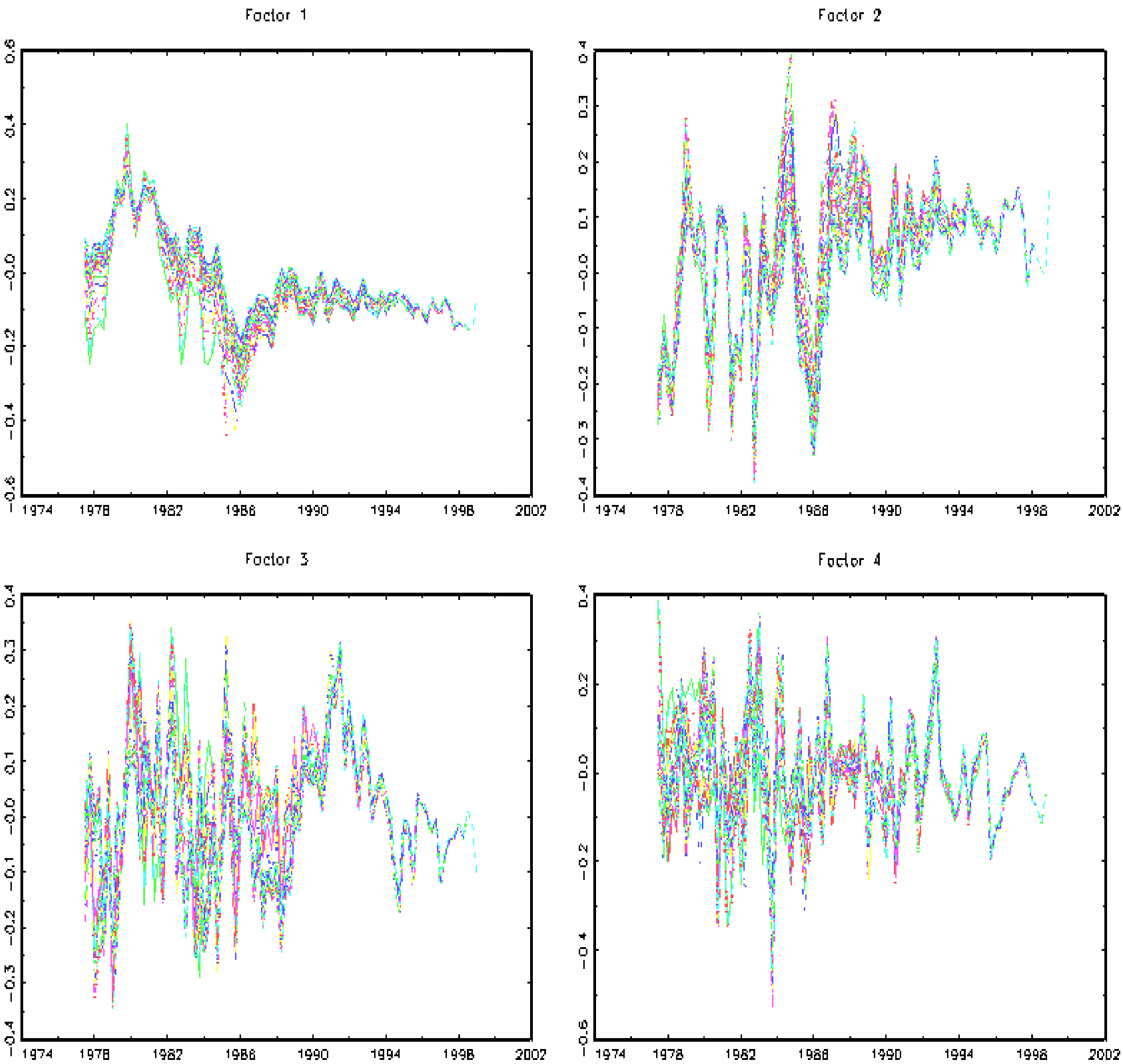


Table 3

Testing for the null of non-stationarity for the first three factors

F1	1977 Q1 – 1999 Q2 shift in mean model, break in 1986 Q4, DF(4) = –2.5
F1	1977 Q1 – 1999 Q2 break in trend model, break in 1985 Q4, DF(4) = –4.0
F2	1977 Q1 – 1999 Q2 standard DF model with an intercept, DF(4) = –3.7
F3	1977 Q1 – 1999 Q2 standard DF model with an intercept, DF(4) = –3.0

3.3 The estimated factors: interpretation

As to the interpretation of the various estimated factors, the properties of the factors and hence of these underlying forces may be gauged by the relationship between the factors and the variables on an individual basis. The interpretation therefore has to be factor-dependent, starting with the standard approach analysing the loadings, which we complement with an econometric time-series analysis of the factors.

The standard and natural way to measure these links is by analysing the loadings, which are the parameters measuring the projection of the factors on each variable. As the variables have been normalised, loadings are such that they lie between 1 and –1 and can thus be understood as correlations between each factor and each variable, while their value squared can be understood as the R^2 of the corresponding regression. Loadings for the balanced panel are collected in the table in Appendix 1, together with their value squared. It is not simple to extract robust conclusions from these numbers because factors and loadings can be rotated without affecting the variance decomposition of the principal-components analysis, but some outstanding facts nevertheless deserve some mention. First and foremost, loadings for the first factor are appreciably higher than the rest of the loadings for *all* variables. Only for variables such as import deflators and the GDP deflator are the loadings for the other factors close to those for the first one. The second outstanding fact is the clearer relationship between factors and variables *across* countries, rather than with countries *across* variables. Although the loadings for some variables show some country-specific behaviour (as, for instance, the relatively high loadings for the second factor for many Spanish series), the variable-specific behaviour is much more widespread and marked (such as the strong loading for the second factor for import deflators, irrespective of the country). This would point to area-wide specific factors as important elements in the description of inflation; on the other hand, the distribution of loadings for most variables across countries appears to be much more dispersed for factors two and three than for the first factor.

The univariate results reported in Table 3 seem to indicate that the first factor has to be treated in a somewhat specific manner with respect to the other ones, to the extent that it is only for that first variance component that cointegration analysis is meaningful. As regards subsequent factors, a correlation analysis with the first differences of the inflation rates should be preferred.

Cointegration analysis in effect supports the hypothesis that the first variance component reflects a common inflation trend for all of the euro area countries. Applying a residual-based test, ie Engle and Granger (1987), both the inflation rate for the consumption expenditure deflator and the HICP for the euro area appear cointegrated with the first factor, albeit at a relatively low level of confidence. The respective test statistics are DF(1) = –4.0 for PCD and DF(8) = –3.4 for CPI.[9] As a matter of fact, and quite consistently with the expectations, the HICP measure and the consumption deflator measure are also cointegrated with each other (DF(5) = –4.3 for CPI and PCD); this result is in line with the ECM specification linking the two prices, which is reported in the euro area model developed by Fagan et al (2001).

The projection of the euro area inflation rates on the first factor would suggest some increase in the inflation rate out-of-sample for the consumption deflator, as observed already for the HICP measure (see Graphs 6 and 7). In addition, the gap between the three indicators seems limited, as can be seen

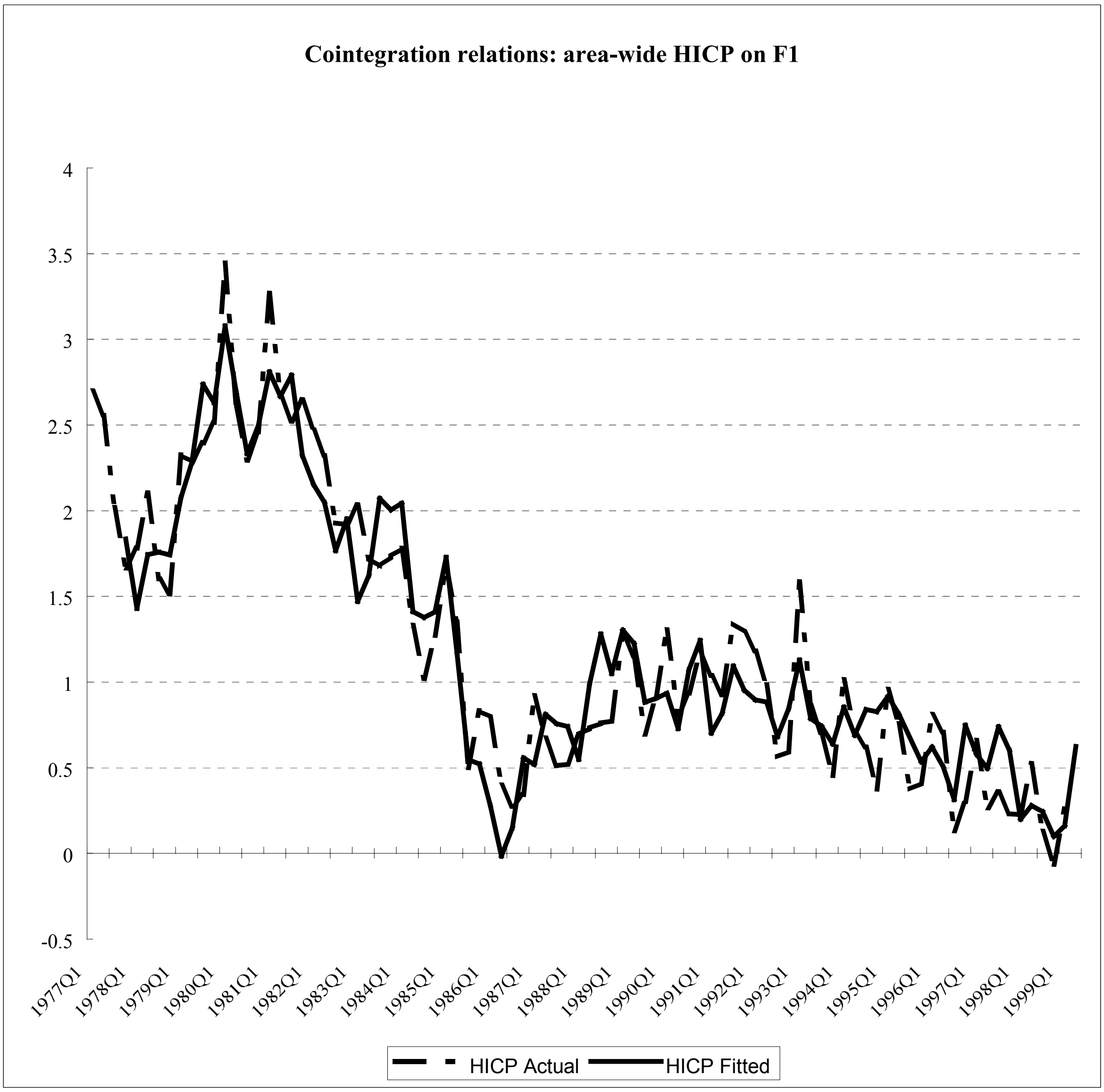
9 In the latter case, the sample is 1977 Q1-1999 Q1 with 1977 Q1-1998 Q3 for the deflator. The discrepancy comes from the fact that the data for the consumption deflator are not the Eurostat ones - for which no longer span of back data exists - but those constructed for modelling purposes; see Fagan et al (2001).

in fact from the residual plots in Graph 8. Although the HICP measure fluctuates more, in particular for seasonality reasons, the cycles remaining once the inflation rates have been filtered out from their common trend component seem to be pretty similar. Of course, further analysis should be conducted to take account of the role of subsequent factors F2 and F3 in explaining the behaviour of both the HICP and the consumption deflator for the euro area before according too much significance to such a conclusion.

In terms of the relationship between inflation for specific countries and the first factor, cointegration regressions supplemented with ADF(4) residual-based tests show that not all countries have inflation rates that are cointegrated with this factor (see Table 4 for the resulting *t*-stats). Interestingly enough, taking a critical value at 10% with 100 observations of –3.0, only four countries have an inflation rate not cointegrated with the common trend; in particular, two low-inflation countries, Germany and the Netherlands, depart somewhat from the average.[10] This is not surprising inasmuch as convergence took place towards such countries, so that the common trend may differ from the one specific to these countries, at least viewed from a relatively long-run perspective using historical data. As to the other countries, namely Finland and Portugal, this may indicate that convergence has been even quicker than in the average euro area country or that the historical inflation pattern is too specific to be close to the "implicit" average just computed. In the case of Germany and Portugal, the lack of cointegration could be related to the relatively weak loadings for the first factor.

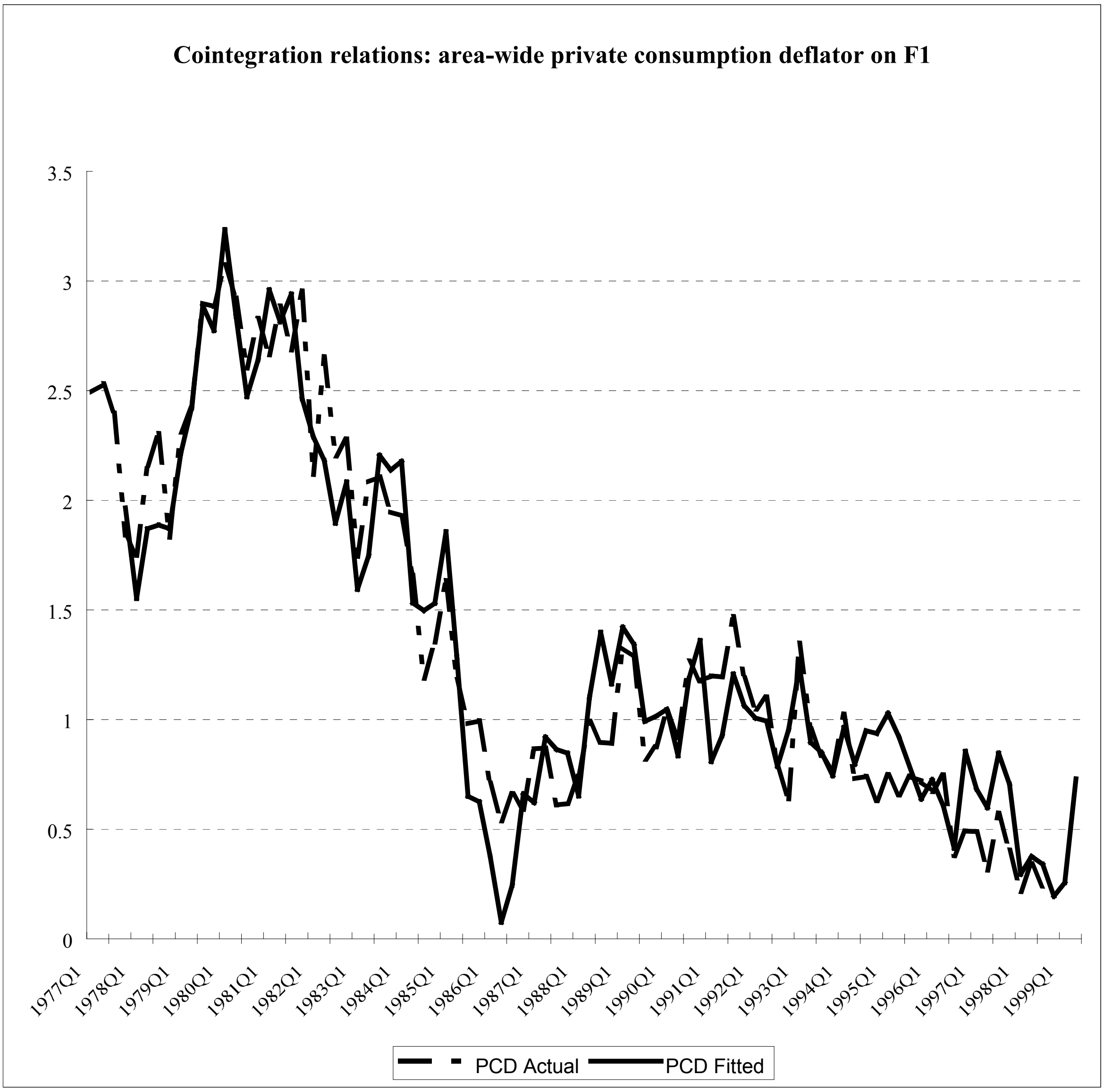
[10] A second - and less rigorous, given the integration properties of the series - exercise was to run stepwise OLS regressions, projecting the factors on all countries' CPI and PC inflation. On that basis, the first factor seems to be more correlated with inflation in Germany, Italy, Portugal and Ireland. For factors beyond the first one, on the other hand, a similar regression approach does not seem to indicate that factors can be associated with specific groups of countries, to the extent that results are highly sensitive to whether the CPI or the private consumption deflator is employed.

Graph 6



Cointegration relations: area-wide HICP on F1
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
1977Q1
1978Q1
1979Q1
1980Q1
1981Q1
1982Q1
1983Q1
1984Q1
1985Q1
1986Q1
1987Q1
1988Q1
1989Q1
1990Q1
1991Q1
1992Q1
1993Q1
1994Q1
1995Q1
1996Q1
1997Q1
1998Q1
1999Q1
HICP Actual
HICP Fitted

Graph 7



Cointegration relations: area-wide private consumption deflator on F1
3.5
3
2.5
2
1.5
1
0.5
0
1977Q1
1978Q1
1979Q1
1980Q1
1981Q1
1982Q1
1983Q1
1984Q1
1985Q1
1986Q1
1987Q1
1988Q1
1989Q1
1990Q1
1991Q1
1992Q1
1993Q1
1994Q1
1995Q1
1996Q1
1997Q1
1998Q1
1999Q1
PCD Actual
PCD Fitted

Graph 8

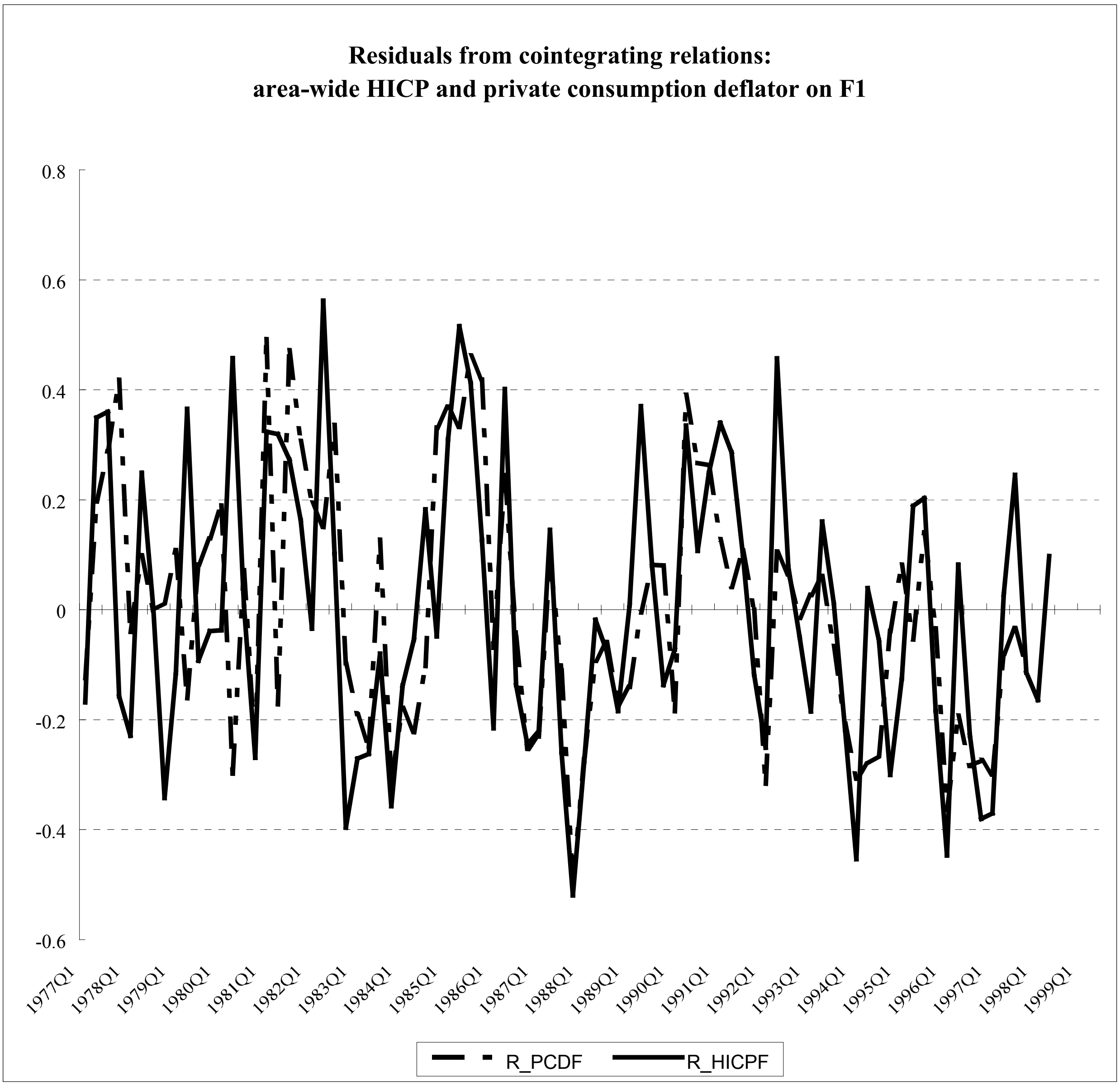

Residuals from cointegrating relations:
area-wide HICP and private consumption deflator on F1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
1977Q1
1978Q1
1979Q1
1980Q1
1981Q1
1982Q1
1983Q1
1984Q1
1985Q1
1986Q1
1987Q1
1988Q1
1989Q1
1990Q1
1991Q1
1992Q1
1993Q1
1994Q1
1995Q1
1996Q1
1997Q1
1998Q1
1999Q1
R_PCDF
R_HICPF

Table 4

ADF(4) cointegration tests for CPI / PCD regressed on F1

(1979 Q1–1999 Q2)[11]

AT –3.1 / –3.5	BE –3.0 / –1.9	DE –2.2 / –2.0	ES –3.9 / –4.0	FI –2.1 / –2.8
FR –3.0 / –2.9	IE –3.2 / –3.7	IT –4.2 / –4.1	NL –2.5 / –2.4	PT –2.7 / –2.8

As to the relationship between changes in inflation and the other factors, no clear conclusion can be elicited from the correlation analysis. Although the second factor appears significantly correlated with changes in inflation in two countries (Germany and the Netherlands) when the full sample and CPIs are used, it seems on the other hand to reflect more the pattern for Italy when consumption deflators are considered over the shorter period. In turn, the third factor is not significantly correlated with any of the country inflation measures, based on the two available consumer prices.

A complementary exercise that was conducted to help interpret the factors was to simply regress factors on the two main measures of inflation for all of the euro area countries, which is tantamount to computing the "implicit" weighting schemes associated with any given factor.[12] The suggested analysis was carried out for F1, which captures most of the non-stationarity in the country data, but not for the other factors, the contribution of which appears less important. When compared to the explicit weights used in the computation of the two standard measures of average euro area inflation, it appears - see Table 5 - that the implicit weighting scheme leads to less emphasis being put on countries such as Spain, whereas Austria, for example, is given more prominence. All in all, however, the first three weights are attributed to the largest countries in the euro area, which is broadly in line with the idea that the first factor was a proxy for the common average trend in the data.

Table 5

Implicit and explicit weights for the first factor, in CPI terms

(1977 Q1-1999 Q2)

Countries	Implicit	Explicit	Countries	Implicit	Explicit
AT	14.1	3.0	FR	23.1	21.1
BE	0.5	3.9	IE	2.7	1.1
DE	23.7	30.6	IT	15.6	20.4
ES	0.5	10.2	NL	10.4	5.6
FI	6.9	1.7	PT	2.5	2.4

To the extent that, quite clearly, the first factor seems to summarise the non-stationary or stochastic trend component underlying the data employed, a final hypothesis worth checking with reference in turn to the stationary factors is whether they capture the cross-sectional dimension of the data. It is in fact the case that both standard deviations of the CPI and the PCD across countries are significantly correlated over time in particular with the second factor. Regressing the cross-country standard error for both inflation measures on factors two and three gives *t*-stats equal to 4.1 for F2 and 2.2 for F3 in the CPI equation (sample 1977 Q1 to 1999 Q1), with 3.0 and 0.3 respectively for the PCD (sample 1988 Q2 to 1998 Q3).

[11] Some data are missing for the deflators; for Belgium and Portugal, for example, data are available only starting in 1985 and 1988, whereas for Ireland (interpolated from annual frequency) data stops in 1997.

[12] Not to be confused with the factor loadings themselves, which are computed via an OLS regression of each variable on the factors as documented above. Treating the first factor as a specific one appears warranted in view of its particularly persistent behaviour, in comparison with that of the other two factors.

3.4 The estimated factors: potential links with "core" inflation

On the basis of the above-mentioned results, the derived factors might bear some relationship to stable underlying forces of inflation. The first factor could, for example, be a convenient measure of "trend" inflation. A natural and further interpretation of this factor may relate it to "core" inflation indicators.

It is thus worth assessing the degree of potential usefulness of the derived first factor in the light of its potential links with measures of "core" inflation. One possible source for a list of criteria to be met by potential measures of this kind is to be found in Wynne (1999), as already mentioned. The table below gives a brief overview of the extent to which the trend inflation indicator delivered by the first estimated factor could qualify as a "core" inflation measure, on the basis of each of these criteria. The set of criteria is wide enough to cover the analysis of measures of "core" inflation that are very different in nature. Obviously, some ranking is needed to take into account the specific nature of the proposed measure. For instance, dynamic factors extracted from a large panel of data will in all likelihood never be an important element in the communication strategy of central banks vis-à-vis the public. From this point of view, the timeliness and leading-indicator properties of the proposed measure are, in our view, clearly more relevant than its technical simplicity.

Table 6

Factor-based trend inflation as a measure of core inflation

	Relative importance of criteria	Compliance with criteria
Computable in real time	High	Yes
Forward-looking	High	Still to be assessed
Track record	Intermediate	No
Understandable to public	Low	No
History does not change	Low	No
Theoretical basis	Intermediate	No

In most cases, the factor-based trend indicator for inflation quite obviously does not comply with the requirements. In spite of this somewhat negative assessment, two elements should be emphasised. In the first place, the dismal overall performance of the factor-based trend indicator is partially balanced by the relative strength of the measure in criteria that are deemed more important. It is an evident feature of dynamic factors that they can be estimated in real time, and even before the variables entering the initial panel have all been released. Also, there could be grounds in the literature to expect good forecasting properties of the indicator (see Stock and Watson (1999)), a feature that deserves to be explored. Last but not least, factors extracted in the context of this paper have shown a remarkable degree of stability over time, as shown in the first panel in Graph 5.

A fully-fledged analysis of out-of-sample forecasts of inflation using the factor approach is beyond the scope of this paper, and is not developed further. The next section attempts to gauge the in-sample properties of the first factor in relation to observed inflation, with a view to obtaining a better assessment of the performance as to the second most important criterion, ie the amount of forward looking behaviour.

4. The "implicit" inflation Granger-causes the "explicit" inflation

The above-mentioned results suggest that the first factor already possesses a number of interesting properties, namely its relative smoothness, its robustness to changes in the sample, its apparent non-stationarity, its cointegration properties with standard measures of euro area inflation, and finally its seemingly acceptable "implicit" weighting scheme. It therefore seems tempting to pursue the analysis further, extending it to causality considerations. The issue there is to check whether the trend indicator thus found can be used in forecasting average inflation in the euro area, bearing in mind of course that the interpretation is more in terms of forecasting properties than indicator properties as such.[13]

4.1 Causality analysis: the setting

The framework to be employed for the analysis is a bivariate ECM comprising the first factor with euro area inflation, measured alternatively by either the consumption deflator or the HICP. As pointed out in Granger (1988), the standard causality framework has to be adapted in the case where there are some cointegration properties linking the series to be analysed.

In the case of a bivariate cointegrated VAR process, the general framework is the following:

$$\begin{cases} \Delta X = \Phi_{xy}(L)\Delta Y + \Phi_{xx}(L)\Delta X - \gamma_x L(X - \beta Y) + \varepsilon_x \\ \Delta Y = \Phi_{yy}(L)\Delta Y + \Phi_{yx}(L)\Delta X - \gamma_y L(\beta Y - X) + \varepsilon_y \end{cases}$$

where X and Y are I(1) processes, stationary in first difference, $\Phi_{xy}, \Phi_{yy}, \Phi_{xx}$, and Φ_{yx} finite-lag polynomials of degree higher than 1, all roots outside the unit circle, and ε_x and ε_y serially uncorrelated perturbations of zero mean (possibly cross-correlated).

In such a setting, a number of causality tests can be implemented, each of them with a different interpretation in economic and/or econometric terms.[14]

A first test is that for the null of an ECM term equal to zero, namely either γ_x and γ_y can be equal to zero. When holding, this non-causality property, which can be termed "ECM causality", implies that the concerned variable is weakly exogenous with respect to the long-run parameters β. As is well known, the representation theorem in Engle and Granger (1987) implies that causality exists through at least one of the two ECMs in the VAR.

A second test is that of the null of the parameters entering either Φ_{xy} or Φ_{yx} being jointly zero, namely a so-called short-run causality linking the two variables. Combining the two restrictions under a composite hypothesis corresponds to the causality aspects of the strong exogeneity concept. The interpretation in economic terms is that no past information from the other variable can be valuably incorporated to improve a univariate forecast for the other variable (which brings causality results in line with a forecasting approach).

A final remark regards the estimation procedure prior to the test itself. In the reduced form, single equation OLS is suitable since both variables are explained by exactly the same series. However, in the event that some contemporaneous correlation exists across the two perturbation terms (in other words, bidirectional instantaneous causality) entering the equations contained in the above-mentioned system, a structural model has to be estimated, allowing for some term of degree equal to 0 in the lag polynomial involved. In such a case, the estimation process has also to be changed slightly, to the extent that the list of explanatory variables is now variable-specific, and therefore a SURE method is appropriate for estimating and testing further for the various causal links.

4.2 Causality analysis: results

The results of the causality analysis are quite clear as to weak exogeneity of the first factor with respect to the long-run parameters, whereas the causality pattern is somewhat mixed and depends on the inflation measure considered in the analysis.[15]

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[13] A similar approach has been taken, for example, in Davis and Fagan (1997). As a matter of fact, the interesting aspect of this indicator is clearly in terms of providing a measure of trend inflation and some view on longer-run prospects rather than using it as an "indicator" in the context of the lagging-coincident-leading indicator, in particular to the extent that some of the series entering the computation are indeed available *after*, for example, the CPIs - HICPs nowadays - are released.

[14] The results have to be considered as a preliminary investigation, to the extent that the standard critical values to be used may be affected by a "generated regressor" issue; see Pagan (1984). A full and accurate treatment of this issue would, however, go beyond the scope of the present paper and will therefore be left for future work.

Table 7

Causality test results (p-value)

Null of non-causality	Joint hypothesis	ECM non-significant	F1 does not cause inflation
(F1 = X)	$\gamma_x = \Phi_{xy} = 0$	$\gamma_x = 0$	$\Phi_{xy} = 0$
HICP	22%	56%	18%
PCD	4%	38%	7%

First, as regards the relationship between the HICP and the first factor, assessed over the sample 1980 Q1 to 1999 Q1, the latter appears as weakly exogenous with respect to the parameters involved in the long-run relation between the factor and euro area inflation (at a level of 56%). In addition, the null of no short-term causality from the HICP to the first factor can also be accepted (at a level of 18%). Taking both hypotheses jointly, which is equivalent to the null of non-causality, the restriction is also accepted (at a level of 22%), thereby implying that the first factor incorporates specific information which is useful for forecasting euro area inflation, as measured by the headline CPI growth rates. However, this is not to be considered as a leading indicator analysis, to the extent that no out-of-sample tests have been carried out.

The results are somewhat different for the private consumption deflator, computed over the sample 1980 Q1 to 1998 Q3. In that case, weak exogeneity of the first factor is also accepted at the 38% level; however, short-run non-causality is marginally significant at the 7% level, and the p-value at only 4% for the corresponding joint restriction of non-causality leads to the rejection of the latter.

On the basis of such results, it seems fair to advance that the first factor, as computed in the balanced panel, does provide some additional information on future euro area inflation for consumer prices, with respect to the information already embedded in the past values of inflation itself. To some extent, the combination of such properties with the relatively smooth behaviour of the corresponding factor in comparison with standard "explicit" weight measures of inflation could signal that underlying trends and also longer-run prospects of euro area inflation could be assessed valuably by looking at such an indicator.

It is the case, however, as rightly pointed out by Wynne (1999) when discussing criteria for measuring "core" inflation, that such an econometrically computed indicator suffers from two major drawbacks from a policy viewpoint. First, the relative intricacy which would render communication to the public difficult and, second, the fact that additional observations would lead to re-estimation of the whole history of the factor although such a drawback would probably be less pressing than with, for example, dynamic factors.

On the other hand, mention has already been made of the forecasting properties of the factors, and the out-of-sample approach necessary for analysing them. Such an approach is clearly worth pursuing, as is done in the seminal paper by Stock and Watson (1998) and subsequently in Stock and Watson (1999), but is left for further work. The focus in the current paper has indeed been on detecting potential common trends in nominal variables for a number of countries and their link to inflation itself for the area as a whole. In contrast, the focus on the leading-indicator properties pertains to the second step of the factor analysis, by which they are fitted against a number of alternative indicators to test their predictive power as regards, for example, inflation. In this sense, the analysis is

[15] Such results are information-set-dependent, so that, for example, adding or removing lags could lead to different results. For the time being, no particular care has been taken regarding lag selections (eight lags have been employed in all cases), so that results should be viewed with caution. In addition, when a SURE method is employed, some significant contemporaneous correlation is found among the three series, so that causality results become less clear-cut than in the reduced form.

fundamentally different from the one undertaken here, as the goal is to find the links between the calculated factors and data not used beforehand in their derivation.[16]

5. Conclusions

The first step of the "diffusion indices" approach proposed by Stock and Watson (1998), namely factor analysis, has been applied to a panel comprising time series for a number of price and cost indicators for all of the member countries. This approach allows the econometrician to capture both the time and the cross-country dimension of the information available, with a view in particular to computing summary indicators of the path for inflation in the euro area, without imposing ex ante any given weighting scheme. It was also intended to better understand the cross-country dimension of past inflation developments.

A number of interesting, albeit provisional, results have been obtained, as described below.

First, some summary indicator of inflation trends in the euro area has been derived, through the first estimated factor. The resulting indicator is non-stationary, and also cointegrated with standard measures of euro area inflation that are otherwise available, such as the HICP and the private consumption deflator, ie the indicator seems to represent a "common trend" in the inflation measures.

Second, this "implicit" measure of inflation appears moreover to be quite stable, to the extent that recursive estimates show low dependence of the factor on the sample used. It remains to be checked, however, whether the inclusion of series with missing observations would greatly disturb that picture.

Third, a by-product of the analysis is that the dispersion of inflation across countries seems to be captured by the subsequent factors, which are stationary. Nevertheless, it appears quite difficult to associate any given set of countries with those lower-order factors, which may in fact be deemed an interesting property.

Fourth, an assessment of the causality properties of the "implicit" measure of inflation with respect to explicit measure(s) shows that there is evidence of unilateral causality from the factor to especially the CPI inflation indicator, so that the factor could possibly be valuably employed in forecasting aggregate inflation.

Such an assessment should of course trigger further research, part of it being quite straightforward, namely a comparison exercise with standard indicators of "core" inflation, for example the trimmed mean, for which data are available only as of 1996, or some ex-food and ex-energy measures in order to cover a larger sample. Further work could pave the way for a further paper, involving the extended version of the dataset, with a view to carrying out the second step of the analysis in Stock and Watson (1999), namely running the forecasting routines.

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16 True out-of-sample analysis also implies that the variable to be forecast should *by definition* not belong to the dataset from which factors were derived. Whether observed realisations of the variable to be forecast (ie contemporaneous and past values) are used to extract factors, on the other hand, is a matter of choice. It is thus possible to use the same variables to extract factors as done in this paper, or alternatively to conduct a similar analysis after having dropped variables that are too close to the one to be forecast, such as country CPIs with respect to the euro area HICP.

Appendix 1: Loadings

The table below contains the loadings of the balanced panel (and their squared value), in order to help illustrate the basic properties of the factors.

Balanced panel

Variable	Loadings			Loadings squared		
	F1	F2	F3	F1	F2	F3
CPIAT	0.73	-0.04	0.33	0.54	0.00	0.11
CPIBE	0.82	0.09	0.09	0.68	0.01	0.01
CPIDE	0.69	-0.31	0.49	0.47	0.10	0.24
CPIES	0.81	0.42	-0.08	0.66	0.17	0.01
CPIFI	0.82	0.25	-0.07	0.68	0.06	0.00
CPIFR	0.93	0.25	-0.05	0.87	0.06	0.00
CPIIE	0.84	0.16	0.06	0.70	0.03	0.00
CPIIT	0.92	0.21	0.02	0.85	0.05	0.00
CPINL	0.76	-0.15	0.33	0.58	0.02	0.11
CPIPT	0.69	0.37	-0.20	0.48	0.14	0.04
PCDAT	0.73	-0.04	0.34	0.54	0.00	0.12
PCDDE	0.66	-0.29	0.42	0.44	0.09	0.17
PCDES	0.77	0.48	-0.03	0.60	0.23	0.00
PCDFR	0.92	0.26	-0.07	0.84	0.07	0.00
PCDIT	0.93	0.22	-0.01	0.87	0.05	0.00
PCDFI	0.79	0.25	0.15	0.63	0.06	0.02
YEDAT	0.51	0.34	0.43	0.26	0.11	0.18
YEDDE	0.40	0.23	0.61	0.16	0.05	0.37
YEDES	0.70	0.54	-0.02	0.49	0.29	0.00
YEDFI	0.59	0.31	-0.18	0.35	0.10	0.03
YEDFR	0.80	0.44	-0.16	0.64	0.20	0.03
YEDIT	0.91	0.26	-0.01	0.82	0.07	0.00
PPIAT	0.68	-0.32	-0.01	0.47	0.10	0.00
PPIDE	0.82	-0.41	-0.01	0.67	0.17	0.00
PPIES	0.88	0.15	-0.16	0.77	0.02	0.03
PPIFI	0.85	-0.23	-0.13	0.72	0.05	0.02
PPIFR	0.80	0.07	-0.34	0.63	0.01	0.12
PPINL	0.75	-0.45	0.02	0.56	0.20	0.00
MTDAT	0.54	-0.50	-0.18	0.29	0.25	0.03
MTDDE	0.67	-0.59	-0.08	0.45	0.35	0.01
MTDES	0.78	-0.23	-0.02	0.61	0.05	0.00
MTDFI	0.59	-0.27	0.05	0.35	0.07	0.00
MTDFR	0.75	-0.38	-0.08	0.57	0.15	0.01
MTDIT	0.71	-0.48	-0.07	0.51	0.23	0.00
XTDAT	0.74	-0.36	-0.10	0.55	0.13	0.01
XTDDE	0.82	-0.34	-0.17	0.67	0.11	0.03
XTDES	0.87	0.08	-0.07	0.76	0.01	0.00
XTDFI	0.59	-0.09	-0.13	0.35	0.01	0.02
XTDFR	0.82	-0.09	-0.29	0.68	0.01	0.08
XTDIT	0.80	-0.22	-0.07	0.63	0.05	0.01

Variables are those entering the balanced panel, and their label includes the concept in the first three characters of each variable's name, and the country in the remaining two characters. Thus, concepts are:

CPI: consumer price index, national concept

PCD: private consumption deflator

YED: GDP deflator

PPI: producer price index

MTD: import deflator

XTD: export deflator

Countries are:

AT: Austria

BE: Belgium

DE: Germany

ES: Spain

FI: Finland

FR: France

IE: Ireland

IT: Italy

NL: Netherlands

PT: Portugal

Appendix 2:
Data description and coverage ratios

A total of 35 series per country were considered for the creation of the dataset; only the price variables (10 per country) have been used in this paper. The dataset comprises: real variables, national account deflators, and different prices, monetary and credit variables, interest rates, labour statistics, and inventories of finished and ordered manufactured goods. Only 65% of the total data are available for the 10 countries analysed (see the following table). Going beyond this overall picture, the following points can be made:

1. The countries for which severe problems arise in terms of availability are Germany, Ireland, Austria and Portugal, countries for which almost half of the series are not available. For Germany the problem arises from the lack of data for "Germany as a whole" prior to 1991 for most series (the total share of available data is only 43%). Data for Ireland are mostly annual, while for Austria and Portugal the starting dates for many series are only 1985 and 1988. Also worth mentioning is Belgium, for which some series start only in 1985.
2. Some series are not available for all countries; for example WPI (33.4%) is available only for Germany, Ireland, Italy, Austria and Finland. Unit labour costs are covered by only 40% (no data are available for Ireland, Austria or Portugal, and German data start in 1991 Q1).
3. Finally, there is also a timeliness problem, ie, not all countries have yet published data for all series for 1999 Q2; also some series are drawn from annual data, and therefore the latest observation is 1998.

Series	Countries								
	Belgium			Germany			Spain		
	Availability	Observations	Coverage[a]	Availability	Observations	Coverage[a]	Availability	Observations	Coverage[a]
PPI Finished goods (OECD, MEI, and ECB database*)	80q1-99q2	**80**	**68%**	70q1-99q2	**118**	**100%**	70q1-99q2	**118**	**100%**
WPI (ECB database* and BIS)**			**0%**	91q1-99q2*	**34**	**29%**			**0%**
CPI (OECD, MEI)	70q1-99q2	**118**	**100%**	70q1-99q2	**118**	**100%**	70q1-99q2	**118**	**100%**
Private Cons.Deflator (OECD, QNA)	85q1-99q2	**58**	**49%**	91q1-99q2(b)	**34**	**29%**	70q1-99q2	**118**	**100%**
GDP deflator (OECD, QNA)	85q1-99q2	**58**	**49%**	91q1-99q2(b)	**34**	**29%**	70q1-99q2	**118**	**100%**
Government Consumption Deflator (OECD, QNA)	85q1-99q2	**58**	**49%**	91q1-99q2	**34**	**29%**	70q1-99q2	**118**	**100%**
Gross fixed capital formation Deflator (OECD, QNA)	85q1-99q2	**58**	**49%**	91q1-99q2	**34**	**29%**	70q1-99q2	**118**	**100%**
Exports Deflator (OECD, QNA)	85q1-99q2	**58**	**49%**	91q1-99q2(b)	**34**	**29%**	70q1-99q2	**118**	**100%**
Imports Deflator (OECD, QNA)	85q1-99q2	**58**	**49%**	91q1-99q2(b)	**34**	**29%**	70q1-99q2	**118**	**100%**
ULC	85q1-99q2	**58**	**49%**	91q1-99q2(b)	**34**	**29%**	70q1-99q1	**117**	**99%**
TOTAL 10 Series		**604**	**51%**		**508**	**43%**		**1061**	**90%**

Series	Countries								
	France			Ireland			Italy		
	Availability	Observations	Coverage[a]	Availability	Observations	Coverage[a]	Availability	Observations	Coverage[a]
PPI Finished goods (OECD, MEI, and ECB database*)	70q1-99q2	**118**	**100%**	85q1-99q2*	**58**	**49%**	81q1-99q2	**74**	**63%**
WPI (ECB database and BIS*)			**0%**	70q1-99q1*	**117**	**99%**	70q1-97q4**	**112**	**95%**
CPI (OECD, MEI)	70q1-99q2	**118**	**100%**	70q1-99q2	**118**	**100%**	70q1-99q2	**118**	**100%**
Private Cons.Deflator (OECD, QNA)	70q1-99q2	**118**	**100%**	75q1-97q4*	**23**	**19%**	70q1-99q2	**118**	**100%**
GDP deflator (OECD, QNA)	70q1-99q2	**118**	**100%**	75q1-97q4*	**23**	**19%**	70q1-99q2	**118**	**100%**
Government Consumption Deflator (OECD, QNA)	70q1-99q2	**118**	**100%**	75q1-97q4*	**23**	**19%**	70q1-99q2	**118**	**100%**
Gross fixed capital formation Deflator (OECD, QNA)	70q1-99q2	**118**	**100%**	75q1-97q4*	**23**	**19%**	70q1-99q2	**118**	**100%**
Exports Deflator (OECD, QNA)	70q1-99q2	**118**	**100%**	75q1-97q4*	**23**	**19%**	70q1-99q2	**118**	**100%**
Imports Deflator (OECD, QNA)	70q1-99q2	**118**	**100%**	75q1-97q4*	**23**	**19%**	70q1-99q2	**118**	**100%**
ULC (BIS)	78q1-99q2	**118**	**100%**				82q1-99q2	**70**	**59%**
TOTAL 10 Series		**1062**	**90%**		**431**	**37%**		**1082**	**92%**

(a) Coverage stands for the ratio between available data and total number of observations.

(b) Data for Germany is available in most cases only as of 1991, however it is possible to obtain longer series by rescaling them to the Western Germany series.

Series	Countries								
	Netherlands			Austria			Portugal		
	Availability	Observations	Coverage[a]	Availability	Observations	Coverage[a]	Availability	Observations	Coverage[a]
PPI Finished goods (OECD, MEI, and ECB database*)	76q1-99q2*	**94**	**80%**	70q1-99q2	**118**	**100%**			**0%**
WPI (ECB database and BIS*)			**0%**	96q1-99q2**	**14**	**12%**			**0%**
CPI (OECD, MEI)	70q1-99q2	**118**	**100%**	76q1-99q2	**94**	**80%**	88q1-99q2	**46**	**39%**
Private Cons.Deflator (OECD, QNA)	77q1-99q1	**89**	**75%**	76q1-99q2	**94**	**80%**	88q1-98q4	**44**	**37%**
GDP deflator (OECD, QNA)	77q1-99q1	**89**	**75%**	76q1-99q2	**94**	**80%**	88q1-98q4	**44**	**37%**
Government Consumption Deflator (OECD, QNA)	77q1-99q1	**89**	**75%**	76q1-99q2	**94**	**80%**	88q1-98q4	**44**	**37%**
Gross fixed capital formation Deflator (OECD, QNA)	77q1-99q1	**89**	**75%**	76q1-99q2	**94**	**80%**	88q1-98q4	**44**	**37%**
Exports Deflator (OECD, QNA)	77q1-99q1	**89**	**75%**	76q1-99q2	**94**	**80%**	88q1-98q4	**44**	**37%**
Imports Deflator (OECD, QNA)	77q1-99q1	**89**	**75%**	76q1-99q2	**94**	**80%**	88q1-98q4	**44**	**37%**
ULC (BIS)	84q1-99q1	**61**	**52%**			**0%**			**0%**
TOTAL 10 Series		**807**	**68%**		**790**	**67%**		**310**	**26%**

Series	Countries		
	Finland		
	Availability	Observations	Coverage[a]
PPI Finished goods (OECD, MEI, and ECB database*)	70q1-99q2	**118**	**100%**
WPI (ECB database and BIS*)	70q1-99q2**	**118**	**100%**
CPI (OECD, MEI)	70q1-99q2	**118**	**100%**
Private Cons.Deflator (OECD, QNA)	75q1-99q2	**98**	**83%**
GDP deflator (OECD, QNA)	75q1-99q2	**98**	**83%**
Government Consumption Deflator (OECD, QNA)	75q1-99q2	**98**	**83%**
Gross fixed capital formation Deflator (OECD, QNA)	75q1-99q2	**98**	**83%**
Exports Deflator (OECD, QNA)	75q1-99q2	**98**	**83%**
Imports Deflator (OECD, QNA)	75q1-99q2	**98**	**83%**
ULC (BIS)	89q1-99q2	**42**	**36%**
TOTAL 10 Series		**984**	**83%**

Series	Total Coverage[a] For Each Variable
PPI Finished goods (OECD, MEI, and ECB database*)	**75.93%**
WPI (ECB database and BIS*)	**33.47%**
CPI (OECD, MEI)	**91.86%**
Private Cons.Deflator (OECD, QNA)	**67.29%**
GDP deflator (OECD, QNA)	**67.29%**
Government Consumption Deflator (OECD, QNA)	**67.29%**
Gross fixed capital formation Deflator (OECD, QNA)	**67.29%**
Exports Deflator (OECD, QNA)	**67.29%**
Imports Deflator (OECD, QNA)	**67.29%**
ULC (BIS)	**42.37%**
TOTAL (Coverage of the 10 Series)	**65%**

(a) Coverage stands for the ratio between available data and total number of observations.

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Diffusion index-based inflation forecasts for the euro area[1]

Elena Angelini, Jérôme Henry and Ricardo Mestre

1. Introduction

One important development over the last few years has been the steadily growing flow of information accruing to the economist, with data becoming increasingly available at a higher degree of disaggregation, at the regional, temporal and sectoral levels. The availability of such new information has boosted economic analysis in directions other than the traditional economy-wide macroeconomic approach, such as firm-level, panel or high-frequency data analysis. However, macroeconomics could also profit from this richer environment, and work along these lines is nowadays a priority. This is the case for every economy for which sufficiently detailed data exist, but also applies to a particular extent to the euro area. One way to circumvent the relative scarcity of data covering a long period of time for the euro area is to use as much data as are available for all of the member countries. In stark contrast with the area as a whole, most member countries have a long and well established tradition of collecting a broad range of data, for which long time series are therefore available. It is thus particularly important for the analysis of euro area data to explore new techniques or adapt old ones, which would enable the economists to exploit large amounts of country data with only a partial geographic coverage of the area. This paper examines one of these new techniques, with a view to analysing the links between country data of the most diverse nature and a variable of primary interest to the ECB, namely area-wide inflation.

In a recent and influential paper, Stock and Watson (1998) initiated an interesting line of research by proposing the use of dynamic factors - extracted according to their own specific methodology - as potential indicator variables for future inflation. Further, the same authors thoroughly analysed the relative forecasting performance of such factors (see Stock and Watson [1999]) with results that, although far from conclusive, are at least promising. The proposed methodology falls within the dynamic factor analysis in line with research going back to Sargent and Sims (1977) or Quah and Sargent (1993) and continued in recent papers such as Forni and Reichlin (1998), Forni et al (1999) and Forni and Lippi (2000). The approach advocated by Stock and Watson (1998) is being applied in a number of related studies, examples of which for the euro area are Marcellino et al (2000) and a companion paper to this one (see Angelini et al [2001]). In the latter paper, factors are extracted from a large dataset of EMU country-level measures of prices with a view to summarising trend inflation in the euro area as a limited number of indicators.

The main goal pursued in this paper and its companion is to assess ways in which the very rich set of data available for the 11 EMU countries (12 since early 2001) can be exploited for the benefit of the common monetary policy. In a sense, and bearing in mind the obvious differences, the euro area faces a situation akin to that faced by a country with extensive, high-quality regional data. One possible way to exploit this wealth of data is by directly addressing analyses and forecasts at the country level, to be aggregated afterwards at the area-wide level, the so-called “bottom-up” approach to forecasting. Another approach, assessed in this paper and not necessarily at odds with the previous one, is to explore ways to summarise the country information at the area-wide level as a greatly reduced number of series with similar information content, thus exploiting country information without losing sight of the area-wide perspective.

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[1] Opinions expressed in the paper are those of the authors and do not necessarily reflect those of the ECB. This paper, in an earlier version, was presented at a BIS workshop on Empirical Studies of Structural Changes and Inflation in October 2000. The authors are grateful to the BIS for hosting the workshop, and to the discussant of the paper, J Ihrig of the Federal Reserve Board, and attendees of the workshop for useful comments. We also greatly benefited from discussions with J Stock at various stages of this work as well as from input from colleagues at the ECB and an anonymous referee. Remaining errors are the sole responsibility of the authors.

The current paper goes beyond our previous work in three respects. First, the extracted factors are systematically analysed along a dimension which was only marginally addressed previously, ie their ability to forecast inflation. Second, factors associated with non-price variables also receive a great deal of attention in the following, whereas the companion paper is restricted to factors derived from nominal variables. Finally, a thorough account of the basic in-sample properties of the factors is given here with more description and detail than before.

The paper is structured as follows. Section 2 briefly recalls the technical background of the factor extraction procedures, and discusses a number of practical problems found in this process. Resulting factors are then described in Section 3. Section 4 gives details on the forecasting exercise performed, in terms of both the tools (ie the "models" assumed to hold) and the tests for forecasting ability. Section 5 presents and comments on the results. Section 6 concludes.

2. Factor extraction

At this point, it is worth highlighting some technical aspects of the approach.[2] The method uses principal-component analysis to extract information from large macroeconomic datasets. Initial raw data are present in the form of a large number of variables related to the euro area, from which common factors are extracted following standard statistical procedures in a non-standard framework. The analysis starts with a dataset, of possibly large dimension, containing raw variables assumed to be generated by a small number of common factors, as represented by variable x_t in expression (1.1).[3] Variable x_t is a column-vector representation of *N* different variables for period *t*, the total number of observations being *T*. In the expression, x_t is an *N*-column vector, f_t is an *r*-column vector (the factors) and Λ is a matrix with *N* columns and *r* rows (the loadings). Variable ε_t is an error process whose variance depends on the variance of the *N-r* factors missing in the expression. If all the variables indexed by *t* are stacked for the *T* periods of the sample, expression (1.2) results, in which stacked variables appear in upper case.

$$x_t = f_t \cdot \Lambda + \varepsilon_t, \quad t = 1,...,T \tag{1.1}$$

$$X = F \cdot \Lambda + \mathrm{E} \tag{1.2}$$

Factors in (1.2) have to be uncorrelated among themselves and with the residual E (ie ε_t in stacked form), and must be such that the variance of the residual is minimised. As shown by Stock and Watson (1998), under fairly general conditions the factors can be estimated - up to a rotation matrix - by a standard principal-component analysis based on the *NxN* cross-moments matrix *X'X* or alternatively on the *TxT* matrix *XX'*. As is standard, there is a one-to-one mapping - again up to a rotation matrix - between the two approaches, the preferred one being based on the relative size of the two dimensions. In the dataset analysed below the latter approach is taken, as its time dimension is smaller than the variable dimension. One key decision in the analysis is the number of factors that have to be extracted, which can range from 1 to (in the present case) *T*. Although some methods have recently been proposed in the literature to test and choose the underlying number of factors (see, for example, Bai and Ng [2000]), the approach followed in this paper has been simpler. Forecasting tests have been performed with alternative numbers of factors, with an upper limit in their number imposed not by the econometrician but by the quality of the estimated factors in terms of variance explained and also their robustness to missing observations.

One advantage of this approach is the possibility of using expanded sets of information in deriving the factors, ie the possibility of using information from variables that do not cover the whole period in order to fine-tune the estimation of the factors. Variables that are not present for some periods (ie variables with *missing values* for part of the sample) can nevertheless be used to extract factors, thanks to a

[2] For a more detailed discussion, the reader is referred to Stock and Watson (1998) or, for a less technical description, to Angelini et al (2001).

[3] Lags of the factors can enter (1.1) without loss of generality. Mild time variation in Λ is also possible.

slightly more complex factor estimation procedure, as shown by Stock and Watson (1988). The principal-component approach described in the previous paragraph, and the corresponding matrix decomposition problem, are only valid in the presence of complete datasets, ie datasets in which no data are missing (a situation termed as *balanced panel*). Stock and Watson (1988) show that maximising the likelihood of the system (1.2) in the case of a balanced panel results in a standard matrix decomposition problem, but they also prove that it is still possible to perform the estimation in the presence of incomplete information using the well known EM algorithm. In this case, the system (1.2) itself can be used to derive expected values of missing variables (the E step), which can then be used to maximise the system (the M step). The final estimates result from iterations on these two steps until final convergence. It is obviously necessary to provide initial estimates of the parameters for the first iteration. Following a proposal made by the two authors, the initial factors will be given by the larger dataset covering the full sample with no missing data, ie the largest subset of the original dataset providing a balanced panel.[4]

Given the situation for euro area data, characterised by missing observations for a number of countries, it is important to understand the process by which the EM algorithm can be applied to unbalanced panels. Starting from some initial estimates, $\hat{F}$ of the factors and $\hat{\Lambda}$ of the loadings, an estimate of the complete dataset is obtained by replacing missing values in x_t with corresponding elements of $\hat{x}_t = \hat{\Lambda} \cdot \hat{F}$. A corresponding cross-moments matrix can be formed from the generated variables, and factors and loadings re-estimated. Each time an iteration is run, new factors are extracted and used in the following iteration. One important aspect of this algorithm is that iterations can be made taking *all* eigenvalues of the matrix, or selecting only those most significant. Although both approaches provide asymptotically correct estimates of the true factors, the small-sample properties could differ markedly. In the case in question, this may have had an important impact on the calculations.

Data used in this paper relate to the 11 countries of the area that were taken into consideration (ie members before 2001) and cover a broad array of economic items. The rather large dataset comprises 278 variables spanning the period from (roughly) 1977 to 1999. A fuller description of the variables, with a breakdown by country, is provided in Appendix C. Most series are of quarterly frequency, and those present at monthly frequency were transformed into the lower frequency, because of the lack of monthly data for many series used and also the sensitivity of the results to missing observations when the latter become too numerous, as described below. One notable feature of the series is the presence of nominal and real variables in the dataset from which factors were extracted, which raises the possibility of separating purely nominal factors from other influences affecting inflation. This is a desirable feature. The analysis has thus proceeded with two different sets of dynamic factors: first, those extracted from purely nominal information (ie deflators, wages and prices contained in the original database) and, second, all-encompassing dynamic factors as obtained from the complete dataset. Furthermore, some interesting facts were discovered regarding factors extracted from a dataset comprising all the variables except those used for the nominal-only factor extraction. The three sets of factors will be discussed, with a special emphasis on factors extracted from the all-encompassing dataset.

Original series were firstly checked for the presence of outliers and then transformed to get rid of non-stationarity and heteroskedasticity, by taking logs or ratios of variables and differencing the series appropriately. Further to that, all series were standardised by removing their mean and dividing them by their standard error. Factors extracted from the complete dataset will be termed "overall factors", those extracted from a dataset comprising only prices will correspondingly be termed "nominal factors" and those extracted from non-price variables "non-nominal factors". As mentioned earlier, nominal factors are already extensively analysed in the companion paper; see Angelini et al (2001).

As documented and discussed in detail in Angelini et al (2001), a number of numerical problems appear when estimating factors from an unbalanced panel. Distortion in the final estimates can be present and unbalanced-panel factors can differ considerably from balanced-panel ones and end up being much less plausible. When the number of factors selected in each EM iteration (see above) is

[4] Other options are available which are worth exploring, due to the high likelihood of the last observation being sparse. This paper does not explore these alternatives, but this is an item on our agenda.

relatively large (higher than three or four in our case), numerical problems can be found in the estimation. In the present case, a closer inspection of results highlighted a couple of interesting points. First, the degradation of results in unbalanced-panel estimation is not gradual but increases visibly when more than three or four factors are used. Second, this is especially the case for the "nominal factors", for which results are affected as soon as four factors are computed.[5] In turn, "overall factors" remain plausible when computed with the unbalanced panel until up to five factors are taken into account in the EM algorithm. Finally, "nominal factors" were significantly different when using balanced- or unbalanced-panel estimation, while "overall factors" were much more robust to the inclusion of series with missing observations.

Graph 1

Comparison of factors

[5] Additional information, including graphs, regarding the unbalanced-panel distortion with five factors may be found in the companion paper.

A graphic representation of the "overall factors" is shown in Graph 1. The upper left-hand panel shows the first "overall factor" for all estimations, ie for the balanced panel and the unbalanced panel with one-, two-, three- and four-factor EM iterations respectively. The upper right-hand panel shows correspondingly the second "overall factor" for the balanced panel and the unbalanced panel with two- three- or four-factor estimation respectively. (Obviously, no second factor was extracted in one-factor unbalanced-panel estimates.) Although not reported, the "nominal factors" also showed some (lesser) degree of stability across models, with the exception that at most three-factor EM iterations were acceptable instead of four-factor estimations. Beyond this number (ie for EM iterations taking four or more factors) results were clearly unsatisfactory.

The two lower panels of Graph 1 depict another interesting fact about these estimates. They show the first "nominal factor" and the first "non-nominal" factor, to be compared with the "overall factors" of the upper panels. Results clearly point to very different factors according to the information used to extract them. On the other hand, the first "overall factor" is visibly similar to the first "nominal factor", while the second "overall factor" looks very much like the first "non-nominal factor". Very probably, there is a clear separation between "nominal" and "non-nominal" factors in the dataset used. Although it is true that the estimated factors can be rotated, the features just described seem to be able to withstand any possible rotation (as a matter of fact, finding criteria to rotate the factors in a homogenous way would seem a desirable development of the technique.)[6]

3. Analysis of extracted factors

Factors extracted following the aforementioned methodology may serve many different purposes. It has become standard in the literature to assume that they correctly summarise the economy the initial variables refer to, and thus may be a good indicator of important forces underlying the economy. In particular, it has been put forward that these factors may provide good leading-indicator properties and may thus show good forecasting ability (see Stock and Watson [1999]). The main aim of this paper is to test this specific feature of the estimated factors, both the "nominal" and the "overall" ones. It is nevertheless necessary to first give a broad overview of the basic features of the factors obtained, in terms of both their shape and their relationship with the original variables.

Probably the most notable feature of the three sets of factors (ie overall, nominal and non-nominal factors) is the striking similarity of pattern between, respectively, the first "overall" and the first "nominal" factors, and also the second "overall" and the first "non-nominal" factors, as already seen in Graph 1.

Another interesting feature is the lower percentage of the variance explained by the first few factors in the "overall" case: while the first "nominal factor" explained 59% of the variance of prices, the first "overall factor" only explains about 25% of the corresponding data variance. Not surprisingly, the first - ie most important - "non-nominal factor" also explains only a tiny fraction of data variance, thus giving clear indications that the variance in the nominal dataset is highly concentrated around a small number of factors, whereas the non-price system of variables seems to be of a more intricate nature.[7]

Links between factors and variables are also a relevant piece of information, which can be best analysed using the estimated loadings. The latter express the projection of the factors onto the variables, variable Λ in expression (1.1). With a convenient rescaling of the factors, the loadings must lie between -1 and 1, thus giving a direct and easily readable measure of how well the projection for each variable fits. In fact, loadings give a measure of the correlation between factors and each variable since both factors and variables have been normalised beforehand and thus have unit variance. Further, the fact that factors are uncorrelated means that loadings squared can be read as R-squared measures of the regression of individual factors on each variable. Tables 1 and 2 in

6 All the graphs show the factors estimated with the full sample. Factors were estimated recursively in the course of the forecasting test and found to be relatively stable when increasing the estimation sample.

7 As the dataset termed as non-nominal comprises variables usually treated as nominal - foremost among them, money - it is not possible to assign this complexity only to real-activity variables.

Appendix A show the loadings and their squares for all the variables, distinguishing between variables in the balanced panel and those entering only the unbalanced panel.[8]

A quick overview of the tables in Appendix A leads to a number of general conclusions. To begin with, the first "overall factor" is very similar to the first "nominal factor" also in view of the loadings.[9] The table indeed confirms that most, if not all, price variables are strongly correlated with this factor. Other variables with a significant relationship with this factor are earnings, employment and unemployment series, most notably the unemployment rate. More striking is the fact that survey variables related to manufacturing also show a visible degree of correlation: capacity utilisation, order book commands, new orders or stocks in manufacturing firms. The rest of the variables are clearly less related to this factor, most notably GDP and monetary aggregates.

In general terms, the second "overall factor" is much less correlated with variables, although capacity utilisation, survey-based manufacturing series, earnings, employment and unemployment show a relatively sizeable degree of correlation with it. In fact, these series share some degree of correlation with *both* factors. Another interesting point is the relatively high correlation between the second factor and the short- and long-term interest rates, which on the other hand are not strongly correlated with the first factor. Variables belonging to the expenditure side of national accounts do not show a clear-cut correlation pattern with any factor, ie GDP, private consumer expenditure, exports or imports, nor do retail sales variables.

Regarding unbalanced-panel estimates, caution is needed in interpreting them because of the somewhat more complex estimation method used. Caution is particularly needed for the third factor, for which there is evidence of increasing distortion. Nevertheless, there is evidence that the first "overall factor" is still correlated with price variables, although evidence is less compelling than in the balanced panel. For the other variables and factors, it is more difficult to extract unambiguous conclusions.

Last but not least, country-specific evidence is not strong. Most countries show specific correlation patterns for a few variables, but not as a general feature. Finland is probably the clearest case of a general specificity. All in all, correlation patterns along variables are stronger, or at least more visible than along the country dimension.

4. Forecasts

As mentioned above, the backbone of the analysis herein is an exploration of the inflation forecasting ability of factors, with particular emphasis on the euro area. In line with previous and related studies, the current section presents a discussion of the specific forecasting techniques that are to be used for the exercise.

Three preliminary steps need to be covered before going further. It is first of all necessary to spell out clearly what the real-life problem is that one is expected to face. In our case, the main focus is on how to forecast the inflation rate of the euro area. Secondly, it is also important to describe (and to try to approach in the analysis) the real circumstances in which the actual forecast may take place. Regrettably, real-life forecasts based on dynamic factors are difficult to replicate ex post: they usually involve large amounts of data, much of which are provided with lags and delays and are also likely to be revised subsequently. The framework of our analysis will be simpler than the real-life task in that a final, fully revised dataset will be used, but some degree of realism will be achieved by performing true out-of-sample forecasts based on this dataset. As a third and final step, it is important (although maybe less critical) to set the general technical procedures that might be followed to perform the forecasts themselves. Most forecasts embody a lot of discussion among participants with heterogeneous backgrounds and views, and probably will include some degree of judgment. The analysis in this paper, on the other hand, is restricted to automatic and simple procedures, which

8 For those variables entering both the balanced- and the unbalanced-panel estimation, corresponding loadings were very similar.

9 Loadings for the "nominal factors", in a format similar to Table 1, can be found in Angelini et al (2001).

cannot reflect a more protracted and complex forecasting process. The strength of the analysis will lie rather in the many replications of simulated out-of-sample forecasts and their comparison with a predefined benchmark forecasting tool or model, in the belief that procedures able to consistently beat the benchmark are worth developing further. In this, we follow an entirely standard approach within the literature (see Stock and Watson [1999]).

In line with the stated goals, the forecasting exercises are performed on three alternative measures of the euro area inflation rate: the harmonised index of consumer prices (HICP), the consumption deflator and the GDP deflator of the ESA95 euro area national accounts. Data limitations prevent the use of raw data, as they cover only a relatively short amount of time, and necessitate some pre-treatment of the data: the three series were backdated with data from the OECD.[10] Moreover, it was decided to focus on quarterly forecasts due to the quarterly nature of the last two variables, but also because of the much richer set of quarterly series that were available for extracting the factors. Last but not least, the aforementioned problems with unbalanced-panel estimations militated against carrying out the analysis at the higher frequency. Obviously, this is a limitation of the analysis that has to be remedied as soon as possible, for example by collecting as much monthly data for the euro area member states as are available.

As stated, no attempt was made to replicate true forecast circumstances, as for the time being it is prohibitively expensive to prepare a real-time dataset with an accurate representation of the real state of information at each point in time. As has become standard in most of the related literature, the way to approximate this situation has been to use a single final (ie fully revised) dataset covering the whole period, but performing rigorous out-of-sample forecasts using no information belonging to periods later than that at which the forecast is assumed to take place.[11]

The simple techniques followed to derive the forecasts are also fairly standard. A growing body of literature has recently been performing thorough testing exercises on the forecasting ability of sets of variables by running regressions based on (4.1), in which y_t is the variable of interest, assumed to be I(1), z_t is the indicator variable being tested, assumed to be I(0), and ε_t a well behaved error term. In the expression, h stands for the number of periods ahead for which the forecast has to be performed. This expression assumes that there exists a direct mapping from I(0) variables known today to information h-periods ahead. Interestingly, all information required to make the forecast is assumed to be already available, and thus describes a system in which no recursion is needed in order to obtain the forecast.

$$\frac{y_{t+h} - y_t}{h} = A(L) \cdot \Delta y_t + B(L) \cdot z_t + \varepsilon_t \tag{4.1}$$

Expression (4.1) is not the standard approach taken to model dynamic systems outside this brand of literature. Normal procedure is to assume that a one-step-ahead recursive system such as (4.2) applies. This equation seems to be preferable to (4.1) as it apparently uses more information, but this is misleading because our main interest is in deriving forecasts h-periods ahead based on factual data. Equation (4.2) provides such a forecast by recursively generating the periods in between, and thus adds no new information.

$$\Delta y_{t+1} = A(L) \cdot \Delta y_t + B(L) \cdot z_t + \varepsilon_t \tag{4.2}$$

Although (4.1) is nowadays customarily used to make out-of-sample forecasts (see, for example, Stock and Watson [1999], Bernanke [2000] or Marcellino et al [2000]), it is worthwhile exploring the actual differences between the two expressions. Such a step has, to the best of our knowledge, strangely enough been skipped in the factor forecast literature, although, in view of the standard

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10 See the discussion in Angelini et al (2001) and references therein.

11 Bernanke (2000) argues that gains in the analysis from dealing with a true real-time dataset may be smaller than previously thought. It may be worthwhile, nevertheless, to at least replicate in a more realistic setting the true-life exercise by performing Monte Carlo simulations with fake revisions of data known to be revised, a task left for further research.

practices of professional forecasters, the lack of explicit discussion on this difference could cast doubts on the results obtained. Indeed, most professional forecasters would, if they had to forecast variable y_{t+h}, spend a great deal of time considering the expected evolution of z_t, and its impact on y_{t+h}. Thus, they would naturally prefer a forecasting framework described by (4.2). This framework is, however, at odds with the philosophy of dynamic-factor forecasting, precisely because there is in principle not much to be said on the future evolution of the factors. A thorough analysis of the relative forecasting performance of the two approaches is thus warranted. A description of an analysis along these lines is reported in Appendix B, in which the conclusion is reached that for the sample used it is likely that both systems have similar performance.

5. Results

Once the factors have been extracted and the forecasting equations chosen, practical decisions remain to be tackled, such as which variables to forecast, or what indicators to use as benchmarks against which to compare the performance of the dynamic factors. Another practical matter relates to the choice of lags in the forecasting equation, as this was left undefined in the previous section. Finally, it is necessary to set the number of periods ahead that will be tested, and the break date after which the out-of-sample exercises will begin.

As already stated, the basic aim of the paper is to measure accuracy in performing (simple) inflation forecasts. Recall that three variables were retained as measures of inflation: the euro area-wide harmonised index of consumer prices (HICP), the euro area private consumption deflator and the corresponding GDP deflator. The three indexes were treated as I(1) variables, resulting in an assumed I(0) inflation rate. Indicators retained included the "overall", "nominal" and "non-nominal" factors from the balanced panel and the unbalanced panel with one-, two- and three-factor extraction. Alternative indicators employed to forecast euro area inflation were: the euro area unemployment rate, GDP growth, the output gap in the form of a Hodrick-Prescott-filtered GDP, and growth of nominal M3.[12] Both the factors and the output gap were extracted in real-time-like manner, ie were calculated anew each time the starting date for the out-of-sample exercise was changed. The rest of the indicators (ie the unemployment rate and output growth) came from a final database and were thus simply extracted from it after dropping the unneeded observations beyond the starting date of the out-of-sample test.

Contrary to the rest of the indicators, dynamic-factor equations could contain more than one indicator variable, as sometimes more than one factor is used. The simplest equation employed contains only the first factor of the "overall", "nominal" or "non-nominal" datasets. Additional factors are added sequentially, first the second factor added to the first one, and then finally the third one added to the other two. To ensure consistency, unbalanced-panel factors appearing in an equation are always derived from the same underlying estimation, ie the first factor appearing in an unbalanced-panel equation with (say) three factors has to come from the three-factor EM estimation. So doing, it is possible to exploit the natural ranking of factors, since sequentially each one explains less variance of the original dataset. No such natural ranking of indicators is present with observed variables; therefore the other indicators are used in isolation in their own forecasting equation.

As regards multiple-factor regressions, it has become customary to either fix the number of parameters or select them following some information criteria such as the BIC. This option was not followed in this paper because of potential small-sample problems, and the known tendency of some information criteria tests to overstate the number of variables to pick up. Instead, a thorough testing of different combinations of factors was preferred. Hence, out-of-sample forecasts were first run with the first factor, then with the first and second factors, and finally with the first three factors. As already mentioned, the numerical problems found in the derivation of the fourth factor in the unbalanced panel with nominal variables (the fifth one, in the case of the complete database) justified taking into consideration only the first three factors. All factors entered with two lags, although different numbers of lags were tested.

[12] M1 and M2 were also tested, as were real M1, M2 and M3. Nominal M3 was clearly the preferred choice.

Another key choice to make is the number of lags of the dependent variable entering the forecasting equation (ie, Δy_t). There, it is also the standard practice to either fix them a priori or choose them based on an information criteria test. We have in this case slightly departed from these choices and, after a large number of tests, decided to take as many lags as periods ahead to forecast. Thus, our number of lags is h and is made dependent on the particular forecasting horizon. This approach was taken after an exploration of alternative settings, and probably is a reflection of the relatively high persistence of inflation, as this imparts a lot of inertia to the dependent variable that may not be well captured unless a horizon-dependent number of lags of Δy_t are added. (It is important to note that the chosen equations are not recursive and are thus probably less prone to over-parameterisation problems.)

Results are presented in the form of the relative RMSE (root mean square error) of each equation against a convenient benchmark, for different forecasting horizons. The chosen benchmark is a simple version of (4.1) in which no indicator is used. Alternative specifications include as indicators the unemployment rate, GDP growth, the output gap and growth of M3. Dynamic factors comprise from one to three factors of the balanced and unbalanced panels. Each time, forecasting equations are estimated for a conveniently chosen subsample, out-of-sample forecasts made for the necessary steps ahead or until the end of the full sample has been reached, and corresponding RMSEs collected. The same operation is repeated for longer subsamples (extended recursively), each time collecting RMSEs. Finally, all RMSEs are averaged separately for each specific horizon. The RMSE for each combination of equation and horizon is divided by the corresponding one for the benchmark, and the resulting ratio shown in the table. A ratio of less than one means that, for that horizon, the corresponding equation can beat the benchmark, the opposite being true otherwise.

This procedure provides estimates of the true underlying forecasting performance of the equation by simple averaging of forecast errors. These forecasts take place within sample, but in periods not used to estimate the equation. At each step it is necessary to split the observed sample between a part dedicated to the estimation and a part dedicated to the calculation of forecast errors. If care is not exercised, too early a split date may lead to inaccuracies in the first estimations, and may bias the resulting RMSE test. Even worse, structural breaks in the data may lead to seemingly large RMSE numbers because of shifts in the forecasts made before any structural break. These problems dictate prudence in setting the initial date at which recursions are started, compounded in our case by the potentially unstable nature of euro area data. Accordingly, a relatively late first date for the out-of-sample exercises was chosen, ie 1995 Q1. Results for earlier starting dates were performed and are reported, although a structural break before 1995 cannot, in our view, be dismissed, so that greater weight should be attached to the findings for 1995 Q1.

Results from the forecasts are collected in Tables 1, 2 and 3. The first table is our base-case one: it shows results for out-of-sample exercises starting as of 1995 Q1; Table 2 has the same structure but with the initial date set at 1992 Q1; finally, Table 3 has an initial date of 1985 Q1, beyond which results would become highly unreliable. Each table is in turn divided between forecasts for HICP, for the consumption deflator (labelled PCD) and for the GDP deflator (labelled YED). Forecasting accuracy is always measured against a simple forecasting equation with no indicators, ie just lags of Δy, labelled in the table as AR. The comparison between the benchmark and each of the alternative equations is done as the ratio of the RMSEs of both. (Hence the row of ones at the top of each table, in the line corresponding to the benchmark itself.) As in Table 1, a value of less than one in a specific cell means that the corresponding equation has on average been more accurate than the benchmark. The comparisons are made for forecasts one to four periods ahead, and to eight periods ahead. The sample used and the date at which out-of-sample tests were started are also included on the right-hand side of the table.

A number of general conclusions can be drawn from the tables.

Factors generally have relatively good forecasting performance, particularly at medium-term horizons (beyond two quarters). Although factors never fare badly compared to alternative indicators at the one-quarter-ahead range, they have relative RMSEs that are generally lower in four- and eight-quarters-ahead forecasts. Regarding particular measures of inflation, nominal factors are preferable for HICP forecasts irrespective of the break date considered. In particular, forecasting regressions using two or three nominal factors coming from the unbalanced-panel estimates always match the best alternative indicator. To a lesser extent, the same applies for the consumption deflator (PCD in the table), although in this case a general degradation of forecasts can be perceived throughout the tables. On the other hand, the GDP deflator (YED in the table) is best forecast by non-nominal factors, this time by a rather considerable margin. Again, this is particularly true for medium-range forecasts using regressions with two or three unbalanced-panel factors.

Setting the starting date at 1992 Q1 leads to a visible worsening of forecasts. This is an outstanding feature in the tables: for all indicators, including factors, setting the recursion starting date at 1992 Q1 leads to visibly higher RMSEs than in either Table 1 or Table 3. Again, only the factors mentioned in the last paragraph are able to withstand the change in starting date without a large deterioration in results. An intriguing feature of the starting date comparison, upon which it would be unwise to draw unwarranted conclusions, is the relative similarity between Tables 1 and 3 (respectively, with dates at 1995 Q1 and 1985 Q1) and Table 2. This somewhat surprising feature certainly deserves further investigation since it may suggest that the period between 1992 and 1995 played a particular role in terms of structural changes affecting the underlying forecasting model.

Among alternative indicators (ie those not based on factors), unemployment outperforms the rest. The unemployment rate is very often the alternative indicator delivering lower RMSEs for most horizons, irrespective of the chosen inflation measure or recursion starting date. On the other hand, M3 is surprisingly good at forecasting HICP for all recursion starting dates (see Nicoletti-Altimari [2001] for similar findings.) This feature, however, is not found to hold for the consumption deflator and the GDP deflator, for which M3 has a reasonable but lacklustre performance. Finally, the output gap shows an unpromising forecasting performance, a fact in contrast with its widespread use in the literature but which could originate in the recursive end-of-sample revisions of the series performed. The Hodrick-Prescott filter was run each time an out-of-sample iteration was started, and this led to large revisions of the end point of the resulting output gap series. This conclusion, if granted, would highlight further the well known problem incurred in using filtered versions of potential output and the ensuing end-of-sample problem.

Additional tests were carried out that are not reported to save space. For instance, adding seasonal dummies and a German reunification dummy marginally improved the forecasting ability of the observed indicators but left almost unchanged that of the dynamic factors. Also, changing the number of lags for all indicators (tests were made for zero lags to four lags), although changing results, did not alter the conclusions reached.

6. Conclusions

Past developments in data collection and treatment have led over recent years to an explosion in the amount of data available for economic analysis. This increasing wealth of data calls for the exploitation of non-standard econometric techniques. This is specially the case for the euro area, for which specifically area-wide data are still a relative oddity but where a great wealth of data is available for the member countries. One technique developed recently by Stock and Watson (1999) is pursued in a companion paper for the analysis of trends in euro area-wide inflation (see Angelini et al [2001]), and is further used in this paper with the particular aim of forecasting area-wide inflation. The technique entails summarising a large amount of data as a small number of factors using a form of principal-component analysis, and using the resulting factors to forecast inflation. Technical aspects of the task are described, including data treatment and the setup used to forecast. Factors are extracted from a broad dataset comprising country data of the 11 member countries,[13] but also from a breakdown of the aforementioned dataset between price variables and non-price variables. Variables employed to measure inflation are HICP, the consumption deflator and the GDP deflator, for which simulated out-of-sample forecasts are run, using the extracted factors and a set of alternative indicators.

The first task reported in the paper is an in-sample analysis of the basic properties of the factors, and their links with the series included in the dataset which they summarise, which is an extension of evidence presented in our companion paper. One outstanding feature discovered is the (apparently) fundamental simplicity of nominal phenomena: price variables are mainly driven by a single factor mostly unrelated to other factors, while non-price developments show much more complex patterns. This feature is apparent through the double coincidence of two facts, namely a very strong first factor

[13] The analysis is readily extendable to the current 12 countries.

for the price-only dataset almost coincident with the first factor of the all-encompassing dataset, and lack of strong factors for the rest of the variables. Factors in this case are termed strong in terms of both their in-sample significance in the principal-component problem and their links to specific variables. This would point to a predominantly simple nominal behaviour in the dataset, compared to a much more complex behaviour for the rest of the variables. Furthermore, factors seem to be more strongly related to variables as a whole, ie the same type of series irrespective of the country, and have therefore relatively minor country-specific content.

On the other hand, the out-of-sample forecasting evidence found is fairly complex to describe. On top of that, the self-evident conclusion drawn from the in-sample analysis that nominal factors are the most relevant for inflation is now partially reversed. The main conclusion is that factors - but not only those reflecting nominal developments - may be good leading indicators of the various measures of inflation considered, particularly at medium-term horizons (four or eight quarters ahead). More precisely, HICP inflation is best forecast using many nominal factors (but not just the first one), while the GDP deflator inflation is best predicted using non-nominal factors. The consumption deflator is the more difficult to forecast, but shows a pattern similar in general terms to that of HICP. Alternative indicators broadly appear to have slightly worse forecasting properties, although the unemployment rate shows promising results while M3 also leads inflation in many of the cases analysed. Last but not least, experiments carried out changing the date at which the simulated out-of-sample forecasts start show that results are becoming worse for a specific date, 1992 Q1. This could be interpreted as a signal of an important structural break around this date, although evidence presented is certainly not sufficient to allow firm conclusions to be drawn on the issue.

Although the exercises performed in the context of this paper have been kept deliberately simple, they are promising enough to warrant further research, with a view to assessing in greater depth the specific contribution and relevance of the factor method. In terms of the in-sample analysis, for instance, performing rotations of factors in order to clarify their relationship with the original variables might further clarify the role of nominal phenomena. Regarding the out-of-sample analysis, two immediate developments of this work might be, first, to exploit the leading-indicator information of the factors as if in real life, ie checking the importance of updates and successive releases of data, and, second, to seek new ways of implementing the factor-based forecast. An example of the latter might be to extract factors from datasets also including the aggregated area-wide data, thereby drawing forecasts from the extrapolated series for the euro area resulting from the principal-component analysis using jointly all of the country and area-wide information.

Table 1

HICP

Model with 2 lags

Model	Periods Ahead 1	2	3	4	8	Date Range Covered: Start	End	Break
Benchmark								
AR	1.00	1.00	1.00	1.00	1.00	1980Q1	1999Q2	1995Q1
Unemployment	0.82	0.78	0.94	0.87	0.58	1980Q1	1999Q2	1995Q1
GDP	1.00	1.00	0.98	0.92	0.79	1980Q1	1999Q2	1995Q1
Output Gap	0.92	0.90	0.76	0.69	0.83	1980Q1	1999Q2	1995Q1
M3	0.69	0.65	1.02	0.90	0.87	1982Q3	1999Q2	1995Q1
Overall Factors, Balanced Panel								
F1B	0.88	0.89	1.09	1.05	0.92	1980Q1	1999Q2	1995Q1
F1B to F2B	0.89	0.86	1.06	1.06	0.92	1980Q1	1999Q2	1995Q1
F1B to F3B	0.84	0.87	1.13	1.06	1.11	1980Q1	1999Q2	1995Q1
Overall Factors, Unbalanced Panel								
F1U	0.86	0.90	1.25	1.24	1.09	1980Q1	1999Q2	1995Q1
F1U to F2U	0.85	0.72	0.99	0.99	0.94	1980Q1	1999Q2	1995Q1
F1U to F3U	0.84	0.69	0.85	0.74	0.75	1980Q1	1999Q2	1995Q1
Nominal Factors, Balanced Panel								
F1B	0.95	0.90	1.00	0.99	0.93	1980Q1	1999Q2	1995Q1
F1B to F2B	0.85	0.71	0.90	0.79	0.49	1980Q1	1999Q2	1995Q1
F1B to F3B	0.85	0.66	0.96	0.83	0.46	1980Q1	1999Q2	1995Q1
Nominal Factors, Unbalanced Panel								
F1U	0.98	0.94	1.08	1.03	0.96	1980Q1	1999Q2	1995Q1
F1U to F2U	0.90	0.66	0.80	0.73	0.49	1980Q1	1999Q2	1995Q1
F1U to F3U	0.91	0.59	0.82	0.76	0.53	1980Q1	1999Q2	1995Q1
Non-Nominal Factors, Balanced Panel								
F1B	1.00	1.04	1.11	1.06	0.87	1980Q1	1999Q2	1995Q1
F1B to F2B	0.90	0.89	1.04	0.98	0.84	1980Q1	1999Q2	1995Q1
F1B to F3B	0.82	0.87	1.13	1.03	1.14	1980Q1	1999Q2	1995Q1
Non-Nominal Factors, Unbalanced Panel								
F1U	1.01	1.05	1.20	1.21	1.01	1980Q1	1999Q2	1995Q1
F1U to F2U	0.82	0.75	0.91	0.83	0.63	1980Q1	1999Q2	1995Q1
F1U to F3U	0.80	0.77	1.00	0.73	0.48	1980Q1	1999Q2	1995Q1

PCD

Model with 2 lags

Model	Periods Ahead 1	2	3	4	8	Date Range Covered: Start	End	Break
Benchmark								
AR	1.00	1.00	1.00	1.00	1.00	1980Q1	1999Q2	1995Q1
Unemployment	0.79	0.78	0.81	0.86	0.48	1980Q1	1999Q2	1995Q1
GDP	1.92	1.98	1.08	1.04	0.85	1980Q1	1999Q2	1995Q1
Output Gap	1.75	1.78	0.83	0.78	0.89	1980Q1	1999Q2	1995Q1
M3	1.02	1.07	1.30	1.27	1.07	1982Q3	1999Q2	1995Q1
Overall Factors, Balanced Panel								
F1B	1.03	1.05	1.00	0.97	0.75	1980Q1	1999Q2	1995Q1
F1B to F2B	1.19	1.24	1.21	1.18	0.79	1980Q1	1999Q2	1995Q1
F1B to F3B	1.24	1.33	1.35	1.24	1.01	1980Q1	1999Q2	1995Q1
Overall Factors, Unbalanced Panel								
F1U	0.98	1.05	1.10	1.11	0.98	1980Q1	1999Q2	1995Q1
F1U to F2U	1.05	1.15	1.20	1.19	0.89	1980Q1	1999Q2	1995Q1
F1U to F3U	0.94	1.07	0.96	0.88	0.75	1980Q1	1999Q2	1995Q1
Nominal Factors, Balanced Panel								
F1B	1.17	1.11	1.10	1.12	0.83	1980Q1	1999Q2	1995Q1
F1B to F2B	1.01	1.03	1.02	1.02	0.48	1980Q1	1999Q2	1995Q1
F1B to F3B	0.99	1.03	1.08	1.15	0.52	1980Q1	1999Q2	1995Q1
Nominal Factors, Unbalanced Panel								
F1U	1.17	1.13	1.16	1.18	0.89	1980Q1	1999Q2	1995Q1
F1U to F2U	1.05	1.05	1.03	1.05	0.56	1980Q1	1999Q2	1995Q1
F1U to F3U	1.09	1.07	1.10	1.15	0.70	1980Q1	1999Q2	1995Q1
Non-Nominal Factors, Balanced Panel								
F1B	1.03	1.06	1.06	1.04	0.83	1980Q1	1999Q2	1995Q1
F1B to F2B	1.04	1.08	1.10	1.03	0.86	1980Q1	1999Q2	1995Q1
F1B to F3B	1.03	1.13	1.32	1.17	1.21	1980Q1	1999Q2	1995Q1
Non-Nominal Factors, Unbalanced Panel								
F1U	1.01	1.06	1.11	1.14	0.94	1980Q1	1999Q2	1995Q1
F1U to F2U	0.90	0.81	0.74	0.79	0.79	1980Q1	1999Q2	1995Q1
F1U to F3U	0.85	0.71	0.73	0.57	0.57	1980Q1	1999Q2	1995Q1

YED

Model with 2 lags

Model	Periods Ahead 1	2	3	4	8	Date Range Covered: Start	End	Break
Benchmark								
AR	1.00	1.00	1.00	1.00	1.00	1980Q1	1999Q2	1995Q1
Unemployment	0.97	0.90	0.75	0.75	0.26	1980Q1	1999Q2	1995Q1
GDP	2.09	2.30	0.97	0.98	1.23	1980Q1	1999Q2	1995Q1
Output Gap	1.91	2.07	0.75	0.74	1.29	1980Q1	1999Q2	1995Q1
M3	1.13	1.29	1.31	1.30	1.23	1982Q3	1999Q2	1995Q1
Overall Factors, Balanced Panel								
F1B	1.08	1.15	1.25	1.23	1.13	1980Q1	1999Q2	1995Q1
F1B to F2B	1.12	1.23	1.37	1.27	0.90	1980Q1	1999Q2	1995Q1
F1B to F3B	1.33	1.43	1.66	1.55	0.72	1980Q1	1999Q2	1995Q1
Overall Factors, Unbalanced Panel								
F1U	1.06	1.15	1.23	1.27	1.21	1980Q1	1999Q2	1995Q1
F1U to F2U	1.04	1.17	1.32	1.26	1.08	1980Q1	1999Q2	1995Q1
F1U to F3U	1.00	1.10	1.23	1.15	0.69	1980Q1	1999Q2	1995Q1
Nominal Factors, Balanced Panel								
F1B	1.13	1.24	1.38	1.35	1.35	1980Q1	1999Q2	1995Q1
F1B to F2B	1.06	1.21	1.36	1.34	1.38	1980Q1	1999Q2	1995Q1
F1B to F3B	1.01	1.20	1.41	1.43	1.64	1980Q1	1999Q2	1995Q1
Nominal Factors, Unbalanced Panel								
F1U	1.10	1.25	1.39	1.37	1.38	1980Q1	1999Q2	1995Q1
F1U to F2U	1.03	1.22	1.43	1.38	1.38	1980Q1	1999Q2	1995Q1
F1U to F3U	1.02	1.29	1.56	1.50	1.62	1980Q1	1999Q2	1995Q1
Non-Nominal Factors, Balanced Panel								
F1B	1.01	1.01	0.98	0.96	0.73	1980Q1	1999Q2	1995Q1
F1B to F2B	0.97	0.99	1.05	0.95	0.78	1980Q1	1999Q2	1995Q1
F1B to F3B	1.20	1.31	1.43	1.37	0.85	1980Q1	1999Q2	1995Q1
Non-Nominal Factors, Unbalanced Panel								
F1U	1.00	0.99	0.97	0.98	0.97	1980Q1	1999Q2	1995Q1
F1U to F2U	0.95	0.85	0.85	0.68	0.76	1980Q1	1999Q2	1995Q1
F1U to F3U	0.95	0.84	0.89	0.72	0.66	1980Q1	1999Q2	1995Q1

Table 2

HICP

Model with 2 lags

Model	Periods Ahead					Date Range Covered		
	1	2	3	4	8	Start	End	Break
Benchmark								
AR	1.00	1.00	1.00	1.00	1.00	1980Q1	1999Q2	1992Q1
Unemployment	0.94	0.99	1.31	1.30	1.06	1980Q1	1999Q2	1992Q1
GDP	1.01	1.02	1.06	0.98	0.92	1980Q1	1999Q2	1992Q1
Output Gap	0.94	0.98	1.40	1.71	2.69	1980Q1	1999Q2	1992Q1
M3	0.67	0.67	0.82	0.75	0.78	1982Q3	1999Q2	1992Q1
Overall Factors, Balanced Panel								
F1B	0.99	0.99	0.96	0.94	0.79	1980Q1	1999Q2	1992Q1
F1B to F2B	0.89	0.81	1.01	1.16	2.01	1980Q1	1999Q2	1992Q1
F1B to F3B	0.81	0.80	1.03	1.36	2.79	1980Q1	1999Q2	1992Q1
Overall Factors, Unbalanced Panel								
F1U	0.95	0.97	1.04	1.07	0.93	1980Q1	1999Q2	1992Q1
F1U to F2U	0.83	0.66	0.93	1.10	1.83	1980Q1	1999Q2	1992Q1
F1U to F3U	0.86	0.70	0.79	1.00	1.93	1980Q1	1999Q2	1992Q1
Nominal Factors, Balanced Panel								
F1B	0.88	0.83	0.86	0.88	0.90	1980Q1	1999Q2	1992Q1
F1B to F2B	0.79	0.66	0.79	0.74	0.89	1980Q1	1999Q2	1992Q1
F1B to F3B	0.80	0.65	0.86	0.78	0.89	1980Q1	1999Q2	1992Q1
Nominal Factors, Unbalanced Panel								
F1U	0.91	0.86	0.90	0.89	0.93	1980Q1	1999Q2	1992Q1
F1U to F2U	0.82	0.58	0.66	0.69	0.74	1980Q1	1999Q2	1992Q1
F1U to F3U	0.83	0.55	0.70	0.71	0.79	1980Q1	1999Q2	1992Q1
Non-Nominal Factors, Balanced Panel								
F1B	1.01	1.01	1.31	1.36	2.00	1980Q1	1999Q2	1992Q1
F1B to F2B	0.98	0.99	1.34	1.30	2.05	1980Q1	1999Q2	1992Q1
F1B to F3B	0.87	0.95	1.36	1.42	2.57	1980Q1	1999Q2	1992Q1
Non-Nominal Factors, Unbalanced Panel								
F1U	1.01	1.00	1.27	1.32	1.76	1980Q1	1999Q2	1992Q1
F1U to F2U	0.95	1.01	1.51	1.53	2.71	1980Q1	1999Q2	1992Q1
F1U to F3U	0.91	0.95	1.37	1.35	2.71	1980Q1	1999Q2	1992Q1

PCD

Model with 2 lags

Model	Periods Ahead					Date Range Covered		
	1	2	3	4	8	Start	End	Break
Benchmark								
AR	1.00	1.00	1.00	1.00	1.00	1980Q1	1999Q2	1992Q1
Unemployment	0.96	1.01	1.17	1.34	0.98	1980Q1	1999Q2	1992Q1
GDP	1.68	1.82	1.27	1.18	1.00	1980Q1	1999Q2	1992Q1
Output Gap	1.56	1.75	1.67	2.06	2.91	1980Q1	1999Q2	1992Q1
M3	0.97	0.99	1.09	1.04	0.96	1982Q3	1999Q2	1992Q1
Overall Factors, Balanced Panel								
F1B	1.08	1.06	0.96	0.97	0.74	1980Q1	1999Q2	1992Q1
F1B to F2B	1.06	1.05	1.12	1.53	1.85	1980Q1	1999Q2	1992Q1
F1B to F3B	0.96	1.08	1.26	1.74	2.52	1980Q1	1999Q2	1992Q1
Overall Factors, Unbalanced Panel								
F1U	1.03	1.05	1.00	0.98	0.87	1980Q1	1999Q2	1992Q1
F1U to F2U	0.95	0.98	1.12	1.46	1.53	1980Q1	1999Q2	1992Q1
F1U to F3U	0.94	0.94	0.91	1.25	1.57	1980Q1	1999Q2	1992Q1
Nominal Factors, Balanced Panel								
F1B	1.03	1.04	1.05	1.05	0.96	1980Q1	1999Q2	1992Q1
F1B to F2B	0.93	0.99	1.00	0.96	0.86	1980Q1	1999Q2	1992Q1
F1B to F3B	0.93	1.00	1.05	1.05	0.90	1980Q1	1999Q2	1992Q1
Nominal Factors, Unbalanced Panel								
F1U	1.02	1.04	1.07	1.07	1.00	1980Q1	1999Q2	1992Q1
F1U to F2U	0.90	0.92	0.95	1.03	0.98	1980Q1	1999Q2	1992Q1
F1U to F3U	0.96	0.95	0.96	1.02	1.03	1980Q1	1999Q2	1992Q1
Non-Nominal Factors, Balanced Panel								
F1B	1.05	1.01	1.14	1.59	1.71	1980Q1	1999Q2	1992Q1
F1B to F2B	0.96	1.00	1.18	1.56	1.72	1980Q1	1999Q2	1992Q1
F1B to F3B	0.86	0.98	1.26	1.67	2.19	1980Q1	1999Q2	1992Q1
Non-Nominal Factors, Unbalanced Panel								
F1U	1.05	0.99	1.19	1.55	1.53	1980Q1	1999Q2	1992Q1
F1U to F2U	0.97	1.04	1.26	1.71	2.11	1980Q1	1999Q2	1992Q1
F1U to F3U	0.93	0.92	1.12	1.46	1.95	1980Q1	1999Q2	1992Q1

YED

Model with 2 lags

Model	Periods Ahead					Date Range Covered		
	1	2	3	4	8	Start	End	Break
Benchmark								
AR	1.00	1.00	1.00	1.00	1.00	1980Q1	1999Q2	1992Q1
Unemployment	1.11	1.19	1.28	1.22	1.22	1980Q1	1999Q2	1992Q1
GDP	1.95	2.04	1.19	1.03	1.23	1980Q1	1999Q2	1992Q1
Output Gap	1.82	1.96	1.56	1.80	3.58	1980Q1	1999Q2	1992Q1
M3	1.10	1.14	1.19	1.14	1.11	1982Q3	1999Q2	1992Q1
Overall Factors, Balanced Panel								
F1B	1.34	1.49	1.84	1.64	1.34	1980Q1	1999Q2	1992Q1
F1B to F2B	1.19	1.22	1.40	1.08	2.10	1980Q1	1999Q2	1992Q1
F1B to F3B	1.17	1.23	1.42	1.18	2.05	1980Q1	1999Q2	1992Q1
Overall Factors, Unbalanced Panel								
F1U	1.27	1.44	1.78	1.66	1.40	1980Q1	1999Q2	1992Q1
F1U to F2U	1.12	1.14	1.30	1.03	1.95	1980Q1	1999Q2	1992Q1
F1U to F3U	1.16	1.17	1.27	1.03	1.71	1980Q1	1999Q2	1992Q1
Nominal Factors, Balanced Panel								
F1B	1.11	1.19	1.36	1.31	1.30	1980Q1	1999Q2	1992Q1
F1B to F2B	1.03	1.21	1.33	1.37	1.45	1980Q1	1999Q2	1992Q1
F1B to F3B	1.09	1.24	1.37	1.36	1.32	1980Q1	1999Q2	1992Q1
Nominal Factors, Unbalanced Panel								
F1U	1.11	1.19	1.36	1.31	1.32	1980Q1	1999Q2	1992Q1
F1U to F2U	1.02	1.17	1.34	1.30	1.30	1980Q1	1999Q2	1992Q1
F1U to F3U	1.05	1.24	1.43	1.41	1.52	1980Q1	1999Q2	1992Q1
Non-Nominal Factors, Balanced Panel								
F1B	1.08	0.99	0.89	1.04	2.52	1980Q1	1999Q2	1992Q1
F1B to F2B	1.20	1.21	1.31	1.12	2.08	1980Q1	1999Q2	1992Q1
F1B to F3B	1.19	1.20	1.36	1.29	2.13	1980Q1	1999Q2	1992Q1
Non-Nominal Factors, Unbalanced Panel								
F1U	1.09	1.01	0.93	1.02	2.29	1980Q1	1999Q2	1992Q1
F1U to F2U	0.98	0.88	0.86	0.95	2.34	1980Q1	1999Q2	1992Q1
F1U to F3U	0.98	0.83	0.80	0.86	1.99	1980Q1	1999Q2	1992Q1

Table 3

HICP

Model with 2 lags

Model	Periods Ahead 1	2	3	4	8	Date Range Covered Start	End	Break
Benchmark								
AR	1.00	1.00	1.00	1.00	1.00	1980Q1	1999Q2	1985Q1
Unemployment	0.98	1.14	1.13	1.01	0.55	1980Q1	1999Q2	1985Q1
GDP	1.04	1.02	1.03	1.01	0.98	1980Q1	1999Q2	1985Q1
Output Gap	1.13	1.37	1.52	1.52	1.04	1980Q1	1999Q2	1985Q1
M3	0.77	0.80	0.94	0.89	0.82	1982Q3	1999Q2	1985Q1
Overall Factors, Balanced Panel								
F1B	0.94	0.95	0.92	0.98	0.91	1980Q1	1999Q2	1985Q1
F1B to F2B	0.82	0.73	0.90	1.10	1.28	1980Q1	1999Q2	1985Q1
F1B to F3B	0.79	0.73	0.91	1.16	1.29	1980Q1	1999Q2	1985Q1
Overall Factors, Unbalanced Panel								
F1U	0.92	0.96	0.94	0.99	0.92	1980Q1	1999Q2	1985Q1
F1U to F2U	0.79	0.68	0.85	1.02	1.28	1980Q1	1999Q2	1985Q1
F1U to F3U	0.82	0.68	0.78	1.01	1.15	1980Q1	1999Q2	1985Q1
Nominal Factors, Balanced Panel								
F1B	0.88	0.88	0.94	1.00	1.18	1980Q1	1999Q2	1985Q1
F1B to F2B	0.78	0.70	0.94	0.95	0.86	1980Q1	1999Q2	1985Q1
F1B to F3B	0.79	0.69	0.95	0.92	0.88	1980Q1	1999Q2	1985Q1
Nominal Factors, Unbalanced Panel								
F1U	0.90	0.92	0.97	1.02	1.02	1980Q1	1999Q2	1985Q1
F1U to F2U	0.78	0.65	0.76	0.72	0.66	1980Q1	1999Q2	1985Q1
F1U to F3U	0.78	0.58	0.69	0.69	0.71	1980Q1	1999Q2	1985Q1
Non-Nominal Factors, Balanced Panel								
F1B	1.02	1.06	1.12	1.23	1.28	1980Q1	1999Q2	1985Q1
F1B to F2B	0.94	0.97	1.07	1.18	1.33	1980Q1	1999Q2	1985Q1
F1B to F3B	0.91	1.03	1.13	1.27	1.41	1980Q1	1999Q2	1985Q1
Non-Nominal Factors, Unbalanced Panel								
F1U	1.02	1.06	1.14	1.24	1.29	1980Q1	1999Q2	1985Q1
F1U to F2U	0.93	1.02	1.14	1.23	1.35	1980Q1	1999Q2	1985Q1
F1U to F3U	0.93	1.00	1.09	1.21	1.38	1980Q1	1999Q2	1985Q1

PCD

Model with 2 lags

Model	Periods Ahead 1	2	3	4	8	Date Range Covered Start	End	Break
Benchmark								
AR	1.00	1.00	1.00	1.00	1.00	1980Q1	1999Q2	1985Q1
Unemployment	1.04	1.04	1.06	0.98	0.54	1980Q1	1999Q2	1985Q1
GDP	1.56	1.44	1.10	1.05	1.04	1980Q1	1999Q2	1985Q1
Output Gap	1.69	1.93	1.62	1.58	1.11	1980Q1	1999Q2	1985Q1
M3	1.01	1.00	0.97	0.96	0.72	1982Q3	1999Q2	1985Q1
Overall Factors, Balanced Panel								
F1B	1.05	1.01	0.97	1.10	1.19	1980Q1	1999Q2	1985Q1
F1B to F2B	1.02	1.02	1.02	1.24	1.62	1980Q1	1999Q2	1985Q1
F1B to F3B	1.04	1.07	1.04	1.33	1.54	1980Q1	1999Q2	1985Q1
Overall Factors, Unbalanced Panel								
F1U	1.04	1.00	1.00	1.12	1.14	1980Q1	1999Q2	1985Q1
F1U to F2U	0.99	1.00	1.05	1.22	1.65	1980Q1	1999Q2	1985Q1
F1U to F3U	1.05	0.98	0.94	1.16	1.41	1980Q1	1999Q2	1985Q1
Nominal Factors, Balanced Panel								
F1B	1.05	1.03	0.98	1.04	1.16	1980Q1	1999Q2	1985Q1
F1B to F2B	0.94	0.99	0.96	1.04	0.99	1980Q1	1999Q2	1985Q1
F1B to F3B	0.94	0.96	1.02	1.08	0.81	1980Q1	1999Q2	1985Q1
Nominal Factors, Unbalanced Panel								
F1U	1.06	1.04	1.02	1.10	1.08	1980Q1	1999Q2	1985Q1
F1U to F2U	0.91	0.90	0.89	0.86	0.82	1980Q1	1999Q2	1985Q1
F1U to F3U	0.92	0.90	0.90	0.84	0.80	1980Q1	1999Q2	1985Q1
Non-Nominal Factors, Balanced Panel								
F1B	1.05	1.02	1.04	1.26	1.66	1980Q1	1999Q2	1985Q1
F1B to F2B	0.98	1.00	1.04	1.28	1.79	1980Q1	1999Q2	1985Q1
F1B to F3B	1.01	1.05	1.11	1.40	1.75	1980Q1	1999Q2	1985Q1
Non-Nominal Factors, Unbalanced Panel								
F1U	1.06	1.02	1.07	1.27	1.71	1980Q1	1999Q2	1985Q1
F1U to F2U	1.03	1.00	1.13	1.29	1.79	1980Q1	1999Q2	1985Q1
F1U to F3U	1.05	1.00	1.06	1.28	1.68	1980Q1	1999Q2	1985Q1

YED

Model with 2 lags

Model	Periods Ahead 1	2	3	4	8	Date Range Covered Start	End	Break
Benchmark								
AR	1.00	1.00	1.00	1.00	1.00	1980Q1	1999Q2	1985Q1
Unemployment	1.03	1.16	1.24	1.03	0.54	1980Q1	1999Q2	1985Q1
GDP	1.55	1.64	1.23	1.11	1.38	1980Q1	1999Q2	1985Q1
Output Gap	1.68	2.21	1.80	1.66	1.47	1980Q1	1999Q2	1985Q1
M3	1.09	1.07	1.04	0.97	2.70	1982Q3	1999Q2	1985Q1
Overall Factors, Balanced Panel								
F1B	0.99	1.02	1.13	1.05	0.74	1980Q1	1999Q2	1985Q1
F1B to F2B	1.01	1.06	1.04	0.89	1.16	1980Q1	1999Q2	1985Q1
F1B to F3B	1.05	1.13	1.09	0.94	1.06	1980Q1	1999Q2	1985Q1
Overall Factors, Unbalanced Panel								
F1U	0.97	1.00	1.12	1.02	0.75	1980Q1	1999Q2	1985Q1
F1U to F2U	0.98	1.03	1.05	0.84	0.99	1980Q1	1999Q2	1985Q1
F1U to F3U	1.07	1.11	1.08	0.89	0.89	1980Q1	1999Q2	1985Q1
Nominal Factors, Balanced Panel								
F1B	1.00	1.01	1.01	1.02	0.67	1980Q1	1999Q2	1985Q1
F1B to F2B	0.98	1.04	1.01	1.09	0.79	1980Q1	1999Q2	1985Q1
F1B to F3B	1.00	1.07	1.08	1.12	0.74	1980Q1	1999Q2	1985Q1
Nominal Factors, Unbalanced Panel								
F1U	0.98	1.02	1.06	1.03	0.63	1980Q1	1999Q2	1985Q1
F1U to F2U	0.96	1.04	0.99	1.03	0.69	1980Q1	1999Q2	1985Q1
F1U to F3U	1.00	1.11	1.13	1.16	0.65	1980Q1	1999Q2	1985Q1
Non-Nominal Factors, Balanced Panel								
F1B	1.03	1.03	1.04	0.97	1.11	1980Q1	1999Q2	1985Q1
F1B to F2B	1.00	1.04	1.04	0.88	1.06	1980Q1	1999Q2	1985Q1
F1B to F3B	1.01	1.05	1.06	0.92	0.89	1980Q1	1999Q2	1985Q1
Non-Nominal Factors, Unbalanced Panel								
F1U	1.03	1.05	1.07	1.00	0.98	1980Q1	1999Q2	1985Q1
F1U to F2U	0.91	0.91	0.94	0.81	0.96	1980Q1	1999Q2	1985Q1
F1U to F3U	0.93	0.90	0.88	0.82	0.78	1980Q1	1999Q2	1985Q1

Appendix A: Loadings

Table 1
Balanced panel

Variable	Loadings					Loadings Squared				
	F1	F2	F3	F4	F5	F1	F2	F3	F4	F5
CPIAT	0.73	-0.11	0.22	-0.09	-0.18	0.53	0.01	0.05	0.01	0.03
CPIBE	0.84	-0.03	-0.08	0.05	0.09	0.70	0.00	0.01	0.00	0.01
CPIDE	0.69	-0.06	0.44	-0.15	0.02	0.47	0.00	0.19	0.02	0.00
CPIES	0.82	-0.15	-0.25	0.20	-0.19	0.67	0.02	0.06	0.04	0.04
CPIFI	0.78	-0.31	-0.05	0.32	0.04	0.61	0.09	0.00	0.10	0.00
CPIFR	0.92	-0.20	-0.17	0.15	0.01	0.84	0.04	0.03	0.02	0.00
CPIIE	0.83	-0.20	-0.03	0.20	0.15	0.68	0.04	0.00	0.04	0.02
CPIIT	0.90	-0.20	-0.13	0.15	0.03	0.80	0.04	0.02	0.02	0.00
CPINL	0.75	-0.13	0.16	-0.12	-0.07	0.56	0.02	0.03	0.01	0.01
CPIPT	0.70	-0.12	-0.31	0.15	-0.23	0.48	0.01	0.10	0.02	0.06
MTDAT	0.45	-0.34	0.23	-0.29	0.12	0.20	0.12	0.05	0.08	0.01
MTDDE	0.54	-0.44	0.20	-0.40	0.19	0.29	0.19	0.04	0.16	0.04
MTDES	0.75	-0.15	0.11	-0.18	0.29	0.56	0.02	0.01	0.03	0.09
MTDFI	0.54	-0.18	0.24	-0.19	0.04	0.29	0.03	0.06	0.04	0.00
MTDFR	0.64	-0.39	-0.01	-0.29	0.24	0.41	0.15	0.00	0.09	0.06
MTDIT	0.64	-0.21	0.24	-0.36	0.25	0.41	0.05	0.06	0.13	0.06
PCDAT	0.74	-0.05	0.12	-0.10	-0.18	0.55	0.00	0.02	0.01	0.03
PCDDE	0.66	-0.11	0.42	-0.09	0.12	0.43	0.01	0.18	0.01	0.01
PCDES	0.80	-0.09	-0.22	0.27	-0.18	0.63	0.01	0.05	0.07	0.03
PCDFR	0.91	-0.18	-0.20	0.14	0.00	0.82	0.03	0.04	0.02	0.00
PCDIT	0.92	-0.18	-0.14	0.15	0.03	0.84	0.03	0.02	0.02	0.00
PCDFI	0.79	-0.16	0.01	0.26	-0.05	0.62	0.03	0.00	0.07	0.00
PPIAT	0.58	-0.40	0.18	-0.19	0.04	0.34	0.16	0.03	0.04	0.00
PPIDE	0.68	-0.51	0.15	-0.25	0.11	0.46	0.26	0.02	0.06	0.01
PPIES	0.85	-0.20	-0.24	-0.08	-0.01	0.72	0.04	0.06	0.01	0.00
PPIFI	0.76	-0.36	0.11	-0.16	0.17	0.58	0.13	0.01	0.03	0.03
PPIFR	0.72	-0.34	-0.32	-0.08	0.12	0.52	0.12	0.10	0.01	0.01
PPINL	0.64	-0.43	0.14	-0.34	0.05	0.40	0.18	0.02	0.12	0.00
XTDAT	0.62	-0.40	0.03	-0.32	0.01	0.39	0.16	0.00	0.10	0.00
XTDDE	0.71	-0.43	0.07	-0.26	0.12	0.51	0.18	0.00	0.07	0.01
XTDES	0.88	-0.05	-0.13	-0.05	0.15	0.78	0.00	0.02	0.00	0.02
XTDFI	0.54	-0.19	0.04	-0.19	-0.06	0.29	0.04	0.00	0.04	0.00
XTDFR	0.77	-0.24	-0.24	-0.16	0.23	0.59	0.06	0.06	0.03	0.06
XTDIT	0.73	-0.23	0.11	-0.12	0.16	0.54	0.05	0.01	0.01	0.02
YEDAT	0.55	0.03	-0.04	0.16	-0.33	0.30	0.00	0.00	0.02	0.11
YEDDE	0.44	0.02	0.23	0.31	-0.25	0.20	0.00	0.05	0.09	0.06
YEDES	0.71	-0.12	-0.32	0.29	-0.29	0.51	0.01	0.10	0.08	0.09
YEDFI	0.57	-0.19	-0.15	0.27	0.14	0.33	0.04	0.02	0.07	0.02
YEDFR	0.83	-0.07	-0.27	0.25	-0.03	0.70	0.01	0.07	0.06	0.00
YEDIT	0.88	-0.23	-0.16	0.21	-0.01	0.77	0.05	0.03	0.04	0.00
CAPDE	-0.50	-0.50	0.43	0.32	-0.24	0.25	0.25	0.18	0.10	0.06
CAPES	0.06	-0.62	-0.40	0.42	0.17	0.00	0.38	0.16	0.18	0.03
CAPFR	-0.28	-0.46	0.32	0.39	-0.25	0.08	0.21	0.10	0.15	0.06
CAPIT	-0.62	-0.45	0.39	0.11	0.01	0.38	0.20	0.15	0.01	0.00
CAPNL	-0.79	-0.35	0.33	0.06	-0.09	0.62	0.12	0.11	0.00	0.01
CAPPT	-0.39	-0.54	0.15	0.22	0.17	0.15	0.29	0.02	0.05	0.03
ERNAT	0.37	-0.08	0.21	0.31	-0.15	0.14	0.01	0.04	0.10	0.02
ERNDE	0.23	-0.07	0.25	0.17	-0.08	0.05	0.01	0.06	0.03	0.01
ERNES	0.54	-0.07	0.00	0.16	-0.04	0.29	0.00	0.00	0.03	0.00
ERNFI	0.31	-0.28	-0.12	0.12	0.06	0.10	0.08	0.01	0.02	0.00
ERNFR	0.85	-0.12	-0.22	0.27	-0.02	0.72	0.01	0.05	0.07	0.00
ERNIT	0.82	-0.13	-0.17	0.21	-0.03	0.68	0.02	0.03	0.04	0.00
ERNNL	0.34	0.04	0.00	0.08	-0.04	0.12	0.00	0.00	0.01	0.00

Table 1 (cont)

Balanced panel

Variable	Loadings					Loadings Squared				
	F1	F2	F3	F4	F5	F1	F2	F3	F4	F5
GDPAT	-0.09	-0.36	-0.22	-0.26	-0.27	0.01	0.13	0.05	0.07	0.07
GDPDE	-0.12	-0.30	-0.39	-0.20	-0.52	0.01	0.09	0.15	0.04	0.27
GDPES	-0.55	-0.36	-0.27	0.05	0.28	0.31	0.13	0.07	0.00	0.08
GDPFI	-0.02	-0.21	-0.44	-0.17	0.28	0.00	0.04	0.19	0.03	0.08
GDPFR	-0.17	-0.46	-0.49	-0.13	-0.12	0.03	0.22	0.24	0.02	0.01
GDPIT	0.03	-0.42	-0.33	-0.11	-0.17	0.00	0.18	0.11	0.01	0.03
GDPNL	-0.29	-0.19	-0.14	-0.14	-0.18	0.09	0.03	0.02	0.02	0.03
HSTBE	-0.22	-0.16	-0.12	-0.37	-0.10	0.05	0.03	0.01	0.14	0.01
HSTES	-0.14	0.02	-0.12	-0.11	0.11	0.02	0.00	0.02	0.01	0.01
HSTFI	-0.08	-0.38	-0.19	0.18	0.35	0.01	0.15	0.03	0.03	0.12
HSTFR	-0.20	0.02	-0.24	-0.17	0.06	0.04	0.00	0.06	0.03	0.00
HSTNL	0.04	-0.07	-0.11	-0.15	-0.07	0.00	0.00	0.01	0.02	0.00
LFNES	-0.27	0.04	-0.12	-0.12	0.16	0.07	0.00	0.01	0.01	0.02
LFNFI	0.12	-0.15	-0.11	-0.01	0.30	0.01	0.02	0.01	0.00	0.09
LFNFR	-0.07	-0.12	0.26	-0.08	-0.33	0.00	0.01	0.07	0.01	0.11
LFNIT	0.02	-0.22	-0.20	0.26	0.07	0.00	0.05	0.04	0.07	0.00
LFNNL	0.24	-0.22	0.24	0.16	0.26	0.06	0.05	0.06	0.02	0.07
LNNAT	-0.02	-0.09	0.09	-0.10	-0.29	0.00	0.01	0.01	0.01	0.08
LNNBE	-0.58	-0.43	-0.22	0.10	0.11	0.34	0.18	0.05	0.01	0.01
LNNDE	-0.10	-0.61	-0.07	0.36	-0.25	0.01	0.37	0.00	0.13	0.06
LNNES	-0.73	-0.30	-0.23	0.13	0.27	0.54	0.09	0.05	0.02	0.07
LNNFI	0.03	-0.51	-0.43	-0.11	0.47	0.00	0.26	0.18	0.01	0.22
LNNFR	-0.56	-0.49	-0.03	0.15	0.14	0.31	0.24	0.00	0.02	0.02
LNNIE	-0.50	-0.18	0.01	-0.01	0.13	0.25	0.03	0.00	0.00	0.02
LNNIT	-0.03	-0.31	-0.14	0.39	0.08	0.00	0.10	0.02	0.15	0.01
LNNPT	-0.24	-0.49	0.08	0.16	-0.10	0.06	0.24	0.01	0.03	0.01
LTIAT	0.16	-0.59	0.35	-0.07	-0.12	0.03	0.34	0.12	0.00	0.01
LTIBE	0.36	-0.59	0.29	-0.21	-0.02	0.13	0.34	0.08	0.04	0.00
LTIDE	0.22	-0.61	0.20	-0.15	-0.12	0.05	0.37	0.04	0.02	0.01
LTIFI	0.21	-0.50	0.10	0.04	0.06	0.05	0.25	0.01	0.00	0.00
LTIFR	0.29	-0.54	0.32	-0.17	0.04	0.09	0.29	0.11	0.03	0.00
LTIIE	0.25	-0.39	0.24	-0.20	-0.22	0.06	0.15	0.06	0.04	0.05
LTIIT	0.26	-0.47	0.32	-0.03	0.10	0.07	0.22	0.10	0.00	0.01
LTINL	0.14	-0.67	0.26	-0.20	-0.14	0.02	0.44	0.07	0.04	0.02
MFBBE	-0.61	-0.59	0.17	0.09	0.14	0.37	0.34	0.03	0.01	0.02
MFBDE	-0.38	-0.67	0.21	0.39	-0.20	0.14	0.44	0.04	0.15	0.04
MFBFR	-0.48	-0.72	-0.05	0.21	0.26	0.23	0.51	0.00	0.04	0.07
MFBIE	-0.61	-0.42	0.06	-0.16	-0.03	0.38	0.18	0.00	0.03	0.00
MFBIT	-0.59	-0.66	0.19	-0.04	0.11	0.34	0.44	0.04	0.00	0.01
MFBNL	-0.76	-0.44	0.22	-0.03	-0.02	0.58	0.20	0.05	0.00	0.00
MFSBE	0.29	0.37	-0.12	0.01	-0.18	0.08	0.14	0.01	0.00	0.03
MFSDE	0.40	0.66	-0.20	-0.26	0.25	0.16	0.44	0.04	0.07	0.06
MFSFR	0.47	0.55	0.07	-0.09	-0.31	0.22	0.31	0.00	0.01	0.10
MFSIE	0.27	0.50	0.10	0.00	0.09	0.07	0.25	0.01	0.00	0.01
MFSIT	0.46	0.56	-0.23	0.18	-0.25	0.21	0.31	0.05	0.03	0.06
MFSNL	0.77	0.29	-0.19	0.12	0.08	0.59	0.09	0.04	0.01	0.01

Table 1 (cont)

Balanced panel

Variable	Loadings					Loadings Squared				
	F1	F2	F3	F4	F5	F1	F2	F3	F4	F5
MTRAT	-0.10	-0.19	-0.16	-0.18	-0.19	0.01	0.04	0.03	0.03	0.04
MTRDE	-0.22	-0.38	-0.31	-0.20	-0.29	0.05	0.14	0.10	0.04	0.08
MTRES	-0.58	-0.36	-0.27	-0.01	0.04	0.33	0.13	0.07	0.00	0.00
MTRFI	-0.05	-0.12	-0.02	-0.18	0.24	0.00	0.01	0.00	0.03	0.06
MTRFR	-0.19	-0.45	-0.23	-0.20	-0.02	0.04	0.20	0.05	0.04	0.00
MTRIT	-0.12	-0.41	-0.27	-0.27	-0.32	0.01	0.17	0.07	0.07	0.10
MTRNL	-0.30	-0.22	-0.44	-0.35	-0.12	0.09	0.05	0.19	0.12	0.01
PCEAT	-0.01	-0.11	-0.15	-0.06	-0.21	0.00	0.01	0.02	0.00	0.04
PCEDE	-0.20	-0.15	-0.35	0.00	-0.51	0.04	0.02	0.13	0.00	0.26
PCEES	-0.65	-0.44	-0.15	0.19	0.09	0.42	0.19	0.02	0.04	0.01
PCEFI	-0.06	-0.15	-0.49	-0.12	0.38	0.00	0.02	0.24	0.01	0.14
PCEFR	-0.10	-0.23	-0.37	0.04	-0.23	0.01	0.05	0.14	0.00	0.05
PCEIT	0.01	-0.64	-0.26	0.08	-0.14	0.00	0.41	0.07	0.01	0.02
PCENL	-0.36	-0.05	-0.21	0.02	-0.27	0.13	0.00	0.04	0.00	0.07
PIHBE	-0.10	-0.01	-0.02	0.01	0.00	0.01	0.00	0.00	0.00	0.00
PIHFI	-0.01	-0.03	-0.04	-0.05	0.13	0.00	0.00	0.00	0.00	0.02
PIHFR	-0.09	-0.02	-0.14	-0.10	-0.09	0.01	0.00	0.02	0.01	0.01
PIHNL	-0.06	-0.07	-0.14	-0.21	-0.13	0.00	0.01	0.02	0.05	0.02
RSLAT	-0.02	-0.14	-0.13	-0.05	-0.14	0.00	0.02	0.02	0.00	0.02
RSLBE	-0.20	-0.23	-0.17	0.09	-0.10	0.04	0.05	0.03	0.01	0.01
RSLDE	-0.14	-0.19	-0.31	0.04	-0.39	0.02	0.03	0.10	0.00	0.15
RSLFR	-0.08	-0.12	-0.11	-0.01	-0.07	0.01	0.01	0.01	0.00	0.00
RSLIE	-0.26	-0.10	-0.06	-0.30	-0.09	0.07	0.01	0.00	0.09	0.01
RSLNL	-0.34	-0.04	-0.05	-0.02	0.02	0.12	0.00	0.00	0.00	0.00
STIAT	0.05	-0.69	0.35	0.05	-0.04	0.00	0.48	0.12	0.00	0.00
STIBE	0.22	-0.58	0.17	-0.03	-0.16	0.05	0.34	0.03	0.00	0.02
STIDE	0.12	-0.64	0.22	-0.13	-0.16	0.01	0.41	0.05	0.02	0.03
STIES	0.05	-0.09	-0.11	0.07	-0.08	0.00	0.01	0.01	0.00	0.01
STIFI	0.10	-0.51	0.12	0.22	0.12	0.01	0.26	0.01	0.05	0.01
STIFR	0.19	-0.45	0.23	-0.11	0.06	0.04	0.20	0.05	0.01	0.00
STIIE	0.11	-0.22	0.15	0.06	-0.05	0.01	0.05	0.02	0.00	0.00
STIIT	0.22	-0.45	0.21	-0.01	0.00	0.05	0.20	0.05	0.00	0.00
STINL	0.06	-0.43	-0.01	-0.13	-0.29	0.00	0.19	0.00	0.02	0.09
STIPT	0.33	-0.23	-0.14	0.14	-0.04	0.11	0.05	0.02	0.02	0.00
UNRAT	0.23	0.44	0.00	0.34	0.06	0.05	0.19	0.00	0.12	0.00
UNRBE	0.44	0.43	0.21	-0.09	-0.07	0.19	0.18	0.04	0.01	0.01
UNRDE	0.47	0.52	-0.04	-0.12	0.43	0.22	0.27	0.00	0.01	0.18
UNRES	0.74	0.37	0.21	-0.13	-0.27	0.55	0.13	0.05	0.02	0.07
UNRFR	0.48	0.40	0.14	-0.26	-0.32	0.23	0.16	0.02	0.07	0.11
UNRFI	0.09	0.52	0.41	0.11	-0.39	0.01	0.28	0.17	0.01	0.16
UNRIE	0.66	0.31	0.09	0.13	-0.18	0.43	0.10	0.01	0.02	0.03
UNRIT	0.19	0.31	-0.09	-0.24	-0.05	0.04	0.10	0.01	0.06	0.00
UNRNL	0.59	0.39	-0.11	-0.01	0.22	0.35	0.16	0.01	0.00	0.05
UNRPT	0.35	0.51	0.09	-0.31	-0.20	0.12	0.26	0.01	0.10	0.04
WINAT	0.05	-0.02	0.04	0.16	-0.09	0.00	0.00	0.00	0.03	0.01
WINDE	0.17	-0.32	0.05	0.10	-0.47	0.03	0.10	0.00	0.01	0.22
WINFR	0.76	-0.32	-0.26	0.30	-0.01	0.58	0.11	0.07	0.09	0.00
WINIT	0.74	-0.35	-0.14	0.18	0.02	0.55	0.12	0.02	0.03	0.00
XTRAT	-0.02	-0.18	-0.28	-0.30	-0.09	0.00	0.03	0.08	0.09	0.01
XTRDE	0.02	-0.40	-0.15	-0.38	-0.21	0.00	0.16	0.02	0.15	0.04
XTRES	0.00	0.23	-0.12	-0.52	-0.02	0.00	0.05	0.01	0.27	0.00
XTRFI	-0.01	0.01	-0.01	-0.33	0.04	0.00	0.00	0.00	0.11	0.00
XTRFR	-0.04	-0.33	-0.10	-0.53	0.04	0.00	0.11	0.01	0.29	0.00
XTRIT	0.03	-0.02	-0.09	-0.37	-0.17	0.00	0.00	0.01	0.13	0.03
XTRNL	-0.14	-0.17	-0.42	-0.42	-0.27	0.02	0.03	0.18	0.18	0.07

Table 2
Unbalanced Panel

Variable	Loadings			Loadings Squared		
	F1	F2	F3	F1	F2	F3
MTDIE	0.71	-0.25	-0.29	0.51	0.06	0.08
MTDNL	0.47	-0.33	-0.26	0.22	0.11	0.07
MTDBE	0.02	-0.27	-0.54	0.00	0.07	0.29
MTDPT	0.23	-0.30	-0.36	0.05	0.09	0.13
PCDIE	0.89	0.01	0.00	0.79	0.00	0.00
PCDBE	0.37	-0.13	-0.13	0.14	0.02	0.02
PCDPT	0.47	-0.32	0.45	0.22	0.10	0.20
PCDNL	0.57	-0.06	0.05	0.33	0.00	0.00
PPIBE	0.68	-0.29	-0.33	0.46	0.08	0.11
PPIPT	0.40	0.00	-0.18	0.16	0.00	0.03
PPIIT	0.87	-0.23	-0.16	0.75	0.05	0.03
PPIIE	0.26	-0.24	-0.23	0.07	0.06	0.05
ULCBE	0.40	0.25	0.44	0.16	0.06	0.19
ULCDE	0.25	0.01	0.39	0.06	0.00	0.15
ULCES	0.57	-0.08	0.27	0.32	0.01	0.07
ULCFI	-0.13	-0.32	0.19	0.02	0.10	0.04
ULCFR	0.18	0.07	0.51	0.03	0.00	0.26
ULCIT	0.78	-0.13	0.21	0.61	0.02	0.05
ULCNL	0.04	0.18	0.33	0.00	0.03	0.11
WPIDE	0.16	-0.18	-0.61	0.03	0.03	0.37
WPIFI	0.48	0.22	-0.19	0.23	0.05	0.04
WPIIT	0.16	-0.22	0.01	0.03	0.05	0.00
XTDNL	0.45	-0.33	-0.35	0.20	0.11	0.12
XTDIE	0.73	-0.01	-0.36	0.53	0.00	0.13
XTDBE	0.00	-0.26	-0.48	0.00	0.07	0.23
XTDPT	0.21	-0.31	-0.15	0.04	0.09	0.02
YEDIE	0.91	-0.18	0.05	0.82	0.03	0.00
YEDNL	0.39	-0.06	0.01	0.15	0.00	0.00
YEDBE	0.50	-0.09	0.12	0.25	0.01	0.01
YEDPT	0.39	-0.26	0.52	0.15	0.07	0.27
CAPIE	-0.78	-0.12	0.02	0.62	0.01	0.00
CRDBE	-0.08	-0.48	0.13	0.01	0.23	0.02
CRDDE	0.12	-0.18	0.27	0.02	0.03	0.07
CRDFR	0.16	-0.16	0.15	0.02	0.03	0.02
EEFAT	-0.03	-0.03	0.42	0.00	0.00	0.18
EEFBE	-0.04	-0.08	0.44	0.00	0.01	0.19
EEFDE	-0.06	-0.03	0.43	0.00	0.00	0.19
EEFES	-0.17	-0.53	0.20	0.03	0.28	0.04
EEFFI	-0.25	-0.45	-0.16	0.06	0.20	0.03
EEFFR	0.00	-0.03	0.41	0.00	0.00	0.17
EEFIE	-0.06	-0.11	0.37	0.00	0.01	0.14
EEFIT	-0.30	-0.18	0.15	0.09	0.03	0.02
EEFNL	-0.08	0.02	0.45	0.01	0.00	0.20
EEFPT	-0.28	-0.18	0.07	0.08	0.03	0.01
ERNBE	0.68	-0.13	0.21	0.46	0.02	0.05
ERNIE	0.68	-0.15	0.10	0.46	0.02	0.01
GDPBE	-0.15	-0.43	-0.27	0.02	0.19	0.07
GDPIE	-0.30	-0.21	-0.21	0.09	0.04	0.04
GDPPT	-0.18	-0.32	-0.13	0.03	0.10	0.02
HSTDE	0.10	0.12	-0.28	0.01	0.01	0.08
LFNAT	0.20	0.08	0.01	0.04	0.01	0.00
LFNBE	0.17	-0.02	-0.11	0.03	0.00	0.01
LFNDE	0.21	0.04	-0.21	0.05	0.00	0.05
LFNIE	-0.24	0.22	-0.03	0.06	0.05	0.00
LFNPT	-0.04	-0.17	0.00	0.00	0.03	0.00
LNIBE	-0.27	-0.33	0.26	0.07	0.11	0.07
LNIDE	0.32	-0.20	0.24	0.10	0.04	0.06
LNIIT	0.00	-0.38	0.53	0.00	0.14	0.28
LNNNL	-0.41	-0.45	0.28	0.17	0.20	0.08
LTIES	0.14	-0.36	0.01	0.02	0.13	0.00
LTIPT	-0.03	-0.34	-0.28	0.00	0.12	0.08

Table 2 (cont)

Unbalanced Panel

Variable	Loadings			Loadings Squared		
	F1	F2	F3	F1	F2	F3
M1AT	-0.41	0.20	-0.24	0.16	0.04	0.06
M1BE	-0.09	0.15	0.05	0.01	0.02	0.00
M1DE	-0.23	0.14	0.21	0.06	0.02	0.04
M1ES	-0.04	-0.48	0.22	0.00	0.23	0.05
M1FI	0.16	-0.03	-0.16	0.03	0.00	0.03
M1FR	0.23	-0.15	0.05	0.05	0.02	0.00
M1IE	-0.21	-0.06	-0.28	0.05	0.00	0.08
M1IT	0.23	-0.04	0.10	0.05	0.00	0.01
M1NL	-0.22	0.19	0.11	0.05	0.04	0.01
M1PT	0.05	0.01	0.26	0.00	0.00	0.07
M2AT	0.35	0.21	0.26	0.12	0.04	0.07
M2BE	-0.13	-0.01	0.01	0.02	0.00	0.00
M2DE	0.02	0.38	0.25	0.00	0.14	0.06
M2ES	0.59	-0.28	0.12	0.35	0.08	0.01
M2FI	0.41	-0.37	0.13	0.16	0.14	0.02
M2FR	0.40	-0.31	-0.11	0.16	0.10	0.01
M2IE	-0.02	0.11	-0.11	0.00	0.01	0.01
M2IT	0.53	0.09	0.22	0.28	0.01	0.05
M2NL	0.10	-0.07	0.36	0.01	0.00	0.13
M2PT	0.70	-0.01	0.27	0.48	0.00	0.07
M3AT	0.36	0.20	0.24	0.13	0.04	0.06
M3BE	-0.05	0.16	0.12	0.00	0.03	0.01
M3DE	0.22	0.30	0.12	0.05	0.09	0.02
M3ES	0.52	-0.33	0.14	0.27	0.11	0.02
M3FI	0.31	-0.24	0.13	0.10	0.06	0.02
M3FR	0.35	-0.50	0.25	0.12	0.25	0.06
M3IE	-0.08	0.08	-0.21	0.01	0.01	0.04
M3IT	0.52	0.04	0.24	0.27	0.00	0.06
M3NL	0.08	-0.10	0.36	0.01	0.01	0.13
M3PT	0.69	-0.05	0.25	0.47	0.00	0.06
MFBAT	-0.10	-0.78	0.37	0.01	0.61	0.14
MFBES	-0.70	-0.68	-0.09	0.49	0.46	0.01
MFBFI	-0.39	-0.61	-0.38	0.15	0.37	0.14
MFBPT	-0.57	-0.72	0.07	0.33	0.52	0.00
MFOBE	-0.33	-0.59	-0.14	0.11	0.35	0.02
MFODE	-0.38	-0.67	-0.06	0.15	0.44	0.00
MFOES	-0.43	-0.56	-0.08	0.18	0.32	0.01
MFOFI	-0.28	-0.11	-0.55	0.08	0.01	0.30
MFOFR	-0.41	-0.71	0.17	0.17	0.51	0.03
MFOIE	-0.65	-0.28	-0.19	0.42	0.08	0.04
MFOIT	-0.63	-0.59	-0.02	0.39	0.34	0.00
MFONL	-0.55	-0.38	-0.20	0.31	0.15	0.04
MFOPT	-0.50	-0.69	0.00	0.25	0.48	0.00
MFSAT	0.14	0.83	-0.21	0.02	0.69	0.04
MFSES	0.65	0.70	0.19	0.42	0.49	0.04
MFSPT	0.45	0.48	0.17	0.21	0.23	0.03
MTRBE	-0.07	-0.26	-0.14	0.00	0.07	0.02
MTRIE	-0.47	-0.07	-0.44	0.22	0.00	0.19
MTRPT	-0.25	-0.29	-0.02	0.06	0.08	0.00
PCEBE	-0.19	-0.38	0.06	0.04	0.15	0.00
PCEIE	-0.48	-0.05	-0.19	0.23	0.00	0.04
PCEPT	-0.26	-0.29	0.09	0.07	0.08	0.01
PIHDE	-0.03	-0.06	-0.10	0.00	0.00	0.01
PIHPT	-0.01	0.06	-0.01	0.00	0.00	0.00
RSLFI	-0.30	-0.20	-0.20	0.09	0.04	0.04
RSLIT	0.01	-0.04	0.04	0.00	0.00	0.00
RSLPT	0.01	-0.17	0.23	0.00	0.03	0.05
WINBE	0.12	-0.32	0.24	0.01	0.10	0.06
WINFI	0.26	-0.44	-0.06	0.07	0.19	0.00
WINNL	-0.06	-0.16	0.16	0.00	0.02	0.03
XTRBE	-0.06	-0.21	-0.19	0.00	0.04	0.04
XTRIE	-0.41	-0.08	-0.46	0.17	0.01	0.21
XTRPT	-0.17	-0.35	-0.31	0.03	0.12	0.09

Coding for the variables consists of five characters, three for the concept portrayed by the variable and two for the country. Thus, variable CPIAT stands for concept CPI (consumer price index) for country AT (Austria). The acronyms used in the table are explained below. (One important point to keep in mind is that the concept sometimes differs across countries, and this entails a rather loose labelling for the variables.)

Countries

AT: Austria

BE: Belgium

DE: Germany

ES: Spain

FI: Finland

FR: France

IE: Ireland

IT: Italy

NL: Netherlands

PT: Portugal

Concepts

Balanced-panel variables

CPI: consumer price index
MTD: import deflator
PCD: private consumption deflator
PPI: producer's price index
XTD: export deflator
YED: GDP deflator
CAP: capacity utilisation
ERN: total earnings
HST: housing starts
LFN: labour force
LNN: total employment
LTI: long-term interest rate
MFB: manufacturing book orders
MFS: level of stocks in manufacturing
MTR: total imports
PCE: private consumer expenditure
PIH: housing permits
RSL: retail sales
STI: short-term interest rate
UNR: unemployment rate
WIN: total compensation of employees
XTR: total imports

Unbalanced-panel variables

ULC: unit labour costs
M1: M1
M2: M2
M3: M3
MFO: new orders in manufacturing

Appendix B:
A discussion on the forecasting framework

As stated in the main text, forecast regressions are based on (B.1), which is expression (4.1) repeated here for convenience. As before, y_t is the variable of interest, assumed to be I(1), z_t is the indicator variable being tested, assumed to be I(0), and ε_t is a well behaved error term, while h stands for the number of periods ahead for which the forecast has to be performed. An explicit model for z_t may be summarised by (B.2), in which a (stochastic) relationship is assumed to exist between that variable and variable x_t. The latter is a vector variable that may contain lags of z_t and lagged values of Δy_t, but which in general will be considered to contain supplementary information.[14] Obviously, variable z_t is assumed to be impossible to forecast with perfect accuracy.

$$\frac{y_{t+h} - y_t}{h} = A(L) \cdot \Delta y_t + B(L) \cdot z_t + \varepsilon_t \qquad \text{(B.1)}$$

$$z_t = \Phi(x_t) \qquad \text{(B.2)}$$

As already expressed in the main text, expression (B.1) is non-recursive in that all information needed to derive an *h*-step-ahead forecast is available at time *t*. Instead, the normal forecasting practice starts from a recursive system like (B.3), a repetition of (4.2) in the main text. A professional forecaster would thus draw a forecast by recursing on (B.3) and (B.2), and would probably be willing to expend some effort in fine-tuning his/her view of the future evolution of z_t, based on the assessment made for x_t.

$$\Delta y_{t+1} = A(L) \cdot \Delta y_t + B(L) \cdot z_t + \varepsilon_t \qquad \text{(B.3)}$$

Expressions (B.4) and (B.5) express how *h*-step-ahead forecasts are obtained with the two approaches. One notable difference between the two expressions is the presence of expectations on the right-hand side of the recursive system, and their absence in the non-recursive one (hence their name).

$$E_t \frac{y_{t+h} - y_t}{h} = A(L) \cdot \Delta y_t + B(L) \cdot z_t \qquad \text{(B.4)}$$

$$E_t \Delta y_{t+h} = A(L) \cdot E_t \Delta y_{t+h-1} + B(L) \cdot E_t z_{t+h-1} \qquad \text{(B.5)}$$

One problem with (B.4) is that it does not clearly define what is the data generating process for z_t, and thus skips entirely the information that could be gained with (B.2). Obviously, if z_t only depends on its own lags and lagged values of y_t there is a one-to-one mapping between (B.4) and (B.5), but if the variable is explained by other variables then necessarily (B.4) lacks information. This can be seen intuitively by noting that $E_t z_{t+h-1}$ only depends, in the latter case, on contemporaneous and lagged values of z_t and Δy_t, all of which already enter (B.4). However, if (B.2) contains extraneous information, the forecasting equation (B.4) will miss relevant regressors. Further to that, it is widely believed that observations *h*-periods apart are less related than contiguous observations, and this may reduce the significance of the estimated parameters in (B.4), and increase the volatility of the forecast. On the other hand, it has to be admitted that the single-step forecast of (B.4) minimises the effect of errors in the model specification, as these are not propagated to periods in between, as is the case in (B.5). It is very difficult to assess formally the relative importance of all these factors, as they involve testing the out-of-sample robustness of the models, a task for which standard in-sample tests may fail to give a proper answer.

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[14] It could also contain contemporaneous values of Δy_t without affecting results, although this would compromise the use of z_t in forecasting.

All in all, it is difficult to decide a priori whether (B.1) or (B.3) is preferable as a forecasting device. This paper has opted for (B.1) not just because it is now widely accepted, but rather because we do not feel comfortable specifying a generating model for the indicators on which we will focus: dynamic factors extracted from a rich dataset.[15] For us, expression (B.1) presents the convenient advantage of not requiring this information. Nonetheless, a number of tests were performed to ensure that the forecasting ability of (B.1) in normal circumstances matches that of (B.3). Thus, loosely speaking, our null hypothesis is that (B.1) is not worse in forecasting than (B.3). Unfortunately, the test cannot be treated explicitly as a standard one, because our centre of interest is the robustness of each system in the face of unforeseen structural breaks, and on this econometrics does not yet have much to say; see, for example Clements and Hendry (1998). The test loosely proposed is thus explicitly one of out-of-sample robustness in the sample under analysis. Instead, a relatively large number of tests were run in which either (B.1) or (B.3) was slightly changed, as local alternatives to the original system, and forecasting tests were run. The relevance of this step lies in the fact that a *consistently* worse performance of (B.1) would make the forecasting tests included in the rest of the paper almost irrelevant.

A number of out-of-sample exercises were run with inflation measured by the HICP and, where required, GDP as an indicator. GDP was chosen as an indicator for the bivariate system below because the inflation-output system is fairly standard in the literature and known to work relatively well: as a benchmark, correspondingly, it may bias results against the non-recursive system, which is the system being tested. In all the systems, the equation for GDP played the role of (B.2). Both variables were in logs, GDP also in the first difference. In each test, the system was changed to homogenise the variables forecast by the two equations, in ways described below.

Test 1. Standard recursive system against re-expressed non-recursive system

In the first test, (B.4) was changed into (B.4') and tested against (B.5). When GDP was used as an indicator, the recursive system was a VAR with inflation and output. In this guise, both the recursive and the non-recursive system modelled the first difference of HICP.

$$E_t \Delta y_{t+h} = A(L) \cdot \Delta y_t + B(L) \cdot z_t \qquad \text{(B.4')}$$

Test 2. Re-expressed recursive system against standard non-recursive system

The second test changed the definition of (B.5) in order for it to model the same variable as (B.4), as in (B.5'). Expression (B.5') is nothing but a standard one-step-ahead recursive equation modelling the same variable as (B.1).

$$E_t \frac{y_{t+h} - y_t}{h} = A(L) \cdot E_t \frac{y_{t+h-1} - y_{t-1}}{h} + B(L) \cdot E_t z_{t+h-1} \qquad \text{(B.5')}$$

Test 3. Cumulated recursive forecasts against standard non-recursive forecasts

The third test took (B.4) and (B.5) unchanged, but cumulated the *h*-recursive forecasts of (B.5) in order to match the variable generated by (B.4).

Test 4. Differenced non-recursive forecasts against standard recursive forecasts

Finally, the fourth test also used (B.4) and (B.5) unchanged, but took first differences of the forecasts generated by the non-recursive system to match the variable generated by (B.5).[16]

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15 In other words, factors are meant to be able to replace all variables that could appear in (B.1) with no significant loss of information. Under this assumption, (B.2) contains no relevant forecasting information and can thus be ignored.

16 More precisely, calling $\Delta_h y_{t+h} \equiv y_{t+h} - y_t$, the forecast is $E_t \Delta_h y_{t+h} - E_t \Delta_{h-1} y_{t+h-1}$.

Table 1

Recursive and non-recursive systems
Relative performance

	Steps ahead							
	1		**2**		**3**		**4**	
Test 1: standard recursive forecast against non-standard non-recursive forecast								
Univariate	1.00	(0.00)	0.98	(0.20)	0.95	(0.41)	0.90	(0.52)
Bivariate	1.00	(0.00)	0.99	(0.11)	0.97	(0.28)	0.99	(0.29)
Test 2: non-standard recursive forecast against standard non-recursive forecast								
Univariate	1.00	(0.00)	1.00	(0.09)	1.05	(0.26)	1.06	(0.17)
Bivariate	1.00	(0.00)	1.01	(0.08)	1.12	(0.38)	1.15	(0.19)
Test 3: cumulation of recursive forecasts against non-recursive forecast								
Univariate	1.00	(0.00)	0.98	(0.20)	0.92	(0.41)	0.87	(0.55)
Bivariate	1.00	(0.00)	1.01	(0.11)	0.99	(0.30)	1.00	(0.32)
Test 4: recursive forecast against decumulated non-recursive forecasts								
Univariate	1.00	(0.00)	0.99	(0.20)	0.94	(0.41)	0.88	(0.55)
Bivariate	1.00	(0.00)	1.00	(0.11)	0.96	(0.30)	0.98	(0.32)

NB A value lower than one indicates the recursive system is to be preferred.

Table 1 collects the relative size of the RMSE of the one-step-ahead to four-steps-ahead forecasts of the chosen non-recursive system compared with the more standard recursive one, for both the univariate (ie inflation-only) system and the bivariate one (ie inflation and output).[17] A number lower than one in a particular cell means that the recursive system is to be preferred, and the converse in the other case.[18] Standard errors for the ratios, reported between parentheses, are a delta-method first-order approximation to the variance of the ratio, corrected for heteroskedasticity and autocorrelation using the Newey-West non-parametric method. Although the evidence on the relative merits of both equations is mixed, results shown lend support to our claim that (B.4) is an appropriate tool for the exercise concerned.

17 The forecasting equations used in Table 1 included four lags of inflation and, where applicable, output.

18 By construction, the ratio for the one-step-ahead forecasts is one.

Appendix C:
Description of data

A total of 35 series per country were considered for the creation of the dataset. The dataset comprises: real variables, national account deflators, and different prices, monetary and credit variables, interest rates, labour statistics, and inventories of finished and ordered manufactured goods. Only 68% of the total data are available for the 10 countries analysed over the sample period of 1970 Q1 to 2000 Q3 (see the following Table). Going beyond this overall picture, the following points can be made:

1. The countries for which severe problems arise in terms of availability are Austria, Germany, Ireland, and Portugal, countries for which almost half of the series are not available. For Germany the problem arises from the lack of data for "Germany as a whole" prior to 1991 for most series (the total share of available data is only 57%). Data for Ireland are mostly annual, while for Austria and Portugal the starting dates for many series are only 1985 and 1998. Also worth mentioning is Belgium, for which some series start only in 1985.

2. Some series are not available for all countries; for example wholesale sales data are available only for France and Finland. Housing starts data, which cover 18%, are available for Belgium, Germany, Spain, France, the Netherlands, Austria and Finland. Data on credit to non-financial institutions and to individuals (21.9% and 25.4% covering sample respectively) are available only for Belgium, Germany and France, and for a very short time span as well. WPI (33.6%) is available only for Germany, Ireland, Italy, Austria and Finland. Unit labour costs are covered by only 40% (no data are available for Ireland, Austria or Portugal, and German data start in 1991 Q1).

3. Some series are available only with annual frequencies for many countries, such as labour force, and others, namely long-term interest rates, have late starting dates (after 1986) for all countries except Belgium and Spain (after 1978).

4. Finally, there is also a timeliness problem, ie not all countries have yet published data for all series for 2000 Q3; also some series are drawn from annual data, and therefore the latest observation is 1999. Very few countries in the BIS database are still publishing credit data; however, the latest observations are 1999 Q3 for Germany and 1998 Q4 for Belgium. Data on permits issued also lag behind a bit (1999 Q4 Germany, Spain and Ireland).

Series	Countries								
	Belgium			Germany			Spain		
	Availability	Observations	Coverage(a)	Availability	Observations	Coverage(a)	Availability	Observations	Coverage(a)
Ind'l Production Total (OECD, MEI)	70q1-99q1	**117**	**99%**	70q1-99q1	**117**	**99%**	70q1-99q1	**117**	**99%**
Capacity Utilization (EC Surveys and OECD, MEI*)	73q1-99q2	**106**	**90%**	80q1-99q2	**78**	**66%**	70q1-99q2*	**118**	**100%**
GDP (OECD, QNA and BIS*)	85q1-99q2	**61**	**52%**	91q1-99q1(b)	**34**	**29%**	70q1-99q2	**118**	**100%**
Labour Force (OECD, Labour Stats. and BIS*)	70q1-98q4	**29**	**25%**	70q1-98q4	**29**	**25%**	70q1-99q2*	**118**	**100%**
Employment (OECD, Labour Stats. and BIS*)	85q1-99q1*	**57**	**48%**	91q1-99q1(b)*	**33**	**28%**	70q1-99q1*	**117**	**99%**
Unemployment Rate (BIS)	70q1-99q2	**118**	**100%**	92q1-99q2(b)	**30**	**25%**	70q1-99q2	**118**	**100%**
Retail Sales (OECD, MEI)	76q1-99q2	**94**	**80%**	70q1-99q2	**118**	**100%**	95q1-99q2	**18**	**15%**
Wholesale Sales (OECD, MEI)			**0%**			**0%**			**0%**
Personal Consumption Expenditure (OECD, QNA)	85q1-99q2	**61**	**52%**	92q1-99q2(b)	**34**	**29%**	70q1-99q2	**118**	**100%**
Housing Starts, Construction put in place (OECD, MEI)	70q1-99q1	**117**	**99%**	91q1-99q1	**33**	**28%**	72q1-99q2	**110**	**93%**
Permits Issued (OECD, MEI)	70q1-99q1	**117**	**99%**	79q1-99q2	**82**	**69%**	92q1-99q2	**30**	**25%**
Stocks of finished goods in manufacturing, Survey Assessme	70q1-99q2	**118**	**100%**	70q1-99q2	**118**	**100%**	87q1-99q2	**50**	**42%**
Orders in manufacturing, Survey Assessment (EC Survey)	70q1-99q2	**118**	**100%**	70q1-99q2	**118**	**100%**	87q1-99q2	**50**	**42%**
Book Orders, Survey Assessment (EC Survey)	70q1-99q2	**118**	**100%**	70q1-99q2	**118**	**100%**	87q1-99q2	**50**	**42%**
Effective Exchange Rate (ECB Database)	83q4-99q2	**66**	**56%**	83q4-99q2	**66**	**56%**	83q4-99q2	**66**	**56%**
Short-Term Interest Rates (Derived ECB database, and AMECO	91q1-99q2(c)	**34**	**29%**	70q2-99q2	**118**	**100%**	77q2-99q2	**118**	**100%**
Long-Term Interest Rates (Derived ECB database)	78q1-99q2(c)	**86**	**73%**	91q1-99q2(c)	**34**	**29%**	78q3-99q2(c)	**86**	**73%**
Money Stock M1 (ECB database)	80q2-99q2	**78**	**66%**	80q2-99q2	**78**	**66%**	80q2-99q2	**78**	**66%**
Money Stock M2 (ECB database)	80q2-99q2	**78**	**66%**	80q2-99q2	**78**	**66%**	80q2-99q2	**78**	**66%**
Money Stock M3 (ECB database)	80q2-99q2	**78**	**66%**	80q2-99q2	**78**	**66%**	80q2-99q2	**78**	**66%**
Credit to non financial institutions (BIS)	80q1-98q4	**76**	**64%**	70q1-97q3	**110**	**93%**			**0%**
Credit to Individuals (BIS)	80q1-98q4	**76**	**64%**	70q2-97q4	**111**	**94%**			**0%**
PPI Finished goods (OECD, MEI, and ECB database*)	80q1-99q2	**78**	**66%**	70q1-99q2	**118**	**100%**	70q1-99q2	**118**	**100%**
WPI (ECB database* and BIS**)			**0%**	91q1-99q2*	**34**	**29%**			**0%**
CPI (OECD, MEI)	70q1-99q2	**118**	**100%**	70q1-99q2	**118**	**100%**	70q1-99q2	**118**	**100%**
Private Cons.Deflator (OECD, QNA)	85q1-99q2	**58**	**49%**	92q1-99q2(b)	**34**	**29%**	70q1-99q2	**118**	**100%**
GDP deflator (OECD, QNA)	85q1-99q2	**58**	**49%**	92q1-99q2(b)	**34**	**29%**	70q1-99q2	**118**	**100%**
Government Consumption Deflator (OECD, QNA)	85q1-99q2	**58**	**49%**	91q1-99q2	**34**	**29%**	70q1-99q2	**118**	**100%**
Gross fixed capital formation Deflator (OECD, QNA)	85q1-99q2	**58**	**49%**	91q1-99q2	**34**	**29%**	70q1-99q2	**118**	**100%**
Exports Deflator (OECD, QNA)	85q1-99q2	**58**	**49%**	92q1-99q2(b)	**34**	**29%**	70q1-99q2	**118**	**100%**
Imports Deflator (OECD, QNA)	85q1-99q2	**58**	**49%**	92q1-99q2(b)	**34**	**29%**	70q1-99q2	**118**	**100%**
Compensation of Employees (OECD,QNA)	85q1-99q2	**58**	**49%**	92q1-99q2(b)	**34**	**29%**	95q1-99q2	**118**	**100%**
Hourly Earnings (OECD, MEI)	80q1-99q2	**78**	**66%**	70q1-99q2	**118**	**100%**	70q1-99q2	**118**	**100%**
Real Exports (OECD, QNA)	85q1-99q2	**58**	**49%**	92q1-99q2(b)	**34**	**29%**	70q1-99q2	**118**	**100%**
Real Imports (OECD, QNA)	85q1-99q2	**58**	**49%**	92q1-99q2(b)	**34**	**29%**	70q1-99q2	**118**	**100%**
ULC (BIS)	85q1-99q2	**58**	**49%**	92q1-99q2(b)	**34**	**29%**	70q1-99q2	**118**	**100%**
TOTAL 35 Series		**2657**	**64%**		**2343**	**57%**		**3170**	**77%**

(a) Coverage stands for the ratio between available data and total number of observations.

(b) Data for Germany is available in most cases only as of 1991, however it is possible to obtain longer series by rescaling and joining to Western Germany series.

(c) Some series have been rescalled and linked to other series as done to solve the German Unification issue and to have series that go as far as 1970.

e.g.This was done for Long - term and Short-term interest rates using AMECO annual data for past data.

Series	Countries								
	France			Ireland			Italy		
	Availability	Observations	Coverage(a)	Availability	Observations	Coverage(a)	Availability	Observations	Coverage(a)
Ind'l Production Total (OECD, MEI)	70q1-99q1	**117**	**99%**	75q3-99q2	**98**	**83%**	70q1-99q1	**117**	**99%**
Capacity Utilization (EC Surveys and OECD, MEI*)	76q1-99q2	**94**	**80%**	76q1-99q2*	**94**	**80%**	70q1-99q2	**118**	**100%**
GDP (OECD, QNA and BIS*)	70q1-99q2	**118**	**100%**	75q1-97q4*	**24**	**20%**	70q1-99q2	**118**	**100%**
Labour Force (OECD, Labour Stats. and BIS*)	70q1-99q2*	**118**	**100%**	70q1-97q4	**28**	**24%**	70q1-99q2*	**118**	**100%**
Employment (OECD, Labour Stats. and BIS*)	70q1-98q4	**29**	**25%**	70q1-97q4	**28**	**24%**	70q1-99q1*	**119**	**101%**
Unemployment Rate (BIS)	70q1-99q2	**118**	**100%**	70q1-99q2	**118**	**100%**	70q1-99q2	**118**	**100%**
Retail Sales (OECD, MEI)	75q1-99q2	**98**	**83%**	70q1-99q2	**118**	**100%**	70q1-99q2	**118**	**100%**
Wholesale Sales (OECD, MEI)	70q1-99q2	**118**	**100%**			**0%**			**0%**
Personal Consumption Expenditure (OECD, QNA)	70q1-99q2	**118**	**100%**	75q1-97q4*	**23**	**19%**	70q1-99q2	**118**	**100%**
Housing Starts, Construction put in place (OECD, MEI)	70q1-99q1	**117**	**99%**			**0%**			**0%**
Permits Issued (OECD, MEI)	70q1-99q1	**117**	**99%**	92q1-99q2	**30**	**25%**			**0%**
Stocks of finished goods in manufacturing, Survey Assessme	70q1-99q2	**118**	**100%**	75q1-99q2	**118**	**100%**	70q1-99q2	**118**	**100%**
Orders in manufacturing, Survey Assessment (EC Survey)	70q1-99q2	**118**	**100%**	75q1-99q2	**118**	**100%**	70q1-99q2	**118**	**100%**
Book Orders, Survey Assessment (EC Survey)	70q1-99q2	**118**	**100%**	75q1-99q2	**118**	**100%**	70q1-99q2	**118**	**100%**
Effective Exchange Rate (ECB Database)	83q4-99q2	**66**	**56%**	83q4-99q2	**66**	**56%**	83q4-99q2	**66**	**56%**
Short-Term Interest Rates (Derived ECB database, and AMECO	72q1-99q2(b)	**118**	**100%**	72q1-99q2(b)	**82**	**69%**	72q1-99q2(b)	**78**	**66%**
Long-Term Interest Rates (Derived ECB database)	88q1-99q2(b)	**50**	**42%**	88q1-99q2(b)	**42**	**36%**	88q1-99q2(b)	**102**	**86%**
Money Stock M1 (ECB database)	80q2-99q2	**78**	**66%**	80q2-99q2	**78**	**66%**	80q2-99q2	**78**	**66%**
Money Stock M2 (ECB database)	80q2-99q2	**78**	**66%**	80q2-99q2	**78**	**66%**	80q2-99q2	**78**	**66%**
Money Stock M3 (ECB database)	80q2-99q2	**78**	**66%**	80q2-99q2	**78**	**66%**	80q2-99q2	**78**	**66%**
Credit to non financial institutions (BIS)	78q1-98q4	**84**	**71%**			**0%**			**0%**
Credit to Individuals (BIS)	78q1-98q4	**84**	**71%**			**0%**	89q3-99q2	**42**	**36%**
PPI Finished goods (OECD, MEI, and ECB database*)	70q1-99q2	**118**	**100%**	85q1-99q2*	**58**	**49%**	81q1-99q2	**114**	**97%**
WPI (ECB database and BIS*)			**0%**	70q1-99q1*	**117**	**99%**	89q1-98q4**	**116**	**98%**
CPI (OECD, MEI)	70q1-99q2	**118**	**100%**	70q1-99q2	**118**	**100%**	70q1-99q2	**118**	**100%**
Private Cons.Deflator (OECD, QNA)	70q1-99q2	**118**	**100%**	75q1-97q4*	**23**	**19%**	70q1-99q2	**118**	**100%**
GDP deflator (OECD, QNA)	70q1-99q2	**118**	**100%**	75q1-97q4*	**23**	**19%**	70q1-99q2	**118**	**100%**
Government Consumption Deflator (OECD, QNA)	70q1-99q2	**118**	**100%**	75q1-97q4*	**23**	**19%**	70q1-99q2	**118**	**100%**
Gross fixed capital formation Deflator (OECD, QNA)	70q1-99q2	**118**	**100%**	75q1-97q4*	**23**	**19%**	70q1-99q2	**118**	**100%**
Exports Deflator (OECD, QNA)	70q1-99q2	**118**	**100%**	75q1-97q4*	**23**	**19%**	70q1-99q2	**118**	**100%**
Imports Deflator (OECD, QNA)	70q1-99q2	**118**	**100%**	75q1-97q4*	**23**	**19%**	70q1-99q2	**118**	**100%**
Compensation of Employees (OECD,QNA)	70q1-99q2	**118**	**100%**	75q1-97q4*	**23**	**19%**	70q1-99q2	**118**	**100%**
Hourly Earnings (OECD, MEI)	70q1-99q2	**118**	**100%**	75q1-99q2*	**118**	**100%**	70q1-99q2	**118**	**100%**
Real Exports (OECD, QNA)	70q1-99q2	**118**	**100%**	75q1-97q4*	**23**	**19%**	70q1-99q2	**118**	**100%**
Real Imports (OECD, QNA)	70q1-99q2	**118**	**100%**	75q1-97q4*	**23**	**19%**	70q1-99q2	**118**	**100%**
ULC (BIS)	78q1-99q2	**86**	**73%**				82q1-99q2	**70**	**59%**
TOTAL 35 Series		**3654**	**88%**		**1957**	**47%**		**3418**	**83%**

(a) Coverage stands for the ratio between available data and total number of observations.

(b) Some series have been rescalled and linked to other series as done to solve the German Unification issue and to have series that go as far as 1970.

e.g.This was done for Long-term and Short-term interest rates using AMECO annual data for past data.

Quarterly data for Ireland for some series has been interpolated from annual data. (GDP, labour force, employment, personal consumption, all deflators, imports and exports).

Series	Countries								
	Netherlands			Austria			Portugal		
	Availability	Observations	Coverage(a)	Availability	Observations	Coverage(a)	Availability	Observations	Coverage(a)
Ind'l Production Total (OECD, MEI)	70q1-99q1	**117**	**99%**	70q1-99q1	**117**	**99%**	70q1-99q1	**117**	**99%**
Capacity Utilization (EC Surveys and OECD, MEI*)	71q1-99q2	**119**	**101%**	96q1-99q2	**19**	**16%**	77q1-99q2*	**90**	**76%**
GDP (OECD, QNA and BIS*)	77q1-99q2	**90**	**76%**	70q1-99q2	**118**	**100%**	88q1-98q4	**116**	**98%**
Labour Force (OECD, Labour Stats. and BIS*)	70q1-99q2*	**30**	**25%**	70q1-98q4	**29**	**25%**	70q1-98q4	**29**	**25%**
Employment (OECD, Labour Stats. and BIS*)	70q1-98q4*	**29**	**25%**	70q1-98q4	**29**	**25%**	70q1-99q1*	**119**	**101%**
Unemployment Rate (BIS)	70q1-99q2	**118**	**100%**	70q1-99q2	**118**	**100%**	70q1-99q2	**118**	**100%**
Retail Sales (OECD, MEI)	70q1-99q2	**118**	**100%**	73q1-99q2	**106**	**90%**	90q1-99q2	**38**	**32%**
Wholesale Sales (OECD, MEI)			**0%**			**0%**			**0%**
Personal Consumption Expenditure (OECD, QNA)	77q1-99q2	**90**	**76%**	70q1-99q2	**118**	**100%**	88q1-98q4	**116**	**98%**
Housing Starts, Construction put in place (OECD, MEI)	70q1-99q2	**118**	**100%**	96Q1-99q1	**13**	**11%**			**0%**
Permits Issued (OECD, MEI)	70q1-99q1	**118**	**100%**			**0%**	78q1-99q1	**85**	**72%**
Stocks of finished goods in manufacturing, Survey Assessme	72q1-99q2	**118**	**100%**	85q1-99q2	**58**	**49%**	87q1-99q2	**50**	**42%**
Orders in manufacturing, Survey Assessment (EC Survey)	72q1-99q2	**118**	**100%**	96q1-99q2	**14**	**12%**	87q1-99q2	**50**	**42%**
Book Orders, Survey Assessment (EC Survey)	72q1-99q2	**118**	**100%**	85q1-99q2	**58**	**49%**	87q1-99q2	**50**	**42%**
Effective Exchange Rate (ECB Database)	83q4-99q2	**66**	**56%**	83q4-99q2	**66**	**56%**	83q4-99q2	**66**	**56%**
Short-Term Interest Rates (Derived ECB database, and AMECO	72q1-99q2(b)	**110**	**93%**	72q1-99q2(b)	**38**	**32%**	72q1-99q2(b)	**38**	**32%**
Long-Term Interest Rates (Derived ECB database)	88q1-99q2(b)	**46**	**39%**	88q1-99q2(b)	**54**	**46%**	88q1-99q2(b)	**54**	**46%**
Money Stock M1 (ECB database)	80q2-99q2	**78**	**66%**	80q2-99q2	**78**	**66%**	80q2-99q2	**78**	**66%**
Money Stock M2 (ECB database)	80q2-99q2	**78**	**66%**	80q2-99q2	**78**	**66%**	80q2-99q2	**78**	**66%**
Money Stock M3 (ECB database)	80q2-99q2	**78**	**66%**	80q2-99q2	**78**	**66%**	80q2-99q2	**78**	**66%**
Credit to non financial institutions (BIS)			**0%**			**0%**			**0%**
Credit to Individuals (BIS)			**0%**			**0%**			**0%**
PPI Finished goods (OECD, MEI, and ECB database*)	76q1-99q2*	**94**	**80%**	70q1-99q2	**118**	**100%**	90q1-99q2*	**82**	**69%**
WPI (ECB database and BIS*)			**0%**	96q1-99q2**	**14**	**12%**			**0%**
CPI (OECD, MEI)	70q1-99q2	**118**	**100%**	76q1-99q2	**94**	**80%**	88q1-99q2	**46**	**39%**
Private Cons.Deflator (OECD, QNA)	77q1-99q2	**90**	**76%**	76q1-99q2	**94**	**80%**	88q1-98q4	**116**	**98%**
GDP deflator (OECD, QNA)	77q1-99q2	**90**	**76%**	76q1-99q2	**94**	**80%**	88q1-98q4	**116**	**98%**
Government Consumption Deflator (OECD, QNA)	77q1-99q2	**90**	**76%**	76q1-99q2	**94**	**80%**	88q1-98q4	**116**	**98%**
Gross fixed capital formation Deflator (OECD, QNA)	77q1-99q2	**90**	**76%**	76q1-99q2	**94**	**80%**	88q1-98q4	**116**	**98%**
Exports Deflator (OECD, QNA)	77q1-99q2	**90**	**76%**	76q1-99q2	**94**	**80%**	88q1-98q4	**116**	**98%**
Imports Deflator (OECD, QNA)	77q1-99q2	**90**	**76%**	76q1-99q2	**94**	**80%**	88q1-98q4	**116**	**98%**
Compensation of Employees (OECD,QNA)	77q1-99q2	**90**	**76%**	70q1-99q2	**118**	**100%**			**0%**
Hourly Earnings (OECD, MEI)	70q1-99q2	**118**	**100%**	70q1-99q2	**118**	**100%**			**0%**
Real Exports (OECD, QNA)	77q1-99q2	**90**	**76%**	76q1-99q2	**94**	**80%**	88q1-98q4	**116**	**98%**
Real Imports (OECD, QNA)	77q1-99q2	**90**	**76%**	76q1-99q2	**94**	**80%**	88q1-98q4	**116**	**98%**
ULC (BIS)	84q1-99q2	**65**	**55%**			**0%**			**0%**
TOTAL 35 Series		**2962**	**72%**		**2403**	**58%**		**2426**	**59%**

(a) Coverage stands for the ratio between available data and total number of observations.

(b) Some series have been rescalled and linked to other series as done to solve the German Unification issue and to have series that go as far as 1970.

e.g.This was done for Long-term and Short-term interest rates using AMECO annual data for past data.

Series	Finland		
	Availability	Observations	Coverage(a)
	70q1-99q1	117	0.99152542
Ind'l Production Total (OECD, MEI)	80q1-99q2	83	70%
Capacity Utilization (EC Surveys and OECD, MEI*)	75q1-99q2	98	83%
GDP (OECD, QNA and BIS*)	70q1-99q2*	118	100%
Labour Force (OECD, Labour Stats. and BIS*)	70q1-99q1*	117	99%
Employment (OECD, Labour Stats. and BIS*)	70q1-99q2	118	100%
Unemployment Rate (BIS)	85q1-99q2	58	49%
Retail Sales (OECD, MEI)	75q1-99q1	97	82%
Wholesale Sales (OECD, MEI)	75q1-99q2	98	83%
Personal Consumption Expenditure (OECD, QNA)	70q1-99q1	117	99%
Housing Starts, Construction put in place (OECD, MEI)	70q1-99q1	117	99%
Permits Issued (OECD, MEI)	93q1-99q2	26	22%
Stocks of finished goods in manufacturing, Survey Assessme	85q1-99q2	58	49%
Orders in manufacturing, Survey Assessment (EC Survey)	85q1-99q2	58	49%
Book Orders, Survey Assessment (EC Survey)	83q4-99q2	66	56%
Effective Exchange Rate (ECB Database)	90q1-99q2(b)	46	39%
Short-Term Interest Rates (Derived ECB database, and AMECO	86q1-99q2(b)	38	32%
Long-Term Interest Rates (Derived ECB database)	80q2-99q2	78	66%
Money Stock M1 (ECB database)	80q2-99q2	78	66%
Money Stock M2 (ECB database)	80q2-99q2	78	66%
Money Stock M3 (ECB database)			0%
Credit to non financial institutions (BIS)			0%
Credit to Individuals (BIS)	70q1-99q2	118	100%
PPI Finished goods (OECD, MEI, and ECB database*)	70q1-99q2**	118	100%
WPI (ECB database and BIS*)	70q1-99q2	118	100%
CPI (OECD, MEI)	75q1-99q2	98	83%
Private Cons.Deflator (OECD, QNA)	75q1-99q2	98	83%
GDP deflator (OECD, QNA)	75q1-99q2	98	83%
Government Consumption Deflator (OECD, QNA)	75q1-99q2	98	83%
Gross fixed capital formation Deflator (OECD, QNA)	75q1-99q2	98	83%
Exports Deflator (OECD, QNA)	75q1-99q2	98	83%
Imports Deflator (OECD, QNA)	70q1-99q2	118	100%
Compensation of Employees (OECD,QNA)	70q1-99q2	118	100%
Hourly Earnings (OECD, MEI)	75q1-99q2	98	83%
Real Exports (OECD, QNA)	75q1-99q2	98	83%
Real Imports (OECD, QNA)	89q1-99q2	42	36%
ULC (BIS)		3080	75%
TOTAL 35 Series		3084	75%

(a) Coverage stands for the ratio between available data and total number of observations.

(b) Some series have been rescalled and linked to other series as done to solve the German Unification issue and to have series that go as far as 1970. e.g.This was done for Long-term and Short-term interest rates using AMECO annual data for past data.

Series	Total Coverage[(a)] For Each Variable
Ind'l Production Total (OECD, MEI)	97.54%
Capacity Utilization (EC Surveys and OECD, MEI*)	77.88%
GDP (OECD, QNA and BIS*)	75.85%
Labour Force (OECD, Labour Stats. and BIS*)	54.75%
Employment (OECD, Labour Stats. and BIS*)	57.37%
Unemployment Rate (BIS)	92.54%
Retail Sales (OECD, MEI)	74.92%
Wholesale Sales (OECD, MEI)	18.22%
Personal Consumption Expenditure (OECD, QNA)	75.76%
Housing Starts, Construction put in place (OECD, MEI)	52.97%
Permits Issued (OECD, MEI)	58.98%
Stocks of finished goods in manufacturing, Survey Assessme	75.59%
Orders in manufacturing, Survey Assessment (EC Survey)	74.58%
Book Orders, Survey Assessment (EC Survey)	78.31%
Effective Exchange Rate (ECB Database)	55.93%
Short-Term Interest Rates (Derived ECB database, and AMECO	66.10%
Long-Term Interest Rates (Derived ECB database)	50.17%
Money Stock M1 (ECB database)	66.10%
Money Stock M2 (ECB database)	66.10%
Money Stock M3 (ECB database)	66.10%
Credit to non financial institutions (BIS)	22.88%
Credit to Individuals (BIS)	26.53%
PPI Finished goods (OECD, MEI, and ECB database*)	86.10%
WPI (ECB database and BIS*)	33.81%
CPI (OECD, MEI)	91.86%
Private Cons.Deflator (OECD, QNA)	73.47%
GDP deflator (OECD, QNA)	73.47%
Government Consumption Deflator (OECD, QNA)	73.47%
Gross fixed capital formation Deflator (OECD, QNA)	73.47%
Exports Deflator (OECD, QNA)	73.47%
Imports Deflator (OECD, QNA)	73.47%
Compensation of Employees (OECD,QNA)	67.37%
Hourly Earnings (OECD, MEI)	86.61%
Real Exports (OECD, QNA)	73.47%
Real Imports (OECD, QNA)	73.47%
ULC (BIS)	40.08%
TOTAL Coverage of the 35 Series	68%

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Why did prices in Japan hardly decline during the 1997-98 recession?

Hideo Hayakawa and Hiroshi Ugai[1]

1. Introduction

Recently, the United States and European economies have been enjoying stable inflation together with continuously diminishing output gaps. Presumably, most of the participants in this meeting will discuss channels that suppress the rise in prices, such as the enhancement of productivity led by information technology, especially in the United States, or changes in wage-setting behaviour. Turning our eyes to Japan, however, we can find contrary developments in prices. The Japanese economy was on the brink of a deflationary spiral in 1998 as the output gap expanded rapidly and the risk of negative interaction between economic activity and financial stability mounted. But, in fact, prices did not fall as much as would have been suggested by classical estimates of the output gap. The main purpose of this paper is to try to find the factors behind these price developments in Japan.

Even if this puzzle is solved, there remains the question of whether information technology or other technological innovations have had any impact on prices in Japan. Looking at the Japanese economy recently, business fixed investment related to information technology has started to increase substantially. In addition, recent changes in the distribution sector are said to be having some effect on price developments in Japan. Taking these into consideration, we will examine how technological innovation and other supply side structural changes have influenced Japan's price developments in recent years and how these differ from experiences in other countries.

This paper tries to present hypothetical answers to the above questions by surveying price developments in Japan in the 1990s and by studying recent effects of structural economic changes on prices.[2]

2. Characteristics of price developments in the 1990s

In this section, we review price developments during the 1990s. As regards relationships between various price indices and economic developments in Japan during this period, prices basically moved along with the supply-demand gap until 1997 (Figures 1 and 2).

In detail, 1990 was when the overheating of the economy was in its last phase as asset prices skyrocketed. From 1991, the euphoria regarding future economic growth collapsed and capital stock adjustment began. Additionally, the balance sheets of firms deteriorated along with the drop in asset prices, and the Japanese economy faced a serious recession. At the beginning of this recession, the deceleration of inflation rates remained moderate as wage adjustments were relatively slow, reflecting a labour shortage among small to medium-sized companies. In these circumstances, consumer price increases peaked at over 3% on a year-to-year basis in 1991. But thereafter, the CPI inflation rate declined until 1993, and domestic wholesale prices dropped.

The economy then bottomed out at the end of 1993 and a moderate economic recovery continued until the beginning of 1997. The money stock increased gradually. Prices basically moved in accordance with the output gap, but there were some phases when prices moved in the opposite

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[1] Hideo Hayakawa is Adviser, Research and Statistics Department, Bank of Japan. Hiroshi Ugai is Senior Economist, Economic Research Division, Research and Statistics Department, Bank of Japan.

[2] The following discussions draw considerable material from a paper released by the Research and Statistics Department (2000-a), and may be understood as excerpts from it.

direction to developments in the gap. For instance, the rate of decline in domestic wholesale prices accelerated during the economic expansion in 1996, when the real GDP growth rate reached 5.1% and the yen depreciated significantly.

In fiscal 1997, Japan's economic growth turned to deceleration, reflecting efforts at fiscal consolidation such as a rise in the consumption tax rate. At the same time, the financial and economic turmoil in Asia started to have its negative effect on the Japanese economy through exports. Furthermore, the disturbance in the financial system triggered by the failure of major financial institutions, including Yamaichi Securities and Hokkaido Takushoku Bank in November 1997, induced a deterioration in corporate and household sentiment as well as a stringent lending stance on the part of financial institutions. The economy then underwent an unprecedented decline during 1998 as both private consumption and business fixed investment fell. Hence, the output gap expanded significantly and immense downward pressure was exerted on prices. Towards the end of 1998, the financial ratings of large firms were lowered frequently, reflecting shrinking corporate profits and worsening balance sheets in line with the economic slowdown. The lending stance of financial institutions became even more cautious. In these circumstances, downward pressure on prices became stronger as the negative link between the weakening of the real economy and the tightening of financial conditions intensified.

From the autumn of 1997 to end-1998, economic deterioration increased the credit risks of firms and a credit contraction occurred, as financial institutions became extremely restrictive about lending. This accelerated the contraction in the real economy. Thus, in 1998, the nominal GDP growth rate dropped to a record low since statistics were first compiled in 1955, and corporate profits were squeezed (Figure 3). Since wage adjustments were slow relative to the contraction in output and prices, corporate profits deteriorated further, and the burden created by the need to repay debts increased in the real term. This led to a further drop in demand. It is usually assumed that the rigidity of nominal wages will stop the fall in prices. In Japan, however, the decline in nominal wages started as a result of efforts by firms to reduce costs (Figure 1). Thus, Japan was at that stage on the brink of a vicious cycle between output and prices, the "deflationary spiral". Fortunately, the threat of a cumulative drop in wages and prices did not turn into reality. Meanwhile, growth in the money stock was relatively rapid, while nominal GDP declined substantially. It seems that further monetary easing and corporate finance policies implemented by the Bank of Japan and the credit guarantee system introduced by the government reduced the downward pressure on prices and kept the economy from a fully fledged deflationary spiral.

From 1999, the disturbance in the financial market observed during 1998 started to become stable. The implementation of the zero interest rate policy and the strong commitment to monetary easing by the Bank of Japan, and easing anxieties over the stability of the financial system resulting from injections of public funds into private banks, helped improve consumer and business sentiment and thereby triggered economic recovery. During this process, downward pressure on consumer prices also weakened. Growth in the money stock dropped slightly.

With respect to the price and economic developments described, the following three observations emerge as puzzles to be solved.

First, why did prices hardly decline from 1998 to the beginning of 1999 during the economic deterioration although the output gap was extremely large? Consumer prices, in particular, should have declined significantly if they were moving along with the Phillips curve that would be estimated by use of the output gap. Yet this relationship suddenly collapsed from 1998 (Figure 2). Even taking the downward rigidity of the consumer price index into consideration, it cannot be explained fully why prices did not decline.[3]

Second, the growth rate of the money stock since 1997 has been paradoxical (Figure 4). The money stock (M2+CDs) grew rapidly from the autumn of 1997 when the real economy underwent a serious recession. On the other hand, money growth recently became sluggish after the economy started to recover, suggesting a wild divergence between money and nominal GDP. Here, it is necessary to

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3 The consumer price index in Japan is expected to have some downward rigidity, particularly in public utilities charges and regulation charges. Kasuya (1999) examined the degree of downward rigidity in the CPI calculating the weights of items of which the change in the price decline is slower than that of the price rise out of the 580 items that constitute the consumer price index, and found that about 20% of items have downward rigidity.

examine the developments in the money stock, especially from 1998 to the start of 1999, in relation to the fact that the economy did not fall into a deflationary spiral.

Third, we need to consider reasons behind divergent developments in each of the price indices. For instance, why did the rate of decline in domestic wholesale prices quicken during the economic recovery in the mid-1990s? Moreover, it may be pointed out that the margin between CPI and WPI inflation rates has significantly narrowed since the mid-1990s[4] (Figure 5). Therefore, it is necessary to examine the relationship between prices and the supply side of the economy, such as technological innovation, increases in imported products, deregulation and the streamlining of distribution channels.

The three puzzles are addressed below.

3. Relationship between the output gap and prices

During the 1997-98 recession, many supply-demand indices showed a substantial output gap suggesting immense downward pressure on prices. But the decline in the consumer price index was extremely moderate in comparison with the suggested deflationary pressures. This is the first puzzle to be examined. There are two clues for this puzzle: first, stagnant domestic supply capacity in the face of economic structural changes, and second; the mismatch in the labour market.

3.1 Measurement of the output gap and potential growth

The output gap captures supply-demand conditions from a macroeconomic perspective by measuring the difference between potential GDP and real GDP. Although there are various estimation methods, we use the following approach. First, we explain Japanese GDP by using a production function that consists of three factors - labour, capital and total factor productivity (TFP). Then, we obtain the output gap from the rate of difference between real GDP and potential GDP, which is the maximum GDP obtained with labour and capital fully utilised.

$$Y_t = A_t \bullet (H_t \bullet L_t)^{1-\alpha} \bullet (Om_t \bullet Km_{t-1} + Oo_t \bullet Ko_{t-1})^{\alpha}$$

Y_t: real GDP, A_t: TFP, H_t: total working hours, L_t: number of workers, α: capital share, Om_t: capacity utilisation rate in manufacturing industries, Km_t: capital stock of manufacturing industries, Oo_t: capacity utilisation rate in non-manufacturing industries, Ko_t: capital stock of non-manufacturing industries.

Recently, the potential growth rate of Japan has been generally considered to be around 2%, and thus, to diminish the output gap, economic growth should surpass this figure. Estimates of the output gap often use only the capacity utilisation rate in manufacturing industries as a demand factor, while ignoring rates in non-manufacturing industries. TFP, which explains the potential growth rate not explainable by the growth in capital and labour, is usually assumed to grow constantly, reflecting technological progress. Indeed, the output gap obtained by this method (thin solid line in Figure 6(1)) expanded in the first half of the 1990s and was temporarily reduced significantly from fiscal 1995 to fiscal 1996.[5] Thereafter, it continued to expand until the end of fiscal 1999. If the output gap followed such a trend, consumer prices should have declined until the end of 1999. Yet consumer prices did not actually decline from 1998. The output gap also contradicts the supply-demand gap indicators

[4] The composition item of consumer goods in the domestic wholesale price index differs from that of the consumer price index. Hence, it is inappropriate to see subtle differences between them. To see changes at the distribution stage, it is not enough to compare import prices at the consumer and wholesale stages. The CPI-related wholesale price index used here is rearranged to match the consumer price index.

[5] The output gap discussed in this paper is defined as a difference between actual GDP and potential GDP, which is obtained when capital and labour are fully utilised. It is necessary to keep in mind that this output gap is larger than those calculated by other methods, such as the output gap between actual GDP and the equilibrium level of GDP where the inflation rate is stable, and the output gap between actual GDP and the average level of GDP when capital and labour are operating at the average level calculated from past data. The level of the output gap differs depending on the calculation method.

based on firms' perceptions, such as the weighted average indicators (Supply and Demand Conditions for Products DI, Production Capacity DI, and Employment Conditions DI in the *Tankan-Short-term economic survey of enterprises in Japan*; Figure 6(2)) that have shown an upturn since the beginning of 1999.

However, it should be noted that when this particular estimation of the output gap is used, large measurement errors occur. In fact, if we estimate the production function by this method, the *Solow residual* obtained by subtracting contributions of capital and labour from GDP has been significantly reduced in recent years. As TFP is assumed to grow smoothly at a constant rate, residuals that cannot be explained by the time trend in the Solow residual are included in components of the output gap which are generated by demand fluctuations. This implies that estimated residuals are all supposed to arise from the fluctuations in the capacity utilisation rate (especially that of non-manufacturers), which cannot be captured statistically. Behind the expansion of the output gap obtained through this method, estimated errors fluctuate largely at random and have been extremely large recently. However, it is doubtful that the capacity utilisation rate of non-manufacturers fluctuates a great deal in the short term. In other words, these unrealistic movements of the output gap may be caused by the assumption that TFP follows a linear time trend and the capacity utilisation rate of non-manufacturing industries is obtained as a residual.

If so, the problem generated by the estimation of TFP trend can be solved by changing the calculation method of the output gap.[6] To do this, we have to estimate the capacity utilisation rate of non-manufacturing industries that has been assumed for convenience to be 100%. Also removing the assumption of the linear trend of TFP, we regard the Solow residual per se as the TFP (hereafter, we call this "the output gap adjusted by the capacity utilisation rate of non-manufacturers"). The functional form used for this is shown in Figure 7. As the capacity utilisation rate of non-manufacturers cannot be observed directly, the production capacity judgment BSI of non-manufacturers (*Business Outlook Survey* of the Ministry of Finance) and the unit of electric power for business use (ratio of electricity consumption for business use to electric power contracted for business use) are used to estimate the rate indirectly. Here, we assume that the BSI captures developments in the capacity utilisation rate in detail, while the unit of electric power for business use is employed to supplement the information at the operating level. More concretely, parameters are estimated by regressing the unit of electric power on the BSI and then the estimate obtained by substituting the BSI is considered to be the capacity utilisation rate of non-manufacturing industries (Figure 8).

TFP calculated in this way fluctuates randomly instead of increasing at a constant rate. Intrinsically, TFP is considered to be the mid- to long-run trend of technological progress and is affected by changes in the quality of capital and labour, efficiency of resource allocation, regulation and deregulation by the government, and social factors such as mobility of labour.[7]

The rate of change in this new output gap (the thick solid line in Figure 6(1)) from its peak in 1990 to the recent trough is smaller than that in the output gap calculated by the classical method. In addition, the new output gap started to close from the beginning of 1999. This indicates that it is moving in tandem with supply-demand indicators based on firms' perceptions (Figure 6(2)).

Next, to get a rough idea of the mechanism that determines prices in Japan, we estimate a Phillips curve based on this output gap. In the estimate, a dependent variable is the inflation rate of consumer

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6 See Kamada and Masuda (2000) for further research on the idea.

7 According to arguments in the United States, TFP includes (1) technological progress, which is intrinsically a quality change of labour but cannot be captured as labour, (2) technological progress which is a quality change of capital but cannot be captured as capital, (3) factors created in compiling data, and (4) other factors. Jorgenson and Griliches (1967) take the view that TFP basically does not move if all noise is removed. This is because if measurement of the input and output data becomes extremely accurate, then technological progress will be reflected in factors such as capital prices. This implies that if there is a problem in the accuracy of measurement, it will also affect TFP. On the other hand, Denison (1979) shows the following four factors as the factors of TFP decline in the United States after 1973: (1) declines in R&D and stock of knowledge; (2) regulation by the government to allocate capital, labour and land to activities other than production, or inefficiency of resource allocation by other regulations and the taxation system; (3) drop in willingness to work among the young generation, and declines of competitive pressure and quality of management; (4) errors caused when compiling data. Moreover, Kendrick and Grossman (1980) indicate the following seven factors as component elements of TFP: (1) accumulation of knowledge; (2) changes in quality of labour; (3) changes in quality of land; (4) the effects of resource reallocation among industries; (5) volume-related factors such as economies of scale; (6) government services; (7) other factors such as changes in legal, institutional and social environment.

prices, and explaining variables are the output gap in the current quarter, the expected inflation rate (proxied by the percentage changes in consumer prices in the previous quarter), and the supply shock (proxied by the percentage changes in import prices in the current quarter). The estimation result was essentially satisfactory (Figure 9) and the basic behaviour of the inflation rate can be explained by this relationship.

$$\pi_t = const + \beta \bullet \pi_{t-1} + \gamma \bullet GAP_t + \delta \bullet WPIIM_t$$

Estimation period: 1983 Q3-1999 Q4

π_t : changes in the CPI (quarter-to-quarter trend cycle annualised, %)

GAP_t : output gap

$WPIIM_t$: changes in import prices (wholesale prices, yen basis, total average, quarter-to-quarter percentage change, annualised, %)

This new estimation shows that the reason that the output gap hit bottom, although the economic growth rate was low in fiscal 1999, was that TFP as a domestic supply factor reflects not only technological progress but also short-term fluctuations caused by various factors. During the 1990s in particular, the external environment changed, as is observed in the changes in industrial structure due to the globalisation of the economy and the recent introduction of information technology (IT). In these circumstances, it is likely that most of the capital stock, accumulated due to the vast business fixed investment until around 1990, has become obsolete, although it still exists.[8] Furthermore, in the process of these structural changes, an increasing number of firms require employees to obtain widely applicable and highly technical skills instead of skills specific to an individual company. When workers are not ready to satisfy this requirement, it is highly probable that labour productivity will decline. As the economic value of capital and labour decreases, TFP in Japan and in turn overall capacity growth seems to be lower than the potential growth rate calculated using the classical method, at least in the short run.[9,10] From this perspective, the contraction of the output gap despite low economic growth since 1999 can be explained.

As indicated, there are various problems surrounding the measurement and concept of the potential growth rate and output gap. The output gap should only be used when explaining price development trends and should not be expected to match short-term price fluctuations. Comparing the estimated values of consumer prices obtained from the Phillips curve and actual consumer prices, however, the estimated value dropped while the actual value increased somewhat at the end of 1998. Therefore, it seems that this factor is not enough to explain why prices did not fall during this recession period.

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8 As regards evaluating the capital stock of private firms in terms of market value using second-hand prices, the growth rate of capital stock has been fairly low in recent years (for details, see Masuda (2000)). Furthermore, it may be that capital stock exists on firm's books but they no longer consider it to be valuable equipment. In this case, the value of capital stock decreases further and the growth rate declines even more. This is highly possible in the present environment, where structural adjustments are ongoing. The classical output gap based on the fixed capacity utilisation rate of the non-manufacturing industries is likely to be overestimated as a result of this factor. In the new output gap, TFP reflects problems surrounding the measurement of capital stock to some extent.

9 The recent growth rate of the domestic supply capacity remains at around 1% when using this output gap. The figure is smaller than the potential growth rate (just below 2%) obtained when using the traditional production function approach. It should be kept in mind that these figures are subject to measurement errors.

10 The following two aspects should be taken into consideration when examining the influence on potential growth of changes in the industrial structure symbolised by the IT revolution. First, in the mid to long run, if IT is to really take root in the Japanese economy, an increase in productivity may be expected as observed in the United States in recent years. Second, in this process, existing capital and human capital will, however, become obsolete and this is likely to reduce the capacity growth in the short run. In fact, even in the United States, the effects of the IT revolution did not appear immediately in the productivity statistics until the mid-1990s and this was regarded as one of the "puzzles". Thus, while existing capital and labour continue to deteriorate in the future, we must take into careful consideration that if IT becomes full-scale, the mid- to long-term potential growth of Japan will not decline significantly even though the prior or the present capacity growth is low.

3.2 Expansion of the mismatch in the labour market

Among the relationships between various supply-demand gap indicators and prices, the divergence between the unemployment rate and prices is the most conspicuous. This means that, especially in the labour market, supply-demand conditions that influence prices cannot be measured just by the unemployment rate. At present, the unemployment rate in Japan stands at 4.6% (as of August 2000), remaining around the highest level since statistics were first compiled. There is a negative relationship between the vacancy rate, which indicates insufficient employment, and the unemployment rate, which shows excess employment (Beveridge curve; Figure 10(1)). From the 1970s, however, the curve has repeatedly shifted to the right or right-upwards. Recently, the vacancy rate has increased slightly but the unemployment rate remains at the highest recorded level. The right shift or the right-upward shift of the relationship between the vacancy rate and the unemployment rate means that firms perceive that excess employment persists, while others feel there is insufficient employment. It is highly probable that some factors of a structural mismatch regarding labour supply and demand have strengthened. This contrasts with the United States experience, where the relationship between the two rates shifted left-downwards from the 1990s (Figure 10(2)). This growing mismatch in the labour market is likely to cause a decline in the equilibrium level of the output gap.[11] In line with the expansion of the output gap during 1998 to 1999, the equilibrium level declined. Thus, it is likely that deflationary pressures were not exerted on the economy, as shown in the gap expansion.

To distinguish the number of workers unemployed as a result of business cycles from those whose unemployment stems from structural factors, we have made four categories to explain unemployment:[12] (1) macroeconomic activity shocks due to business cycles; (2) mismatch in labour supply and demand reflecting age and sex among firms and industries (redistribution shock); (3) exogenous changes in the labour force due to the enlarged female participation rate (labour force shock); (4) hysteresis caused by the above factors and long-term changes in the labour force age composition (for instance, when unemployment occurs due to economic recession, it has irreversible effects on the economy, such as the loss of skills; deterministic trend). The result suggests that the effects triggered by the economic recession have finally weakened from their worst level (Figure 11).[13] On the other hand, the long-term increasing trend of unemployed workers continues, since it takes them a long time to find jobs due to lost labour skills, and the labour force age composition changes. Furthermore, structural adjustments of industries and changes in ways of thinking about employment among young generations seem to have increased the number of unemployed workers since 1995. Recently in particular, firms have been taking globalisation and IT into account. Under these conditions, firms have rapidly changed their stance towards their employees by requiring highly technical skills that are widely applicable for many purposes. In this sense, the factors that cause the stagnant capacity growth by deteriorating the value of the domestic labour force may simultaneously create a supply-demand mismatch in the labour market.

There seem to have been structural changes in recent years in the relationship between the unemployment rate and the change in wages (unit labour cost) (Figure 12(1)). The increase in the number of unemployed workers from 1998 was apparently not only due to economic deterioration, but also due to other structural factors. Hence, downward pressure on prices from 1998 to early 1999 was not as strong as indicated by the increase in the unemployment rate or the expansion in the output gap.[14]

We have presented two hypotheses which should explain why consumer prices did not decrease as much as predicted by the output gap from 1998 to early 1999. The argument is as follows: although

[11] The "equilibrium level" of the output gap refers to the level of the output gap which is analogous to the level of the natural rate of unemployment in the labour market. This is expected to be lower than the level of potential GDP when the mismatch in the labour market is resolved and capital is fully used.

[12] See Nishizaki (2000) for details.

[13] To break down the number of unemployed workers, we estimate reduced form VAR by standardising the Beveridge curve. The impacts of the hysteresis are extracted. Furthermore, structural parameters are estimated on errors to identify the macroeconomic activities shock, redistribution shock and labour force shock. For detailed examples on the United States, see Blanchard and Diamond (1989).

[14] In fact, there exists a negative correlation between unit labour cost and the unemployment rate based on shocks from macroeconomic activities such as economic recovery and recession (Figure 12(2)).

the output gap was large in 1998, it was smaller than calculated based on the medium- to long-term potential growth rate usually imagined. Furthermore, downward pressure on prices moderated somewhat as the equilibrium level also declined. All these factors were confirmed to keep the Japanese economy from falling into a deflationary spiral.

4. Relationship between money stock and nominal GDP

To understand why the Japanese economy did not fall into a deflationary spiral from 1998 to 1999, we need to examine the impact not only on the real side of the economy, but also on the financial side. During this period, an unusual phenomenon seems to have occurred: the money stock continued to grow at a high rate in contrast to nominal GDP. In fact, the relationships among the money stock (M2+CDs), the economy (real GDP), and prices (GDP deflator) show that in 1998, the actual growth rates of the money stock always exceeded their forecast values (Figure 13). This implies that some missing variables that explained money demand played an important role in moving the money stock during this period. This is the second puzzle to be solved.

The fully fledged deterioration of the Japanese economy in 1997 was largely prompted by the disturbance in the financial system caused by the failures of large financial institutions in November 1997 (Sanyo Securities, Hokkaido Takushoku Bank, Yamaichi Securities, etc). As a result, concerns about corporate financing increased rapidly and many risk premiums were added to interest rates for fund-raising (Figure 14). This situation deteriorated further due to a drop in corporate profits from the second half of 1998.

In these circumstances, an increasing number of firms and households not only refrained from spending to secure liquidity, but also increased precautionary fund-raising.[15] It is highly likely that the latter caused the rise in the money. In fact, the money stock continued to grow and the *Marshallian k* (M2+CDs/nominal GDP) increased. Moreover, there was a possibility that if financial institutions could not supply sufficient liquidity, firms might have tried to obtain liquidity even by selling products and inventories, which was indeed seen in some Asian countries during the crisis period. In other words, although the relationship between money and the economy is normally loose, the interaction between lack of liquidity and price decline could become distinct when demand for liquidity increases drastically as seen during this period.

After all, a deflationary spiral did not materialise as various monetary measures or policies adopted by the Bank of Japan and the government wiped out corporate and household anxieties over liquidity during 1998 and 1999.[16] Since 1999, the growth of money stock has become rather slow as precautionary demand for liquidity by firms and households has decreased.

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15 For details on the influence of the anxieties over the financial system on the Japanese economy, see Hayakawa and Maeda (2000).

16 In autumn 1998, the Bank of Japan eased monetary policy further, lowering the target rate of the uncollateralised overnight call rate. Moreover, in response to the credit crunch felt by firms, the Bank expanded CP repo operations and established a temporary lending facility to support firms' financing activities. The Bank also started to consider the implementation of a new market operation scheme, which utilises corporate debt obligations as eligible collateral, and made loans directly or through the Deposit Insurance Corp for bankrupt financial institutions to continue business until final disposals were completed. In addition, the government implemented measures such as enhancing the credit guarantee system (Figure 15). These measures eased anxiety over liquidity, and the risk of further deflation created by selling goods was avoided.

From the beginning of 1999, liquidity risks reduced significantly and the economy started to pick up, due to the easing of financial anxiety which occurred as a result of the Bank of Japan's introduction of the zero interest rate policy and the government's injection of public funds into private banks.

5. Relationship between changes on the supply side of the economy and prices

The third issue to be addressed is how structural changes on the supply side such as technological innovation, increasing import penetration, deregulation and the streamlining of distribution channels affected prices throughout the 1990s. Here, it is interesting to observe that the relationship between real growth and inflation, especially in terms of the GDP deflator, looks rather tenuous, suggesting the importance of supply side developments (Figure 16).

5.1 Technological innovation

In the United States, there are discussions about the channel that suppresses the rise in prices due to the enhancement of productivity led by IT, and whether the United Kingdom follows this trend.[17] In Japan, however, stagnant business fixed investment throughout the 1990s led to a decrease in capacity growth, and as mentioned above, capacity growth recently seems to have been sluggish, at least in the short term. From these facts, it is thought that at present, the downward pressure on prices resulting from technological innovation is not accelerating.

However, the impact of the enhancement of productivity on the manufacturers' side, mainly in electronics equipment, is clearly seen in price indices. For instance, the domestic wholesale price index has been on a decreasing trend, even during the economic expansion phases of the 1980s and 1990s, except for the so-called bubble economy era in the second half of the 1980s. This is because electronics machinery-related technological innovation has exerted downward pressure on domestic wholesale prices through price declines in products such as semiconductors and personal computers. To capture the degree to which the technological innovation factor pushes down domestic wholesale prices, we calculate the contribution of items whose prices tend to be reduced with item-change, reflecting technological innovation. The results are shown in Figure 17. As a whole, technological innovation contributes to the decline in domestic wholesale prices or their final goods prices constantly and rather firmly.

5.2 Industrialisation in Asian countries and the increase in reverse imports

One of the factors that influenced import prices in the 1990s was the appreciation of the yen. From 1993 and also from 1998 (Figure 18), prices of intermediate goods in wholesale prices decreased in parallel with the appreciation of the yen, and after a while prices of final goods in wholesale prices started to decline. Consumer prices of imported/import competitive goods[18] also decreased slightly thereafter. Apart from intermediate goods, the pace of decline in final goods prices slowed, but prices did not increase even though the yen depreciated as from the second half of 1995.

This is not only because the appreciation of the yen pushes down prices of imported/import competitive goods, but also because a rapid expansion of inexpensive imported goods indirectly pushes down the prices of import competitive goods (Figure 19). Behind this essentially lies the price gap between Japan and Asian economies where personnel expenses and intermediate input costs are much lower than in Japan. In addition to the appreciation of the yen in the 1990s, the progress of industrialisation in Asian economies has significantly increased their supply capacity, resulting in a massive inflow of inexpensive final goods into Japan. It is also noted that a shift in production from Japan to Asia was a driving force for the industrialisation in Asian economies during the 1990s. Since 1993, the shift of production to Asia has become fully fledged. In the mid-1990s, an international division of labour between Japan and Asia was established, in which parts of IT-related equipment supplied by Japan were assembled in Asia to produce personal computers and audio equipment,

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[17] See Julius (1999), Vickers (2000), Wadhwani (2000) and Greenspan (2000a, b) for discussions of these aspects of prices.

[18] Composed of imported/import competitive items in the consumer price index. Specifically, items are aggregated that are regarded as import prices in wholesale prices, as well as those that are not included at the wholesaling stage, but obviously have a characteristic of imported/import competitive items. Since there is a high possibility that petroleum product prices move differently to other items, reflecting market conditions for crude oil, disturbance factors including petroleum products are excluded here.

which were then supplied globally. Inexpensive products were also reimported to Japan. The impact of this trend on prices can be confirmed by looking at the list of CPI items where the contribution rates of decline were the largest (top 50 items; Figure 20). The results show that the number of durable consumer goods, such as audio and other electrical appliances, increased rapidly from 1995 to 1996, and there were many items in apparel products in the first half of the 1990s.

5.3 Deregulation

Deregulation's downward pressure on prices has been observed from the beginning of the 1990s. For instance, in 1991 restrictions on beef imports were abolished, and large-scale retailers started to open new stores one after another with the deregulation of the Large-Scale Retail Store Law. Moreover, the Foodstuff Control Law and Provisional Measures Law on the Importation of Specific Petroleum Refined Products were abolished in 1995 and 1996 respectively. There appears to be a continuing impact as a result of these deregulations. Looking at the list of CPI items whose prices are declining fast (Figure 20), it is clear that petroleum products and rice have been constantly affected by deregulation. In addition, the decrease in corporate service prices is influenced by declines in communications fees and the damage insurance premium. In the immediate future, deregulation in electricity charges and communications fees is expected to affect prices.

5.4 Streamlining of distribution channels

Streamlining of distribution channels means the reduction of distribution margins by cutting excess profits or distribution costs, especially at the distribution stage. The streamlining of distribution channels is typically visible in the rapid rise of inexpensive imported apparel products made in China in the first half of the 1990s. The time when these Chinese products were imported rapidly roughly matches the time when discount stores and roadside chain stores started to increase. This boom then seemed to die down. However, since 1999 newly emerging retailing firms have improved both the quality of goods by guiding manufacturing skills in China and the import techniques for a large amount of inexpensive goods, aided by the appreciation of the yen. This movement has steadily taken root and an increasing number of volume sellers are beginning to cut prices to compete with inexpensive imported goods. These points are, once again, confirmed by looking at the list of CPI items whose prices declined fast (Figure 20). The number of items in apparel products in the top 50 has gradually increased since the end of 1998 after items such as suits and women's dresses obtained a majority in the early 1990s. Recent activities of newly emerging retailing firms seem to have encouraged a reorganisation in Japanese distribution industries, which have long been criticised for their inefficiency. In fact, the ratio of sales in wholesaling to sales in retailing, and the ratio of total sales in wholesaling to sales in wholesaling for retailing and final demand have continued to decrease from the beginning of the 1990s (Figure 21).

Among the four points cited as supply side factors, factors 2 to 4, which became prominent in the 1990s, can be understood as part of the price level adjustment process through revisions of high domestic prices and a narrowing of the price gap between Japan and abroad. It has been pointed out that in Japan, the cost of living is high due to relatively high services prices and distribution costs, while the prices of industrial products exposed to world competition are low. These corrections of high prices did not progress very much until the first half of the 1990s, but thereafter the price gap has been gradually reduced (Figure 22). This is because transactions aiming for arbitration of prices have expanded, triggered by an expansion of the price gap between Japan and abroad due to the appreciation of the yen, and by global business relationships in the world economy becoming widespread. In recent years, the introduction of globally used business models that provide inexpensive and high-quality products has exerted adjustment pressure on the price gap between Japan and abroad. Furthermore, intensified global business relationships expand the range of tradable goods and to some extent have arbitrage effects between Japan and abroad on services prices in the form of deregulation.

This "globalisation of prices" eventually enhances both the economic efficiency and the purchasing power of customers in the Japanese economy. Through this process, however, domestic demand partly leaks overseas and profits of specific industries may be squeezed due to the decline in competitive power and the narrowing of margins in existing conventional industries and wholesalers or retailers protected by regulations. The fact that this process has deflationary effects in the short term means that it must be carefully monitored.

6. Concluding remarks

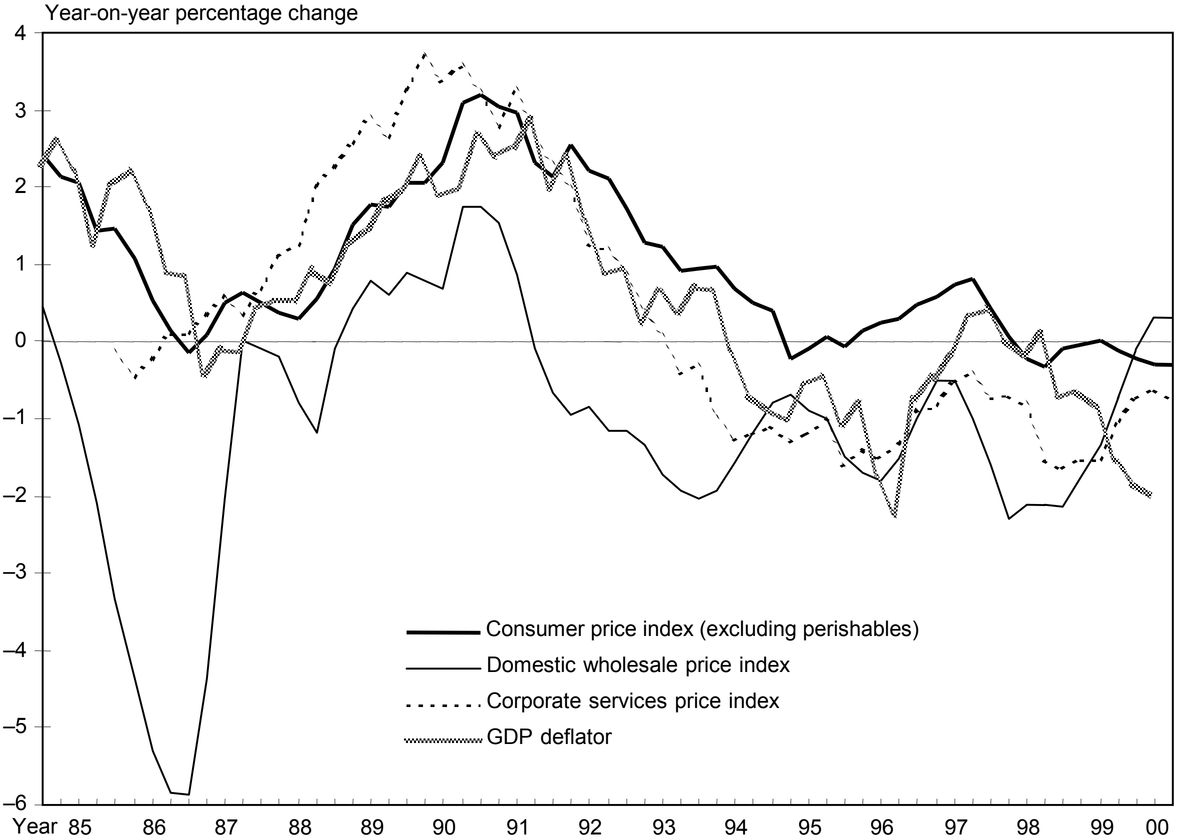
The output gap derived from the classical method does not separate supply factors successfully from demand factors and thus fails to indicate actual supply-demand conditions. We tried to capture the demand side more accurately by estimating the capacity utilisation rate in non-manufacturing industries, and we re-estimated the output gap by measuring short-term capacity growth. We discovered that the rate of change in the gap from its peak in 1990 to the recent trough is smaller and the current output gap is closing gradually in line with the economic recovery that started in spring 1999, although it is still large, and its equilibrium level has been lowered.

However, it is still hard to calculate "the real output gap" as large measurement errors may exist, especially in the current situation where there are structural changes in the Japanese economy. In these circumstances, we should also examine in detail the current movements of price indices to find the effects of supply side factors. Taking the output gap and the details of price indices into consideration, our conclusion is that downward pressure on prices stemming from weak demand seems to be declining significantly.

Needless to say, it is difficult to distinguish how much of the change in price levels comes from weak demand and how much from the supply side. Furthermore, price declines may have a negative impact on the economy in the short run, even though they do not come from weak demand, ie when they are induced by the closing of the gap between domestic and foreign prices. In this situation, one way to see whether the Japanese economy is under deflationary pressure is to examine the background of price behaviour from the distributive side. Currently, corporate profits are increasing without a decrease in the compensation of employees. This implies sustainability of the economic recovery under moderately declining prices.

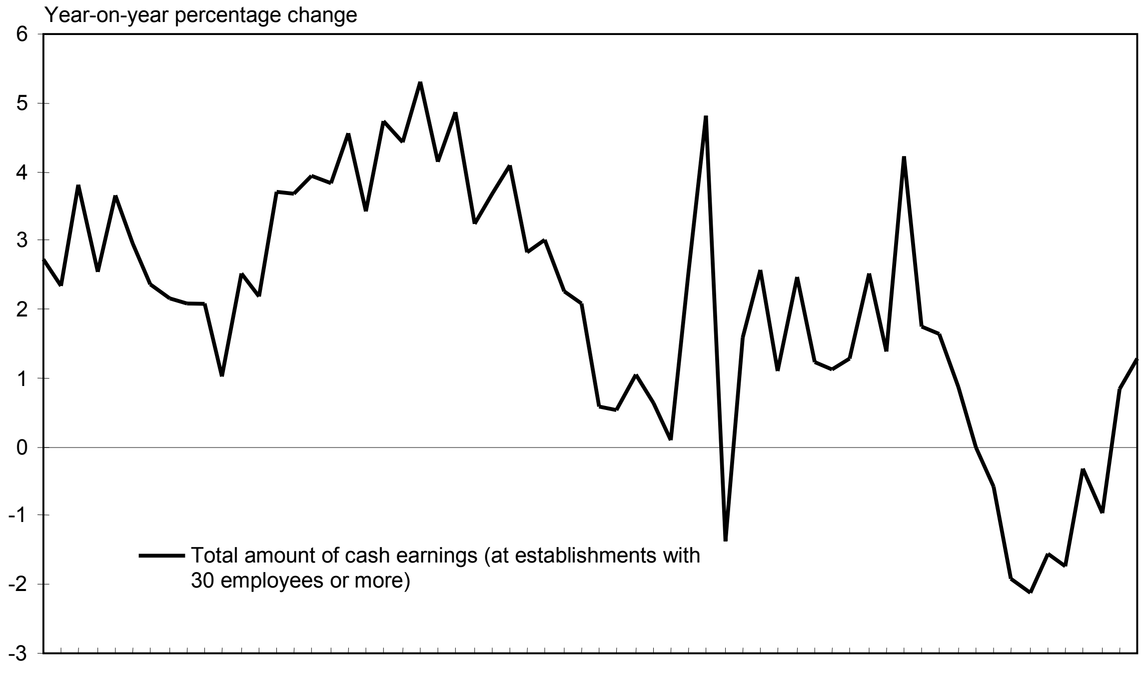
Recently, investment in IT has started to become active in the Japanese economy. If this investment spreads throughout the economy and enhances total productivity, it will constrain price rises. Nevertheless, at present there is no clear evidence that IT is stimulating total productivity, except for enhancing productivity among IT manufacturers, especially that of the electronics machinery industry. It will also take some time before the mismatch in the labour market disappears, but when it does this too will enhance total efficiency in the economy. On the other hand, in the distribution sector, efforts to enhance productivity have started to bear fruit. This phenomenon affects prices at the consumer level, which means that consumer prices are likely to remain weak even amid economic recovery.

Figure 1
Various price indices



Notes: 1. Adjustments for the effects of the consumption tax of April 1989 are made using the level-shift dummy of X-12-ARIMA, while those for the effects of the consumption tax hike of April 1997 use the theoretical value on the assumption that prices of all taxable goods fully reflect the rise in the tax rate. (However, the GDP deflator is adjusted using the level-shift dummy for both April 1989 and April 1997.) 2. Data for 2000 Q3 CPI, Domestic WPI, and CSPI are from July.

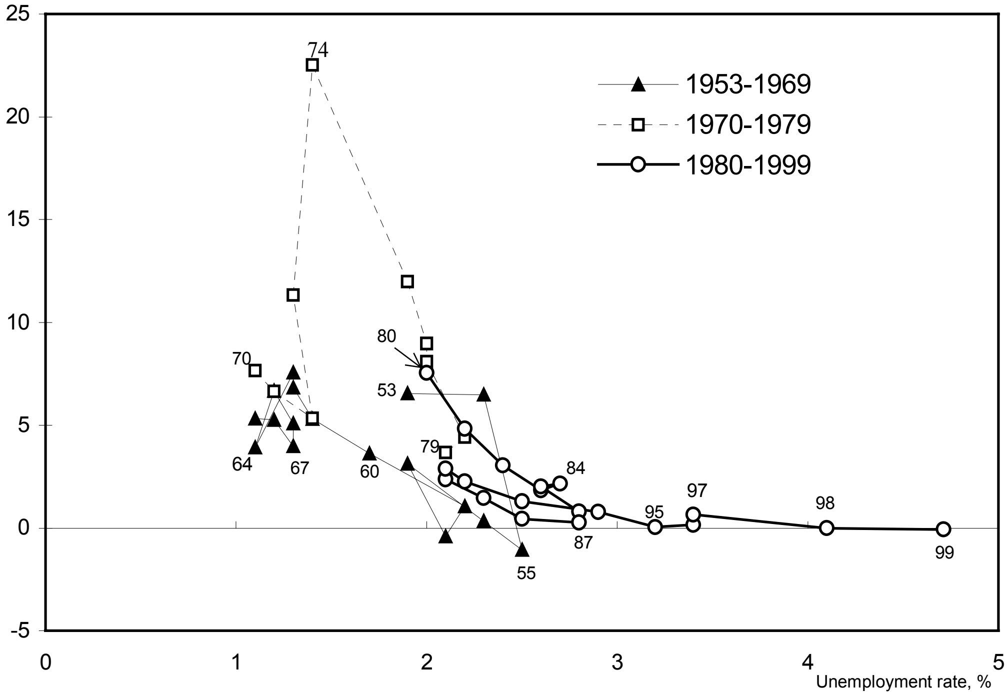
Reference: Nominal wages (total amount of cash earnings)



Sources: Management and Coordination Agency, *Consumer Price Index*; Bank of Japan, *Wholesale Price Indexes*; Economic Planning Agency, *National Income Statistics*; Ministry of Labour, *Monthly Labour Survey*.

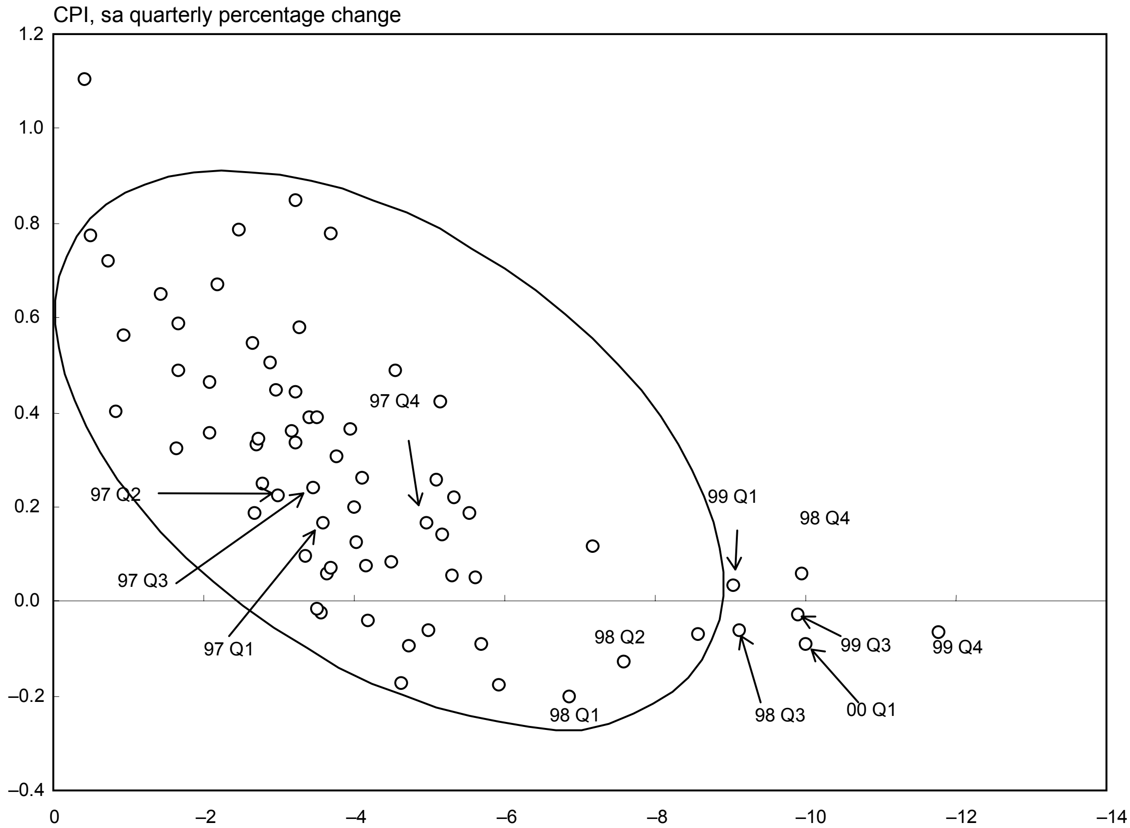
Figure 2
Supply-demand gap and prices

1. Phillips curve of the labour market



Note: General CPI 1953-70 = excluding inputed rent; 1971-99 = excluding perishables (adjusted for effects of comsumption tax).

2. Output gap and inflation rate

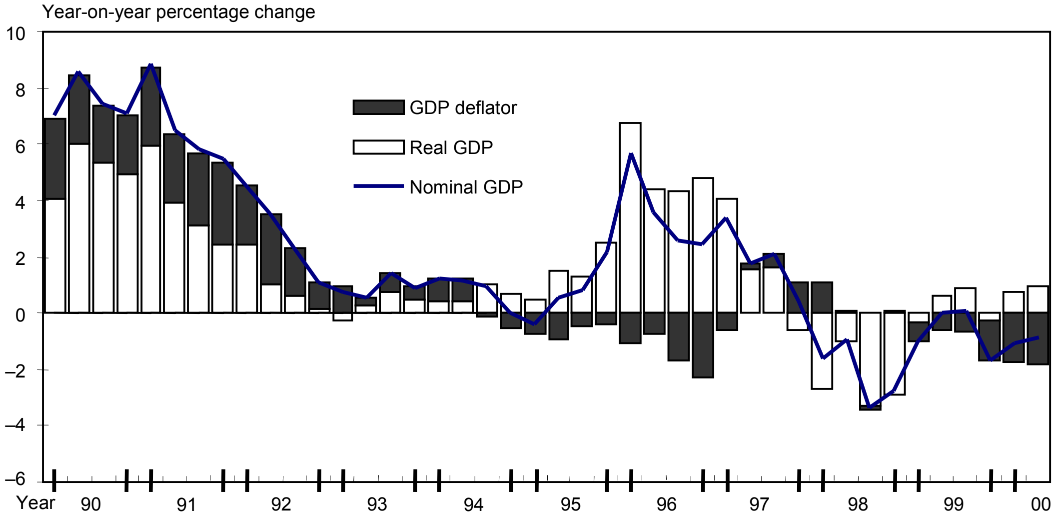


Notes: 1. Period: 1983 Q2-2000 Q1. 2. Output gap = classical output gap obtained by fixing the capacity utilisation rate of non-manufacturers (estimated by the Research and Statistics Department, Bank of Japan). CPI = General, excluding perishables (adjusted for effects of consumption tax).

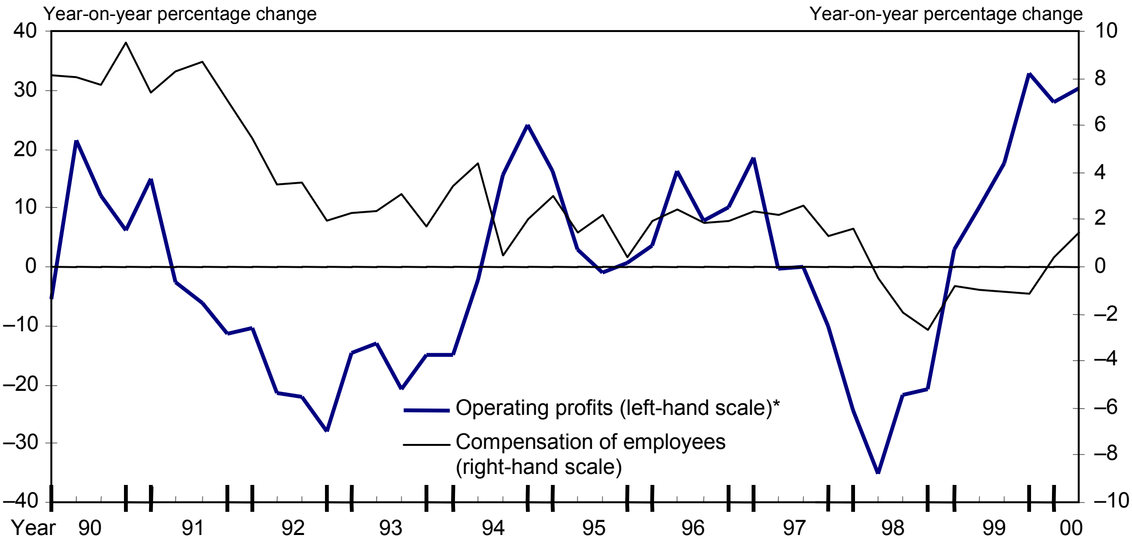
Sources: Management and Coordination Agency, *Consumer Price Index*, *Labour Force Survey*.

Figure 3
Nominal GDP and profit/employment

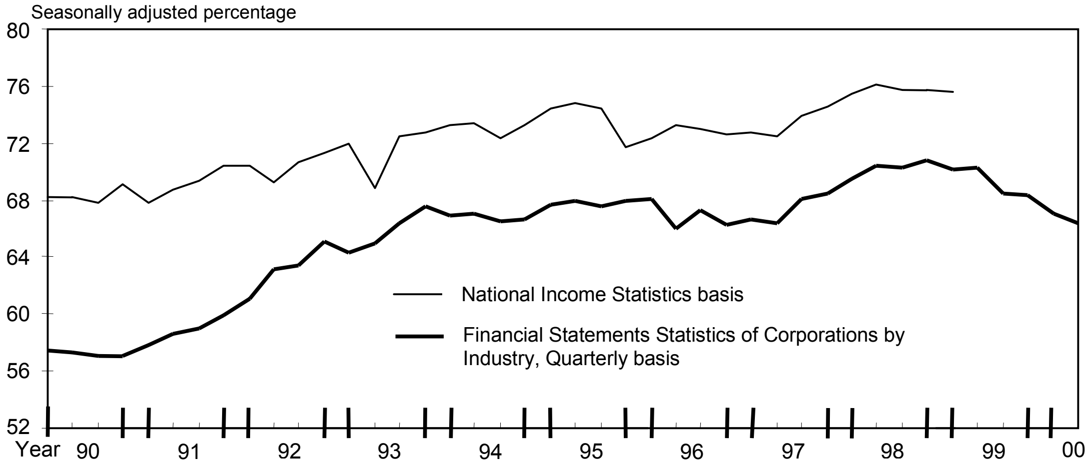
1. Nominal GDP



2. Operating profits and compensation of employees



3. Labour share

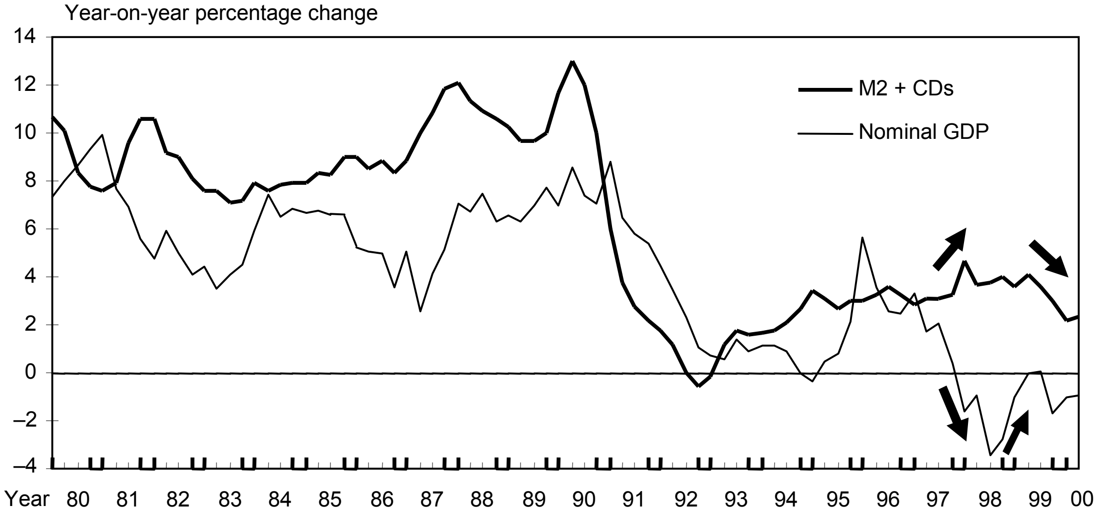


Notes: 1. Operating profits drawn from *Financial Statements Statistics of Corporations by Industry, Quarterly*. Figures of the *Financial Statements Statistics of Corporations by Industry, Quarterly* are based on all industries of all sizes (excluding large firms in medical and other services which include holding companies). Adjusted for discontinuity of data. 2. From 1999 Q1, data for compensation of employees are based on quarterly estimates. 3. Labour share (from *National Income Statistics*) = compensation of employees/ (compensation of employees + operating profits) × 100. 4. Labour share (from *Financial Statements Statistics of Corporations by Industry, Quarterly*) = personnel expenses / (personnel expenses + current profits + interest expense paid + depreciation) × 100.

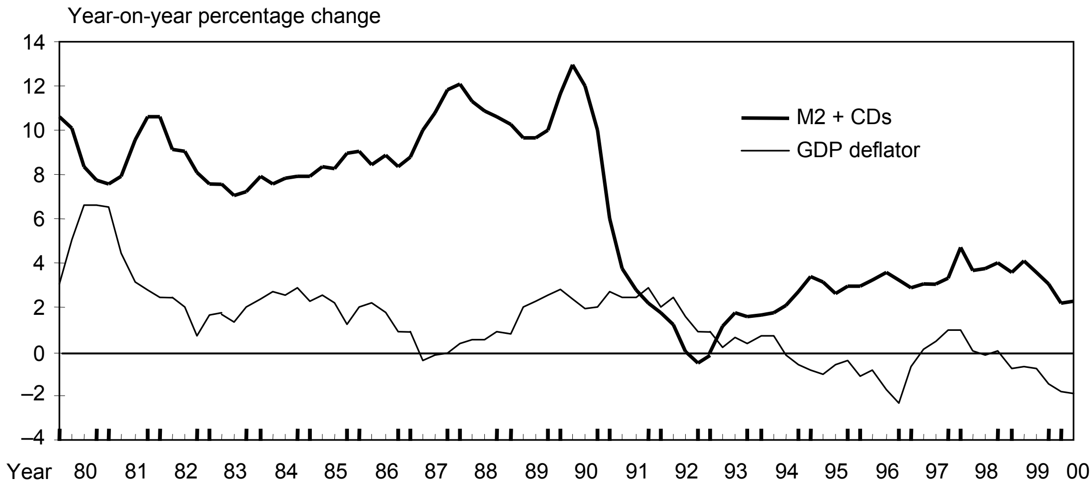
Sources: Economic Planning Agency, *National Accounts*; Ministry of Finance, *Financial Statements Statistics of Corporations by Industry, Quarterly*.

Figure 4
Money stock, prices and GDP

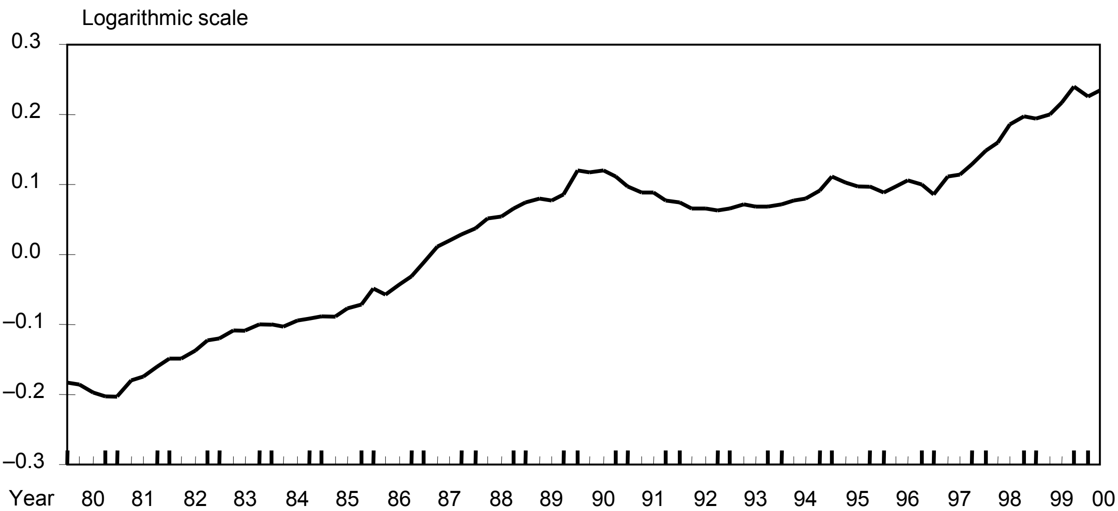
1. M2 + CDs, nominal GDP



2. M2 + CD; GDP deflator

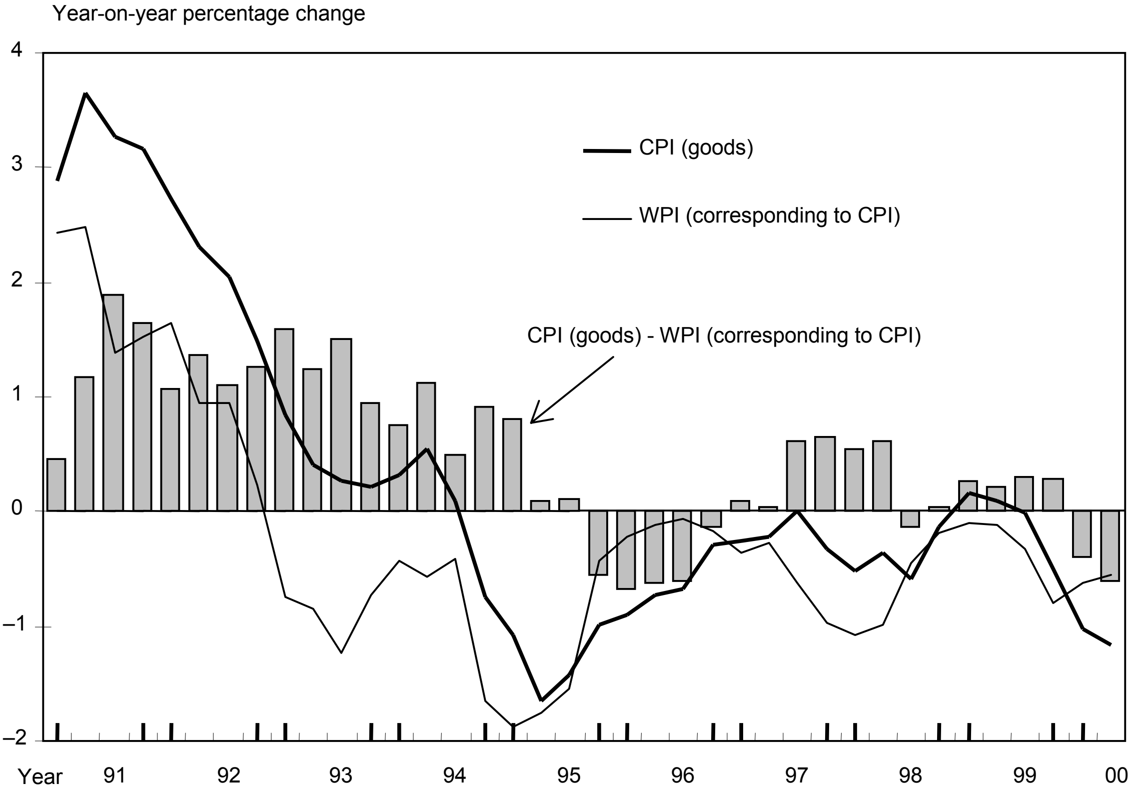


3. Marshallian K (M2 + CDs/nominal GDP)



Sources: Economic Planning Agency, *National Accounts*; Bank of Japan, *Financial and Economic Statistics Monthly.*

Figure 5
CPI (goods) and WPI (corresponding to CPI)



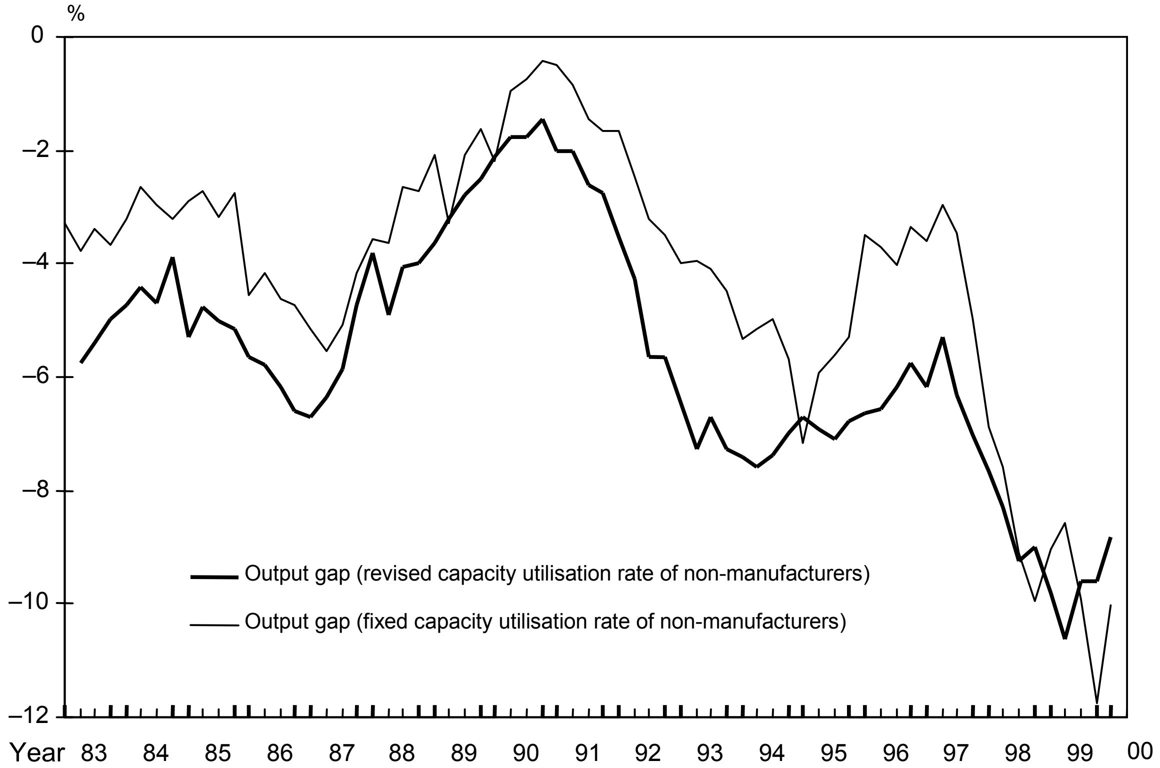
Notes: 1. WPI (corresponding to CPI) = items in the WPI that correspond to items included in CPI (goods) are weighted averages based on CPI weights. 2. Goods exclude perishables, electricity, gas and water charges and petroleum products. 3. Adjusted to exclude the effects of the consumption tax hike in April 1997.

Sources: Bank of Japan, *Wholesale Price Indexes;* Management and Coordination Agency, *Consumer Price Index*.

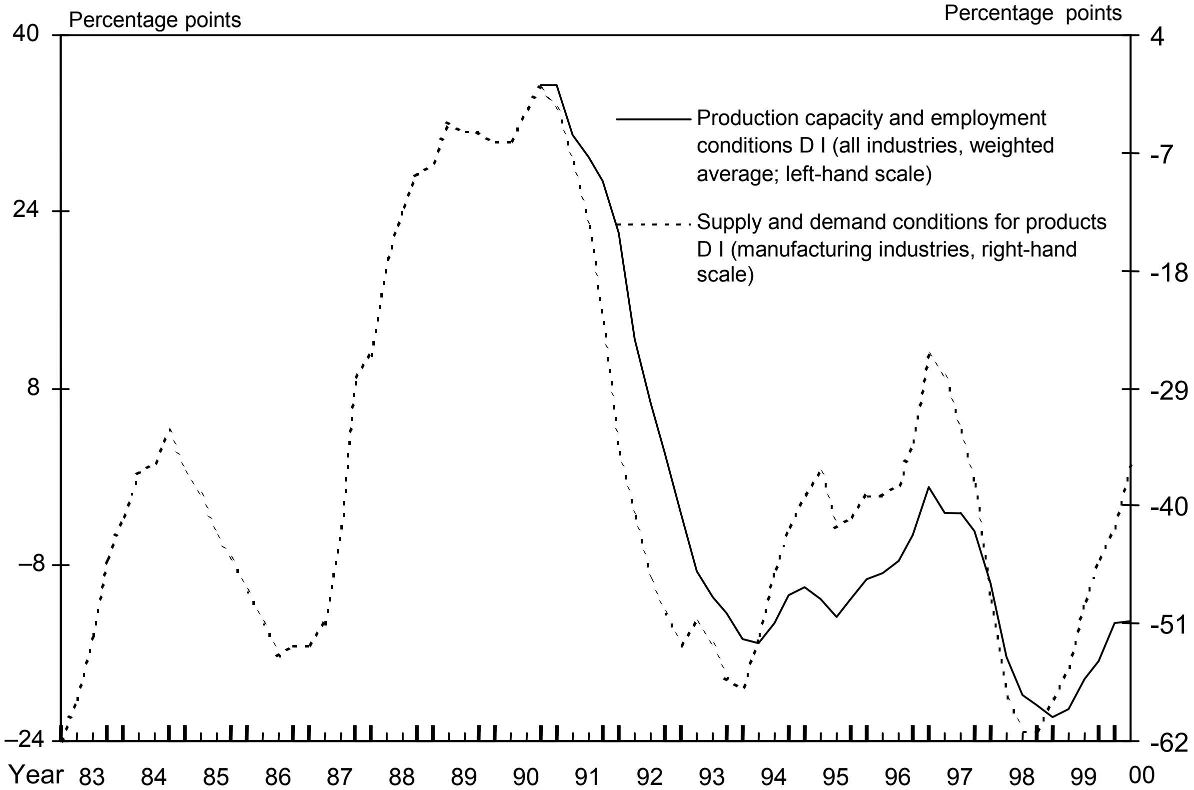
Figure 6

Supply-demand gap

1. Output gap



2. Supply-demand gap indications (from S*hort-Term Economic Survey of All Enterprises in Japan*)



Sources: Ministry of Finance, *Business Outlook Survey of the Ministry of Finance*; Economic Planning Agency, *National Accounts*, *Capital Stock of Private Enterprises*, *etc*; The Federation of Electric Power Companies Japan, *Electricity Demand*; Bank of Japan, *Short-Term Economic Survey of Enterprises in Japan*.

Figure 7

Estimation method for output gap

(Revised capacity utilisation rate of non-manufacturers)

1. Estimation of total factor productivity (TFP)

(1) Assume the Cobb-Douglas production function

$$Y_t = A_t \cdot (H_t \cdot L_t)^{1-\alpha} \cdot (Om_t \cdot Km_{t-1} + Oo_t \cdot Ko_{t-1})^{\alpha}$$

Y_t: real GDP, A_t: TFP, H_t: total hours worked, L_t: number of workers employed,

α: capital share ratio, Om_t: capacity utilisation rate (manufacturing),

Km_t: capital stock (manufacturing), Oo_t: capacity utilisation rate (non-manufacturing),

Ko_t: capital stock (non-manufacturing)

(2) Calculation of TFP

Obtain TFP (A*t*) by taking the logarithm on both sides of the equation and then subtracting the contribution of capital and labour from GDP

$$\ln A_t = \ln Y_t - (1-\alpha) \cdot \ln(H_t \cdot L_t) - \alpha \cdot \ln(Om_t \cdot Km_{t-1} + Oo_t \cdot Ko_{t-1})$$

2. Calculation of potential GDP

Potential GDP = GDP produced using both maximised capital and labour. Then, substitute the maximum input amount of each production factor of capital and labour into the production function calculated in 1.

$$QN_t = A_t \cdot (H\,max_t \cdot L\,max_t)^{1-\alpha} \cdot (Om\,max_t \cdot Km_{t-1} + Oo\,max_t \cdot Ko_{t-1})^{\alpha}$$

QN_t: potential GDP, A_t: TFP, $Hmax_t$: maximum total hours worked,

$Lmax_t$: maximum number of workers employed, α: capital share ratio,

$Ommax_t$: historical maximum value of capacity utilisation rate (manufacturing),

Km_t: capital stock (manufacturing),

$Oomax_t$: historical maximum value of capacity utilisation rate (non-manufacturing),

Ko_t: capital stock (non-manufacturing)

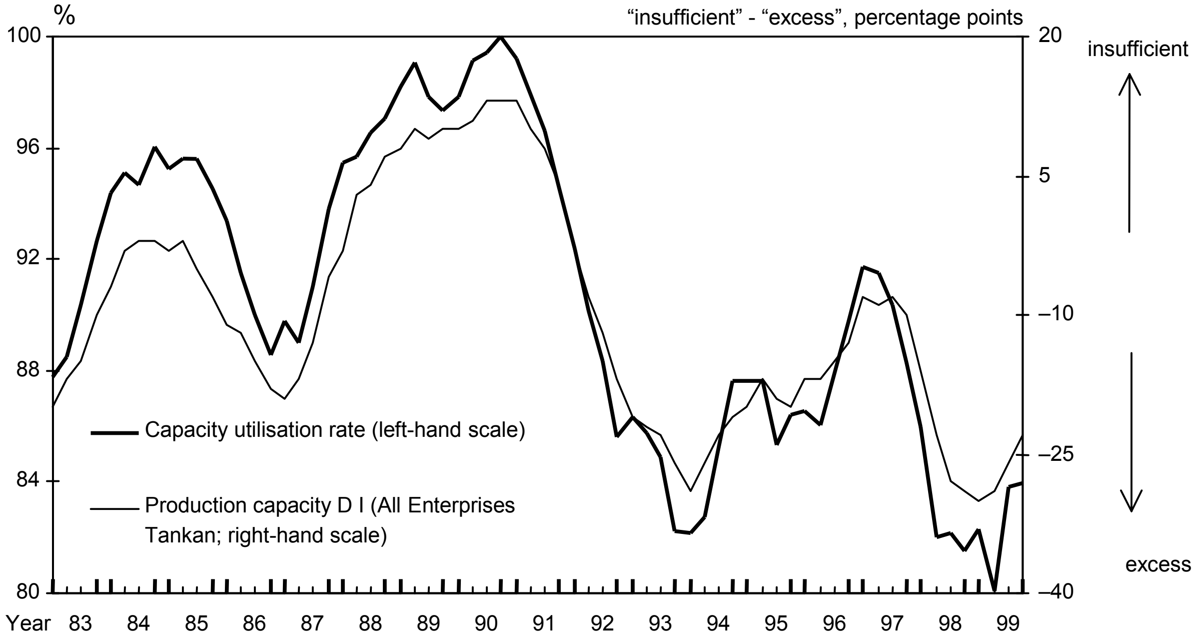
3. Calculation of the output gap

Calculate the output gap using the rate of divergence between GDP and potential GDP.

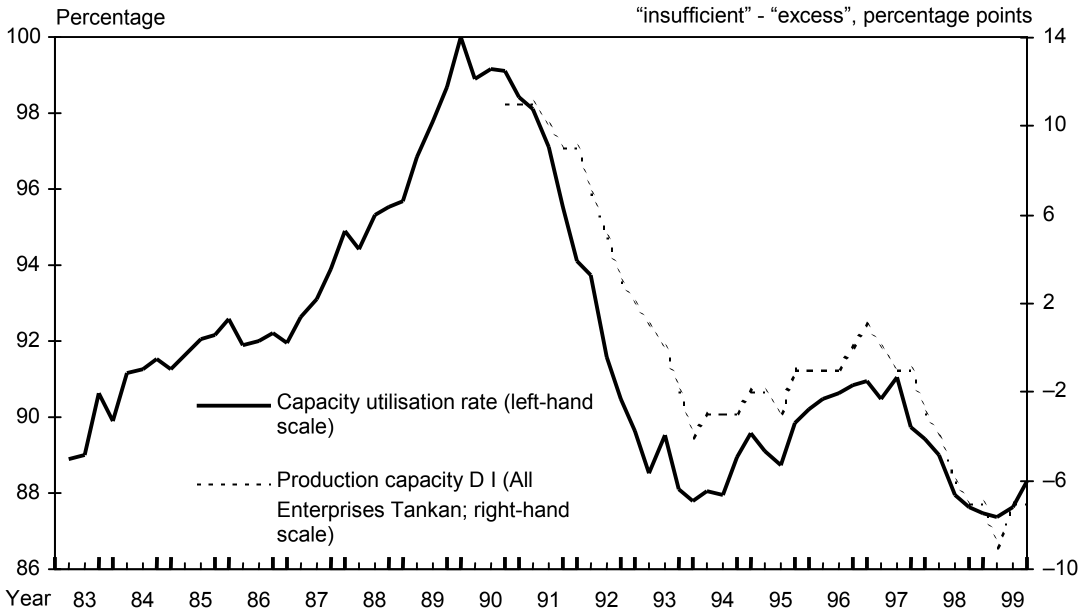
$$GAP_t = \frac{GDP_t}{QN_t} \cdot 100 - 100$$

Figure 8
Capacity utilisation rate (output gap estimation)

1. Capacity utilisation rate of manufacturers



2. Capacity utilisation rate of non-manufacturers



Note: Capacity utilisation rate: historical maximum value = 100.

Estimation method for capacity utilisation rate (non-manufacturing)

1. Regress commercial power unit on BSI and make it level using the parameter.
(Estimation)

Commercial power unit = 487.3 + 2.10 × Trend + 4.72 × BSI + ε
(130.3) (24.7) (11.1)

Estimation period : 1983 Q2-1999 Q4, Adj-R^2: 0.90, D W ratio: 0.58

Unit of electric power for business use:

commercial unit = commercial electricity consumption/commercial power contracts.

Trend: linear trend during the estimation period.

2. From the estimation result, the capacity utilisation rate of non-manufacturers is obtained by:
capacity utilisation rate of non-manufacturers = (487.3 + 4.72 × BSI)/max (487.3 + 4.72 × BSI) × 100.

Figure 9

Estimation of the Phillips curve using the output gap

Estimation

$$\pi_t = \mu + \beta \cdot \pi_{t-1} + \lambda \cdot GAP_t + \delta \cdot WPIIM_t$$

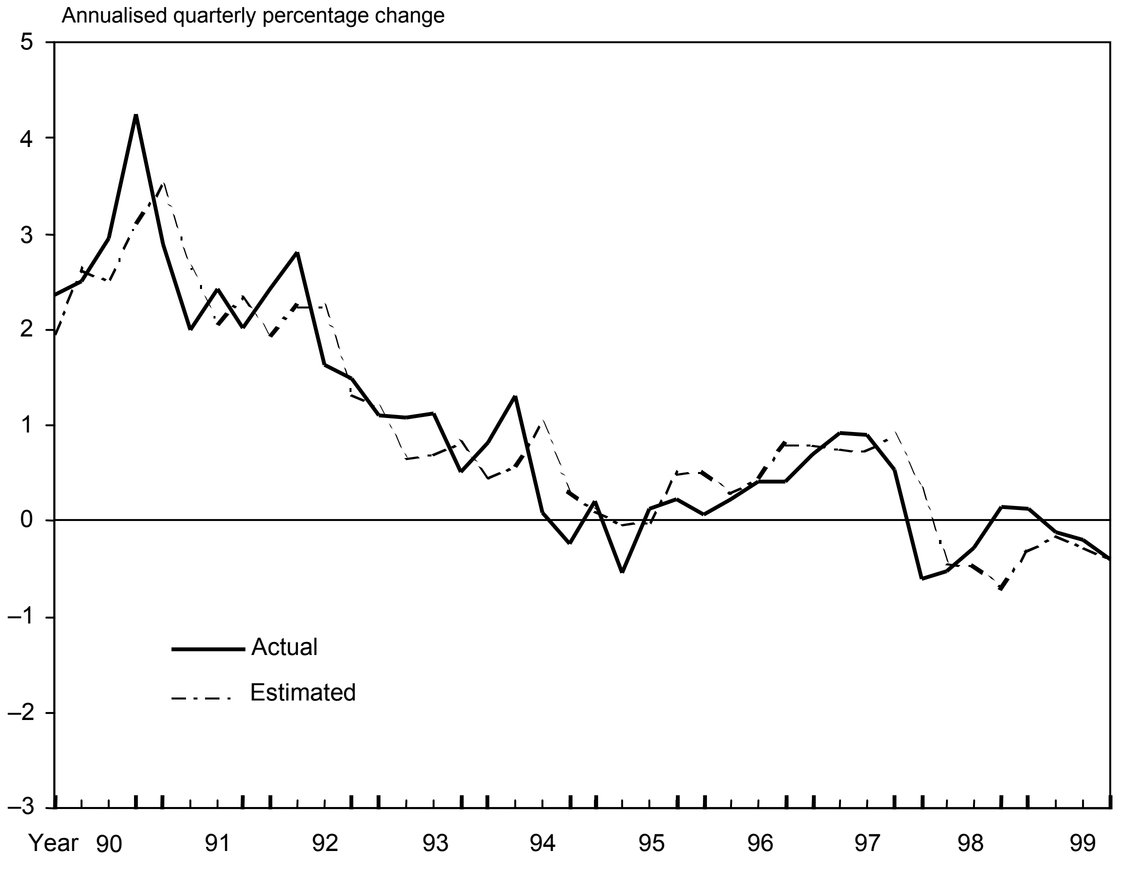
Estimation period: 1983 Q3-1999 Q4

π_t:	quarter-to-quarter trend cycle of the CPI (annualised)
GAP_t:	output gap (revised version incorporating the capacity utilisation rate of non-manufacturers)
$WPIIM_t$:	import prices (wholesale prices, yen basis, total average);quarterly percentage change (annualised)

Estimation results

μ	β	λ	δ	Adj-R^2	Durbin's h
1.172	0.672	0.143	0.010	0.801	0.596
(3.89)	(8.19)	(3.52)	(3.38)		

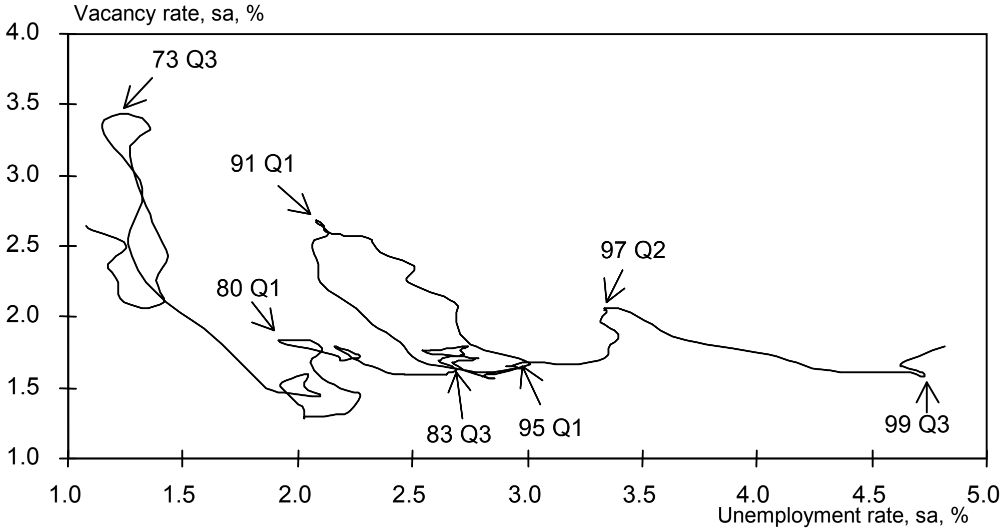
Note: figures in brackets are t-values.



Sources: Economic Planning Agency, *National Accounts, Gross Capital Stock of Private Enterprises, etc;* Management and Coordination Agency, *Consumer Price Index*; Bank of Japan, *Wholesale Price Indexes*.

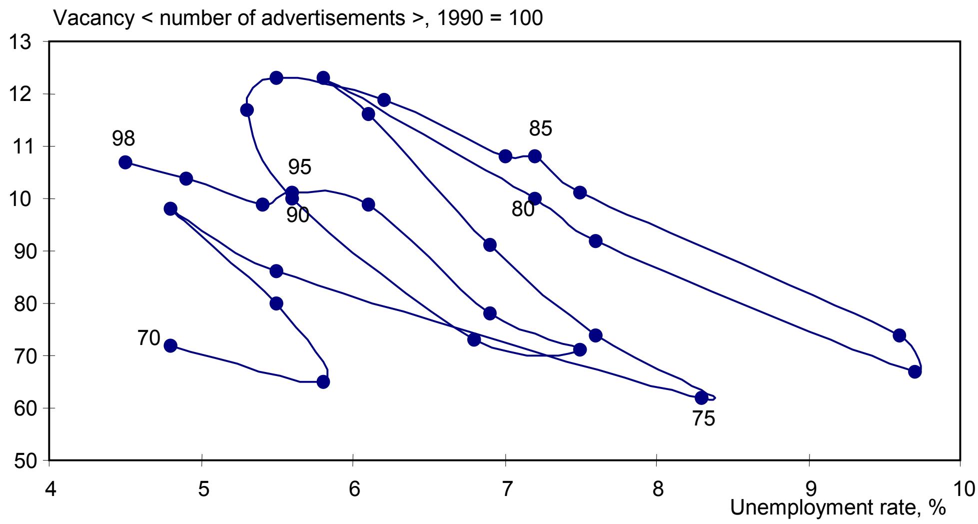
Figure 10
Beveridge curve

1. Beveridge curve (Japan)



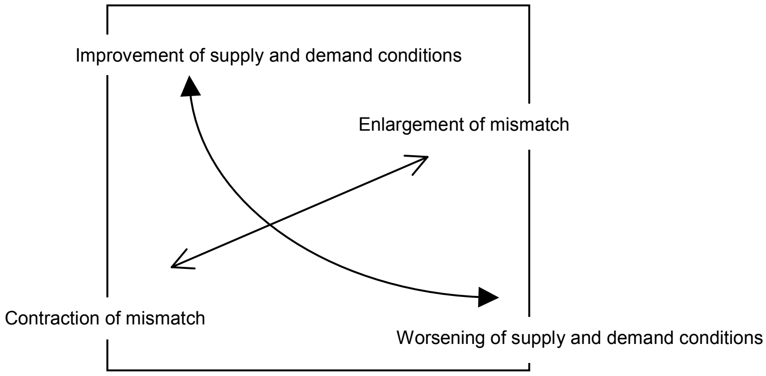
Notes: 1. Period: 1970 Q1-2000 Q1. 2. Vacancy rate = 100 × (number of job offers - number of placements)/(number of job offers - number of placements + number of workers employed).

2. Beveridge curve (United States)



Notes: 1. Period: CY1970-CY1998. 2. Unemployment rate is the "standardised unemployment rate" (compiled by the OECD).

Reference: Beveridge curve

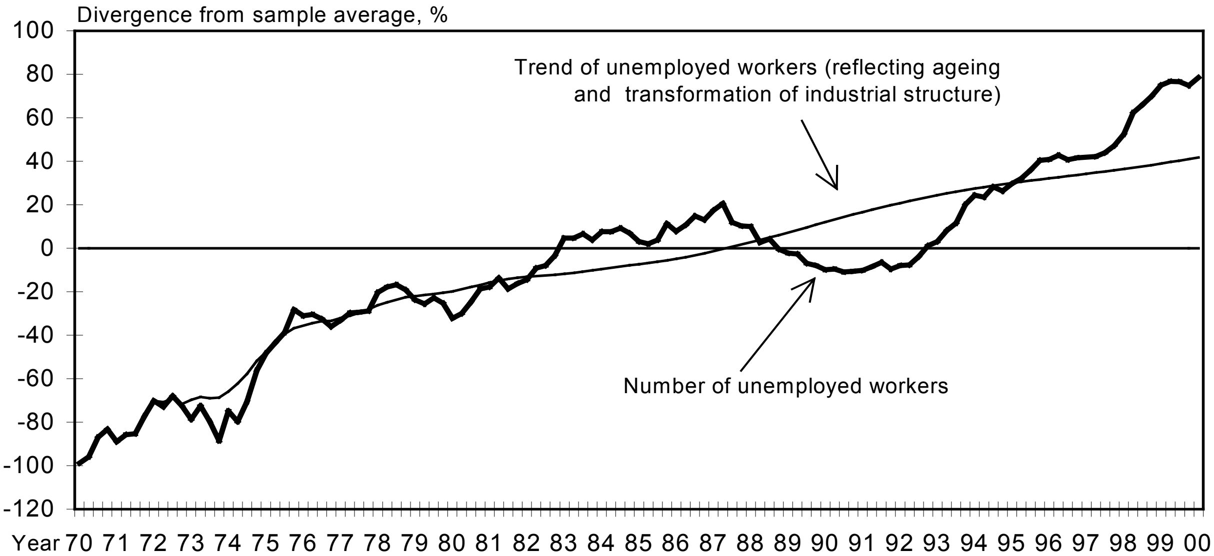


Sources: Management and Coordination Agency, *Labour Force Survey*; Ministry of Labour, *Report on Employment Service*, *White Paper on Labour 1999*.

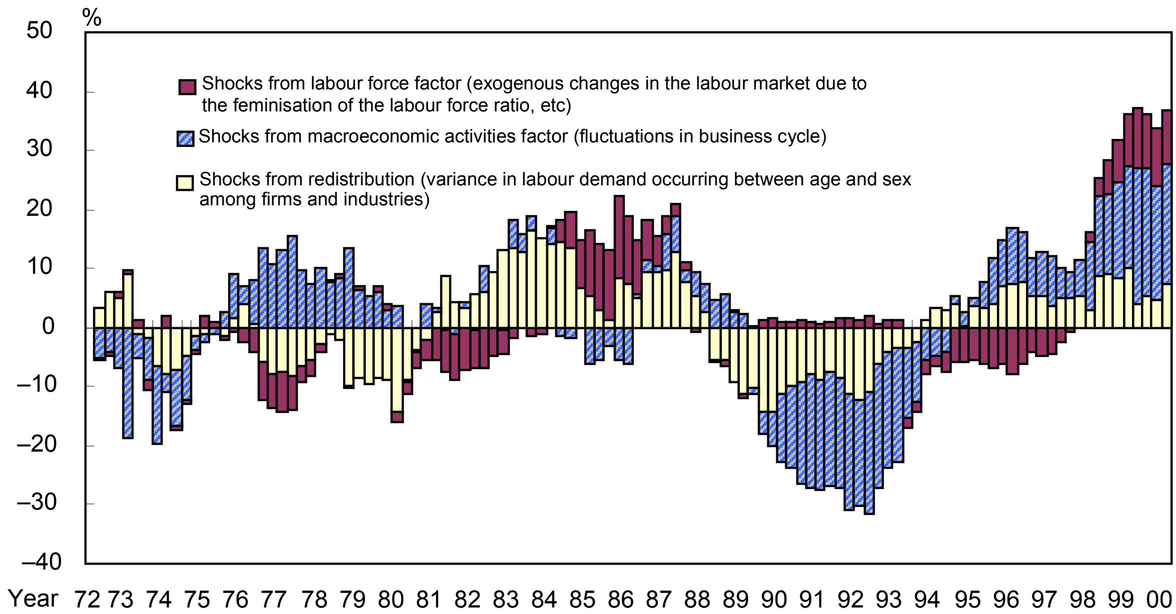
Figure 11

Breakdown of changes in the number of unemployed workers

1. Standardised number of unemployed workers and the trend



2. Breakdown of divergence of unemployed workers from the trend



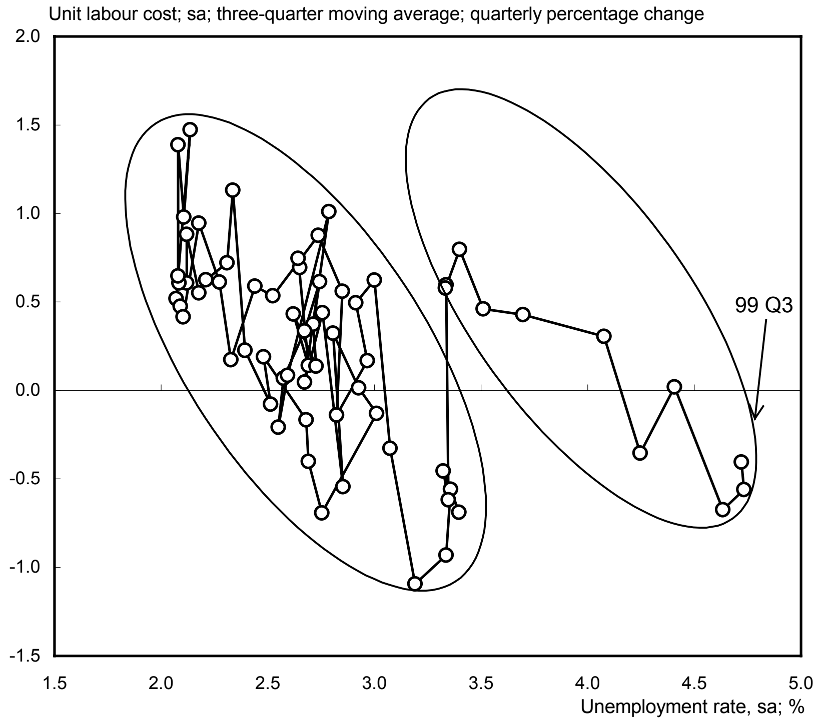
Notes: 1. In order to simplify the analysis, the numbers of unemployed workers, employed workers and vacancies are standardised by dividing them by the sample average and taking the natural logarithm. 2. The breakdown method is: (1) the reduced form VAR of the standardised numbers of unemployed workers, vacancies, and employed workers using the method in note 1 is estimated. The answer obtained is the deterministic trend (long-run hysteresis) reflecting ageing and the transformation of the industrial structure. (2) The random shock to the labour market is divided into three types: shocks from macroeconomic activities<negative correlation between the number of unemployed workers and the number of vacancies>; shocks from redistribution<positive correlation between the number of unemployed workers and the number of vacancies>; shocks from the labour force<number of unemployed workers changes but the number of vacancies is unchanged>. By using the divergence (residual) from the trend obtained in (1), the following two constraints are added: “each shock satisfies the characteristics in the square brackets and does not correlate with the others”, and “the unemployment rate and the vacancy rate both move in the same direction as the redistribution shock for at least nine months”. Then each shock is broken down. (3) Assume each shock is 0 and obtain the divergence between the actual value and the value calculated from the assumption. The divergence gap is the contribution to each shock.

Sources: Management and Coordination Agency, *Labor Force Survey*; Ministry of Labour, *Report on Employment Service*; Nishizaki (2000) “Waga kuni no bebarijji kyokusen ni tsuite (The Beveridge Curve in Japan)”; Research and Statistics Department, Bank of Japan, *Working Paper Series*, forthcoming.

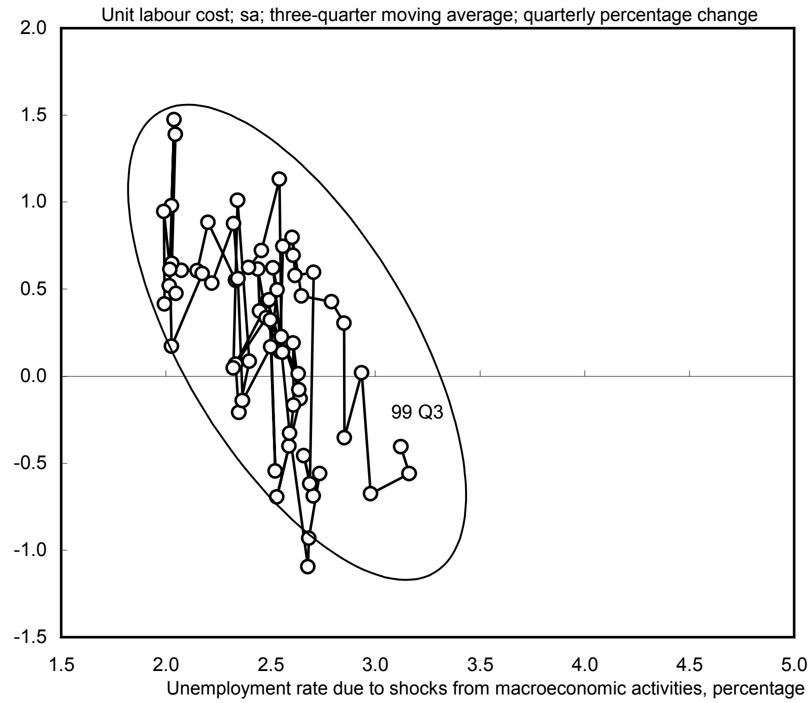
Figure 12

Relationship between unemployment rate and wages (unit labour cost)

1. Relationship between unemployment rate and unit labour cost



2. Relationship between unemployment rate and unit labour cost due to shocks from macroeconomic activities

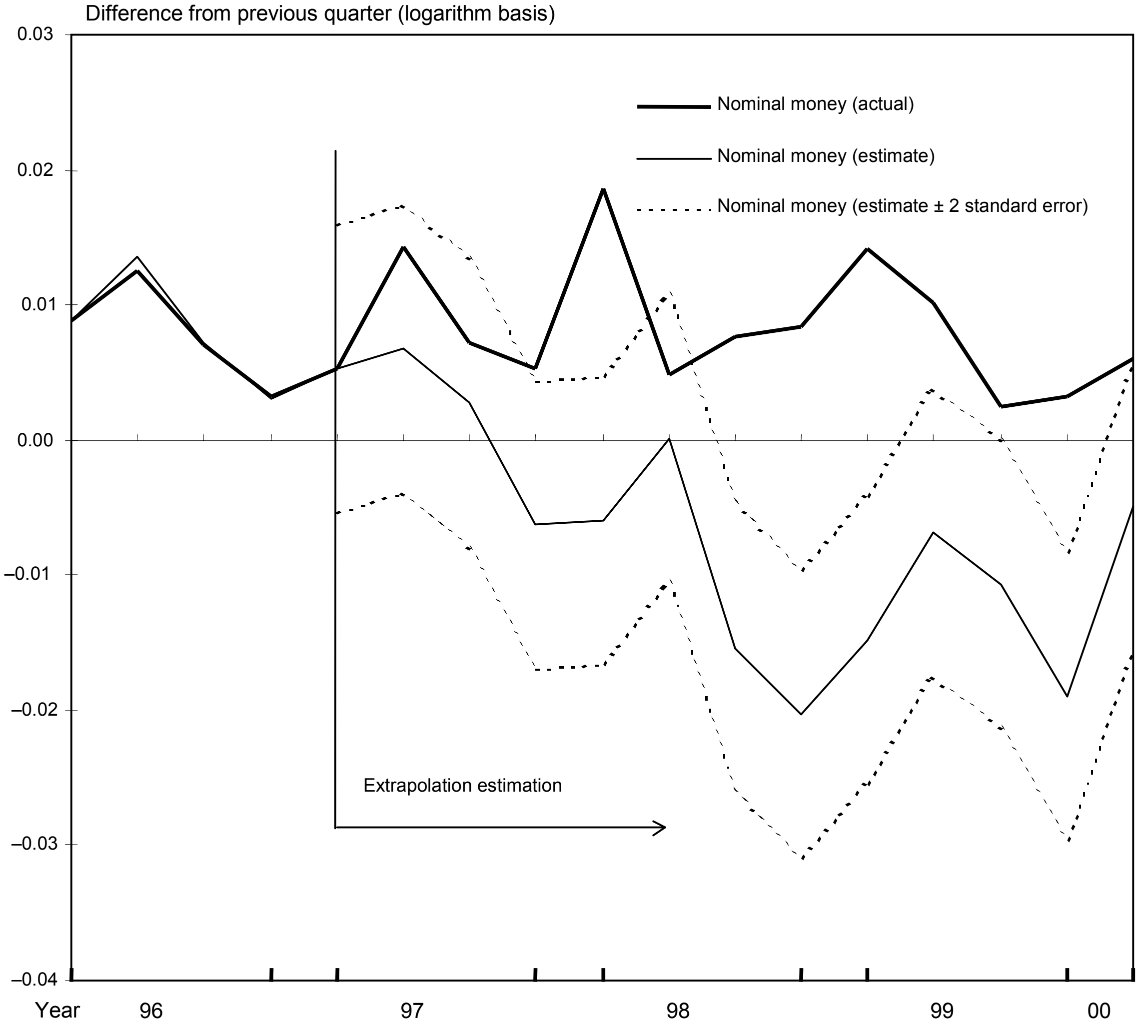


Notes: 1. Unit labour cost = compensation of employees/real GDP. 2. Unemployment rate due to shocks from macroeconomic activities = number of unemployed workers due to shocks from macroeconomic activities/number of employed workers due to shocks from macroeconomic activities. 3. The numbers of unemployed workers and employed workers due to shocks from macroeconomic activities are calculated by using the method in note 2 of Figure 11 and converting the contribution to macroeconomic activities into the number of people. 4. Period: 1983 Q1-1999 Q3.

Sources: Management and Coordination Agency, Labor Force Survey, Ministry of Labour, Report on Employment Service; Economic Planning Agency, National Income Statistics; Nishizaki (2000) "Waga kuni no bebarijji kyokusen ni tsuite (The Beveridge Curve in Japan), Research and Statistics Department, Bank of Japan, Working Paper Series, forthcoming.

Figure 13

Projections on money using a five-variables VECM

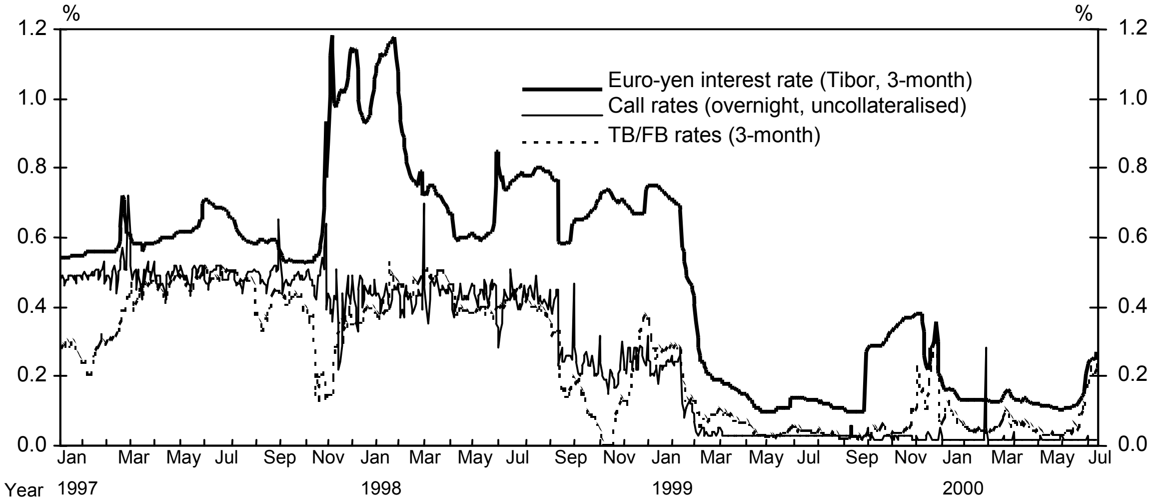


Note: the five variables are nominal money (M2 + CDs), real GDP, GDP deflator, real stock prices (deflate Tokyo Stock Price Index by GDP deflator), real long-term government bond yield (10-year). Using this five-variable VECM (sample period: 1972 Q1-1996 Q4), and results obtained from the extrapolation estimation (1997 Q1-2000 Q1), the changes in nominal money are plotted. Figures used are original series estimated using a seasonal dummy. (Number of lags is set as eight.)

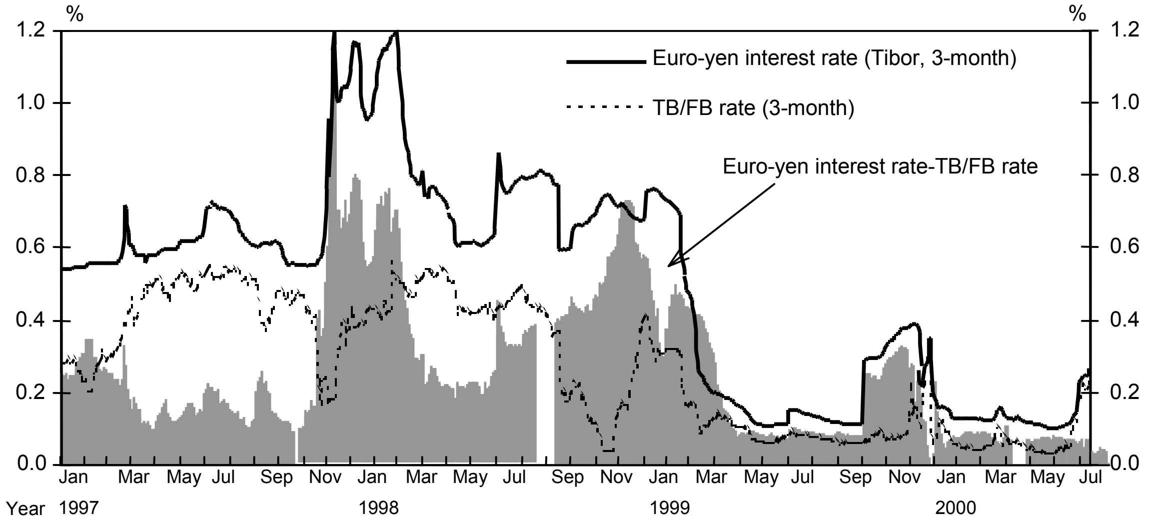
Figure 14

Short-term money market and anxiety over fund management

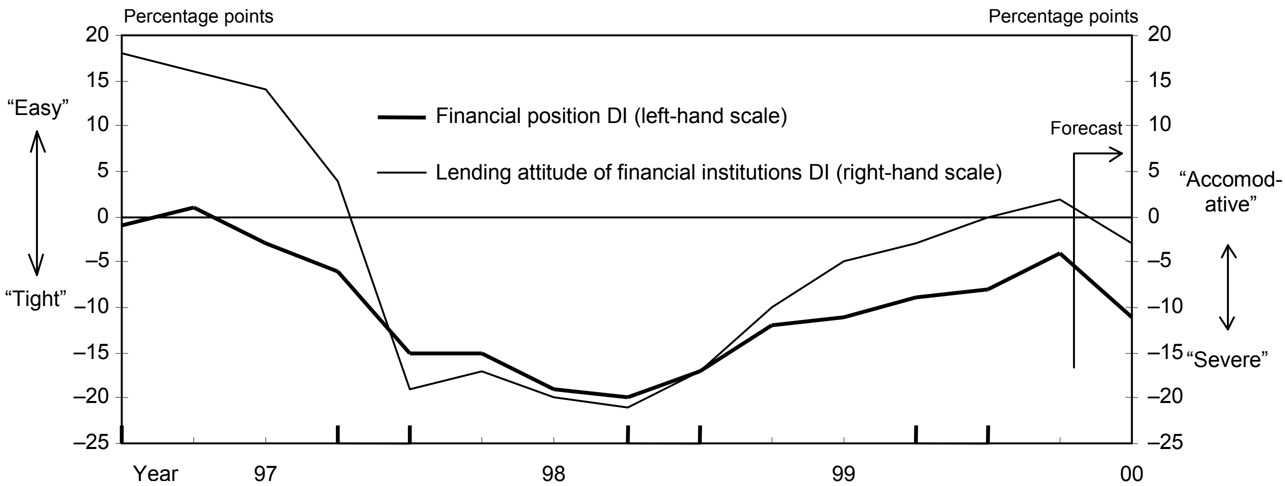
1. Interest rate on term instruments



2. Spread of euro-yen interest rate and TB rate



3. Financial position D I and lending attitude of financial institutions D I (all firms, all industries)

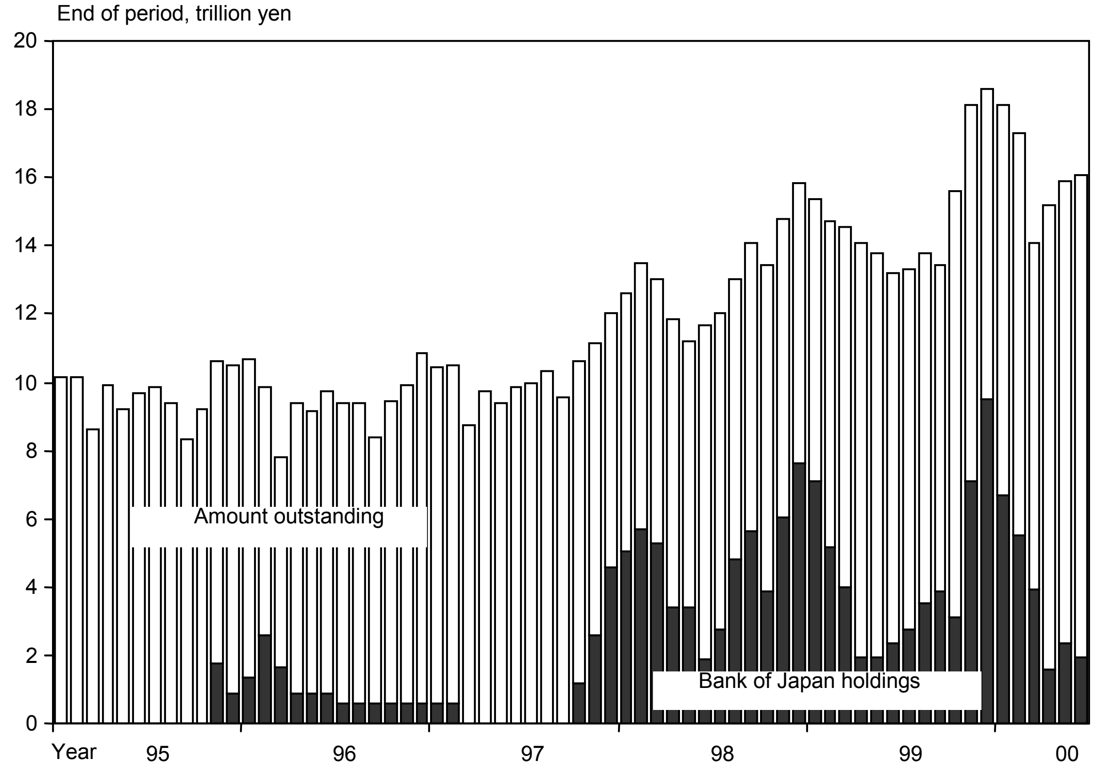


Sources: Bank of Japan, Tankan *Short-Term Economic Survey of Enterprises in Japan*; Japanese Bankers Association; Japan Bond Trading Co, Ltd.

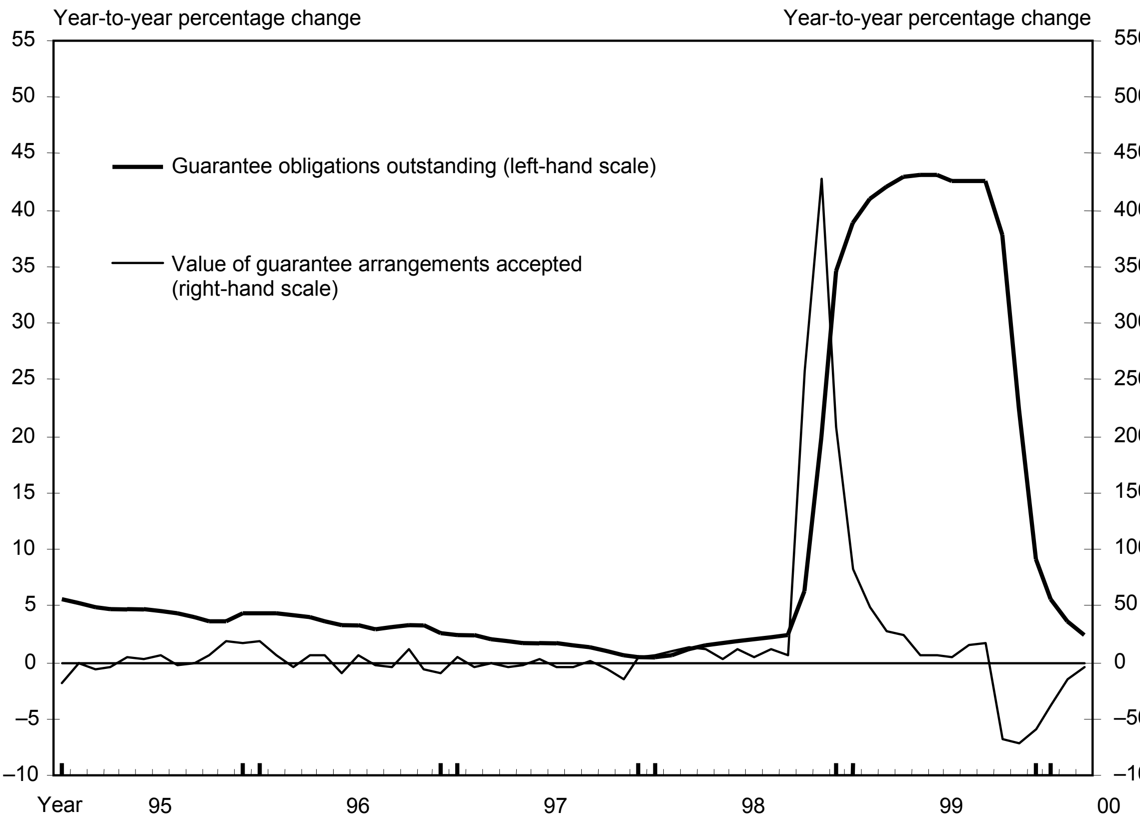
Figure 15

CP operations and credit guarantees

1. Amount outstanding of commercial paper



2. Credit guarantees outstanding



Note: Figures are those of client financial institutions of the Bank of Japan. Excludes those issued by banks.

Sources: National Federation of Credit Guarantee Corporations, *Activities of Credit Guarantee Corporations*; Bank of Japan, *Financial and Economic Statistics Monthly*.

Figure 16
Economic growth rate and prices

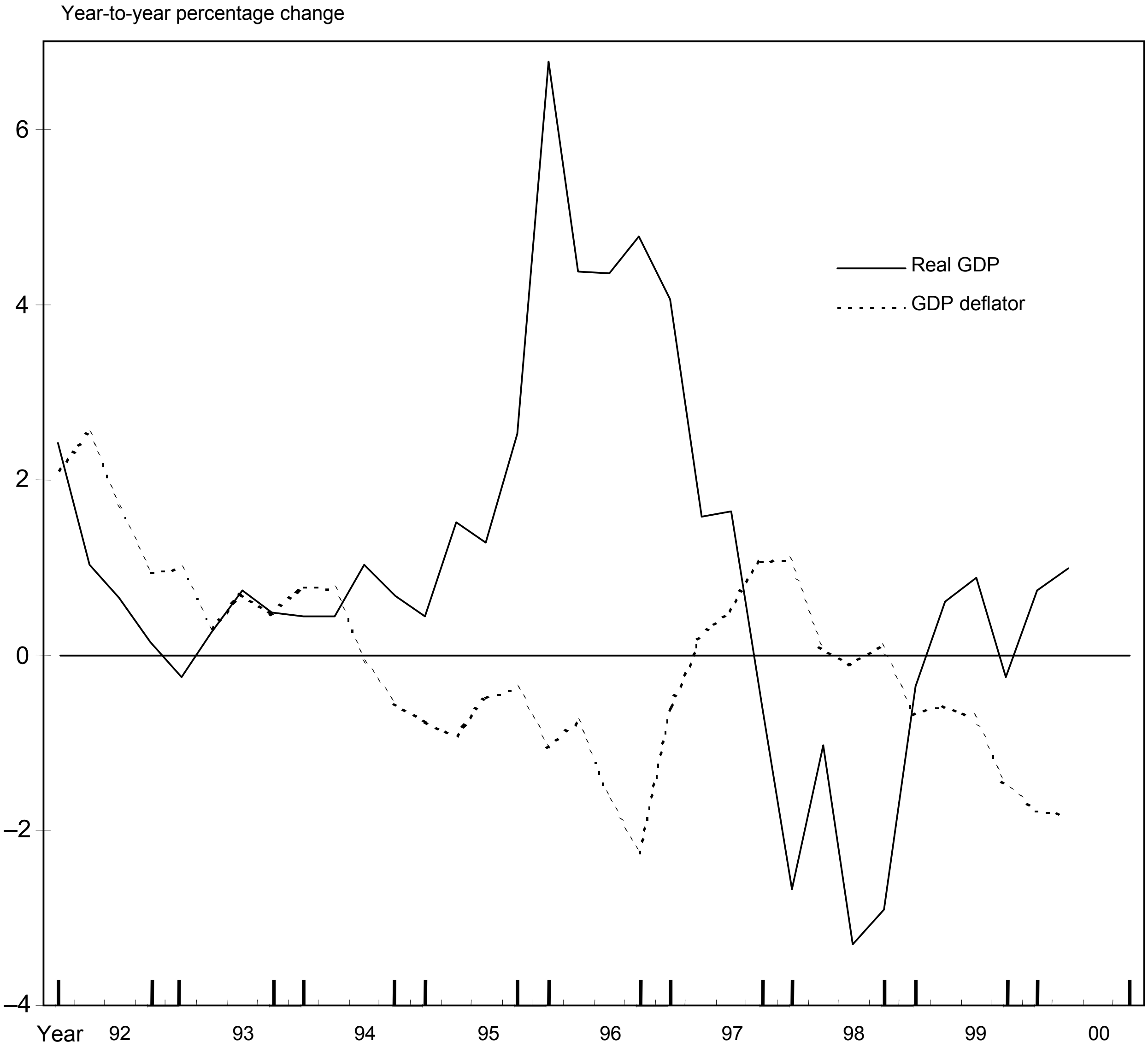
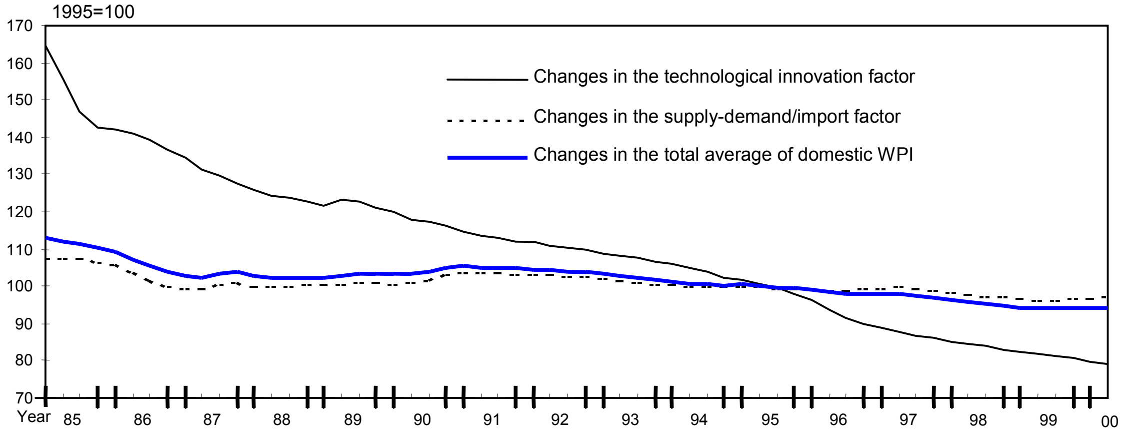


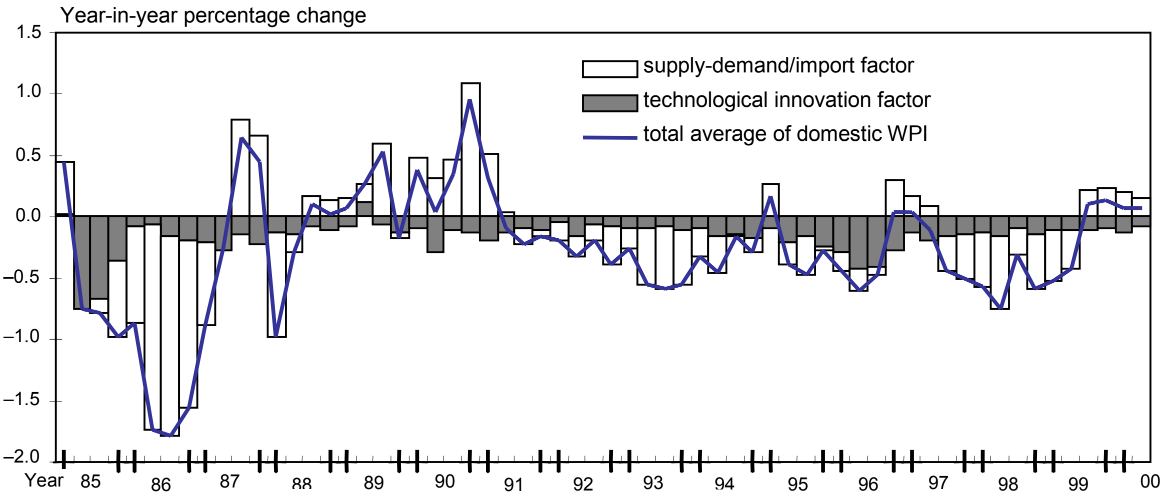
Figure 17

Wholesale price index (technological innovation factor)

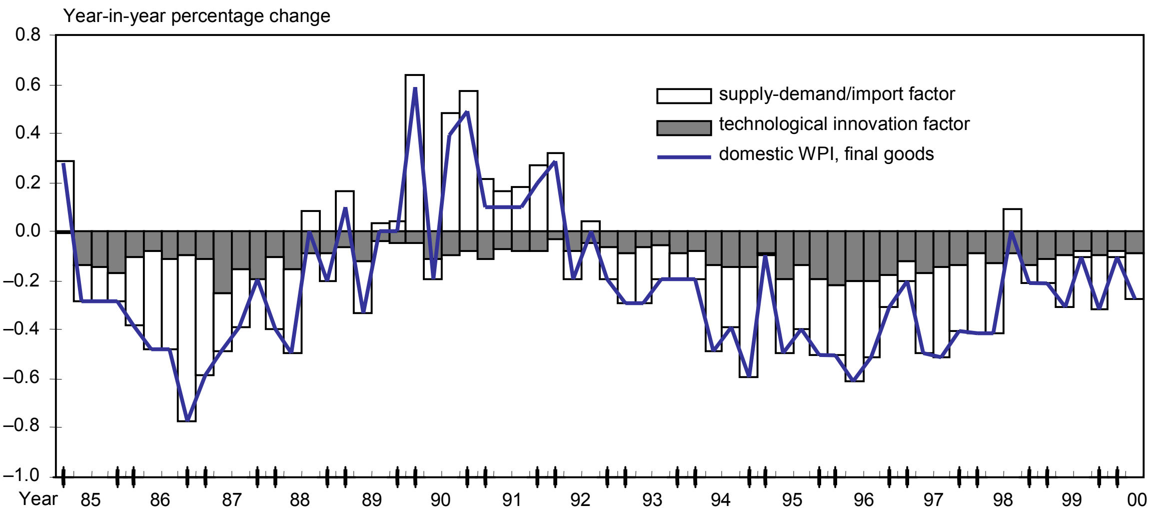
1. Technological innovation and supply-demand factor



2. Breakdown of fluctuations in the wholesale price index



3. Breakdown of fluctuations in final goods of the wholesale price index



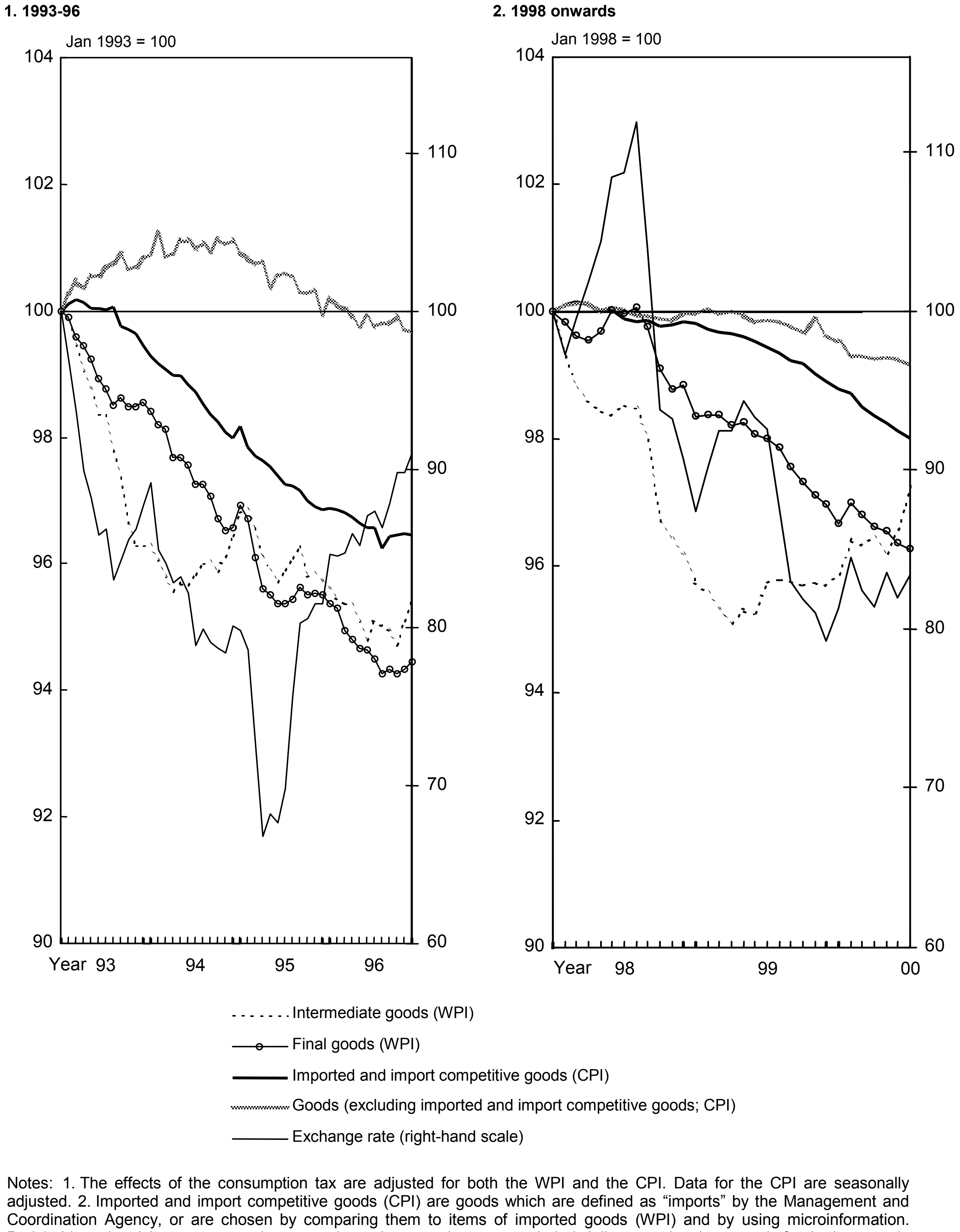
Calculation method: (1) From the domestic WPI, items are chosen of which price fluctuations are mainly due to adjustments reflecting the enhancement of the quality of the item at the time the item is changed (production cost method or hedonic regression approach). There are 72 items on the 1995 base and the weight is 164.3 (1/1000). Most of the items chosen are machinery-related items. For items prior to 1994 on the previous base, similar items are chosen from the 1995 base. (2) The overall fluctuation is calculated from the weighted average of the fluctuation in each chosen item. Then the figure converted into an index (1995=100) is defined as the technological innovation factor index. (3) Supply-demand/import factor index = domestic WPI - technological innovation factor index. (4) Final goods of domestic WPI (69 items, weight 126.3<1/1000>) are also calculated using the same method.

Note: Domestic WPI is based on the total average (excluding the effects of seasonal changes in electricity rates). Adjusted for effects of the consumption tax.

Source: Bank of Japan, *Wholesale Price Indexes*.

Figure 18

Comparison of prices

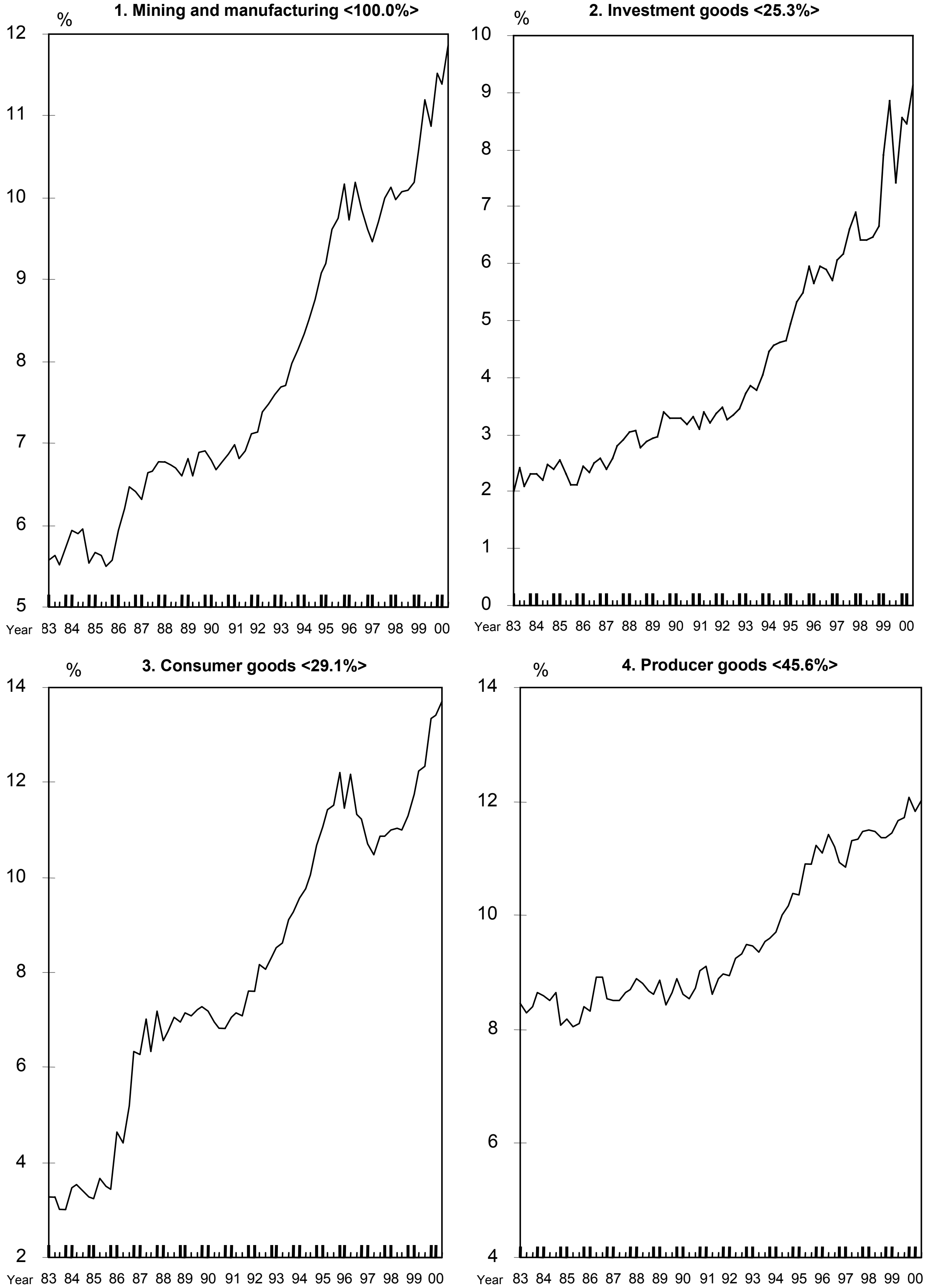


Notes: 1. The effects of the consumption tax are adjusted for both the WPI and the CPI. Data for the CPI are seasonally adjusted. 2. Imported and import competitive goods (CPI) are goods which are defined as "imports" by the Management and Coordination Agency, or are chosen by comparing them to items of imported goods (WPI) and by using microinformation. Perishables, electricity, gas, water charges and petroleum products are excluded. Adjustment has been made for the increase in the tobacco tax from December 1998. "Goods (excluding imported and import competitive goods; CPI)" are goods that are not included in the above definition. These definitions are also used in the analyses hereafter.

Sources : Management and Coordination Agency, *Consumer Price Index* ; Bank of Japan, *Wholesale Price Indexes*.

Figure 19

Import penetration ratio



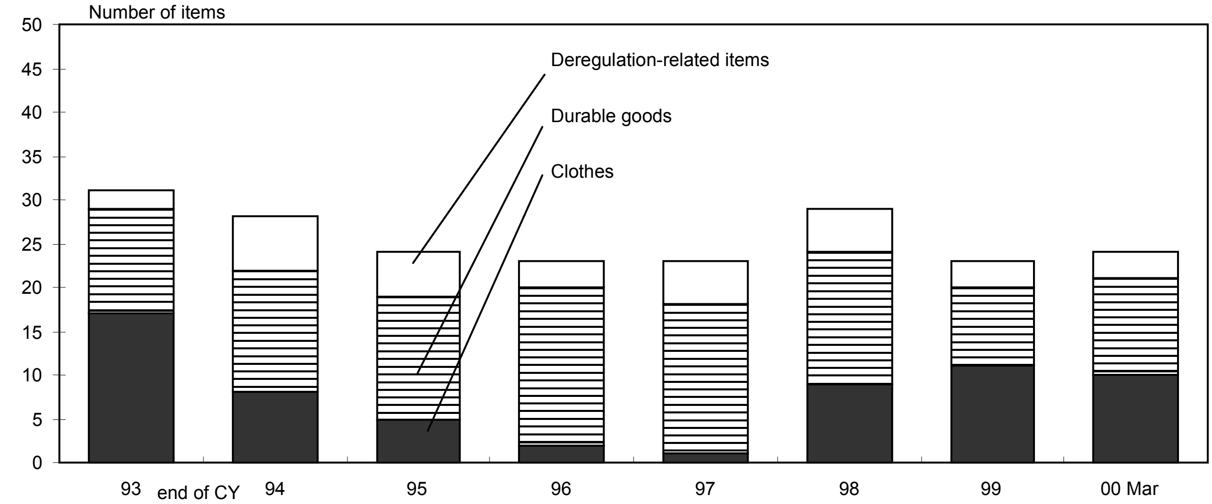
Notes: 1. Import penetration ratio = imports/(shipments to the domestic market + imports). 2. Shares of each type of goods are shown in angle brackets.

Source: Ministry of International Trade and Industry, *Indices of Industrial Domestic Shipments and Imports*.

Figure 20

CPI (declining rate of top items)

1. Breakdown of the top 50 items (declining rate)



2. Top 30 items (declining rate)

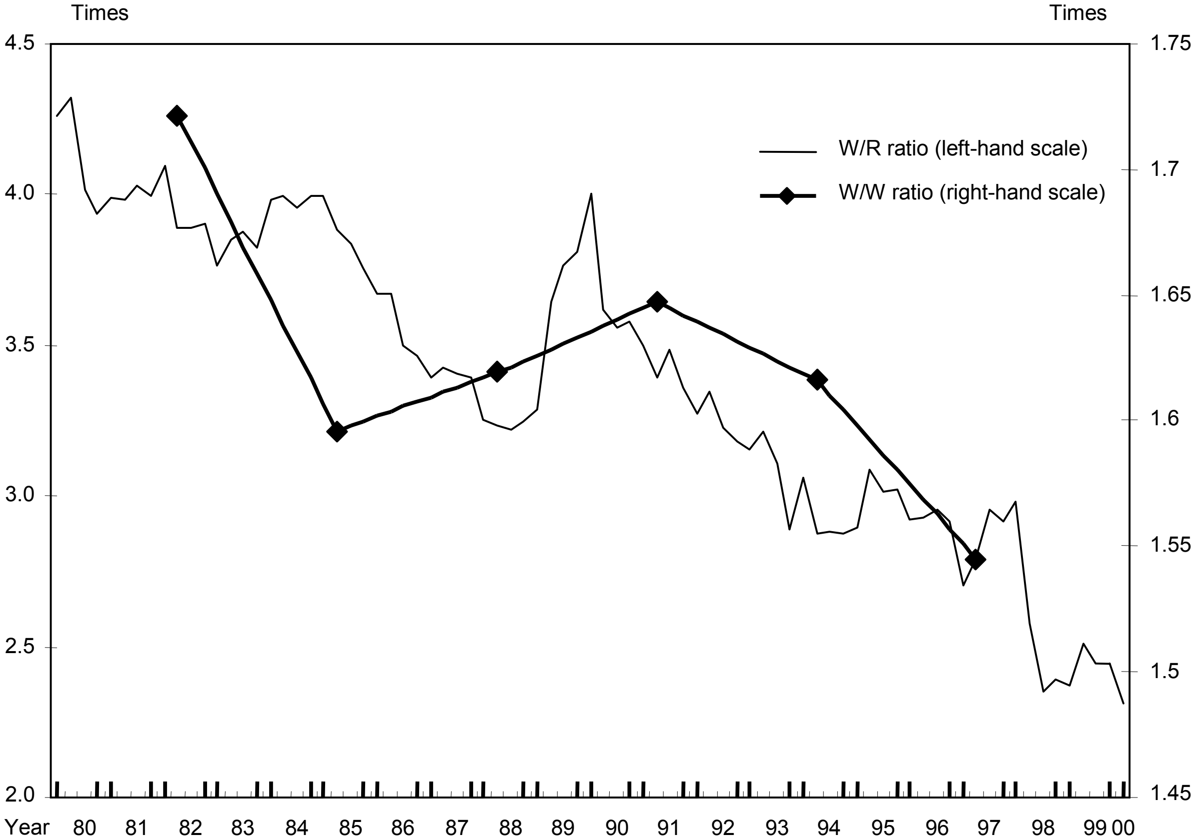
Rank	CY93	94	95	96	97	98	99
1	Monthly magazines, women's	Rice A (domestic)	*Gasoline (regular)*	*Gasoline (regular)*	*Gasoline (regular)*	*Gasoline (regular)*	Rice A (domestic)
2	*Beef (imported)*	***TV sets***	***Word processors***	***TV sets***	Rice A (domestic)	*Kerosene*	***TV sets***
3	*Gasoline (regular)*	*Gasoline (regular)*	***TV sets***	***Word processors***	***Word processors***	*Gasoline (premium)*	*Beef (imported)*
4	***Room air conditioners***	*Beef (imported)*	Rice A (domestic)	Computer games	Clean water equipment	*"Kabayaki", broiled eels*	*Women's overcoats*
5	Hen eggs	Standard rice	***Video tape recorders***	*Tyres*	*Gasoline (premium)*	***Room air conditioners***	Chrysanthemums
6	***Word processors***	*Room air conditioners*	*Car wax*	***Room air conditioners***	Rice B (domestic)	***Word processors***	*"Kabayaki", broiled eels*
7	*Women's overcoats*	Rice B (domestic)	*Kerosene*	*Gasoline (premium)*	***Telephone set***	*Women's overcoats*	***Refrigerators***
8	***Refrigerators***	***Refrigerators***	***Refrigerators***	***Video tape recorders***	Hen eggs	***Refrigerators***	*Handbags*
9	***TV sets***	*Men's suits (for winter)*	*Pants for exercise*	***Refrigerators***	*Kerosene*	Car wax	Carnations
10	*Kerosene*	***Video tape recorders***	Rice B (domestic)	Detergent, laundry	***TV sets***	***Washing machines (full automatic type)***	***Electric rice-cookers***
11	*Men's suits (for winter)*	*Kerosene*	Detergent, laundry	*Electric rice-cookers*	***Video tape recorders***	***Bathtubs***	Flowerpots
12	***Video tape recorders***	Glutinous rice	Salted salmon	*Instant coffee*	Detergent, laundry	*Women's suits (for winter)*	Computer games
13	Salted salmon	Bath preparation	*Women's suits (for spring & autumn)*	***Telephone set***	*Whisky A*	*Dog foods*	*Men's suits (for summer)*
14	*Women's slacks (for winter)*	*Men's suits (for summer)*	Chrysanthemums	Car wax	*Refrigerators*	*Sausages*	***Video tape recorders***
15	*Men's sweaters*	*Dog foods*	*Men's suits (for summer)*	*Pants for exercise*	*Potato chips*	Fresh milk (sold in stores)	*Women's suits (for summer)*
16	Bath preparation	***Automobiles (1700cc-2000cc), imported***	***Room air conditioners***	*Rice (imported)*	***Kerosene stoves***	*Women's blouses (short sleeves)*	Rice B (domestic)
17	*Women's sweaters (long sleeves)*	*Women's suits (for spring & autumn)*	***Tape recorders***	*Women's overcoats*	***Washing machines (full automatic type)***	Fried food	*Men's three-season coats*
18	*Quilts*	Blended rice (domestic)	*Handbags*	***Tape recorders***	Blended rice (domestic)	*Handbags*	*Coffee cups & saucers*
19	*Men's jackets*	Detergent, laundry	*Face cream*	***Video cameras***	Chrysanthemums	*Tyres*	*Beer*
20	*Sausages*	Salted cod roe	Yogurt	*Quilts*	***Microwave ovens***	***Electric shavers***	*Men's sweaters*
21	***Tape recorders***	***Cameras***	"Gyoza"	***Washing machines (full automatic type)***	Disposable diapers	Detergent, laundry	*One-piece dresses (for summer)*
22	*Men's suits (for summer)*	Salted salmon	Frozen croquettes	*Dolls*	Bath preparation	Disposable diapers	Beef (shoulder)
23	Cream puffs	***Word processors***	Mayonnaise	Salted cod roe	*Whisky C*	Fluorescent lamp fittings	*Women's sweaters (short sleeves)*
24	***Bicycles***	***Tape recorders***	*Ice cream*	Clean water equipment	***Electric rice-cookers***	*100% fruit drinks*	Clean water equipment
25	***Carpets***	***Video cameras***	***Bathtubs***	Fresh milk (sold in stores)	Facial tissue	*Rings*	Disposable diapers
26	Detergent, laundry	"Mochi", rice-cakes	*Quilts*	***Carpets***	Computer games	***Tape recorders***	Pickled chinese cabbage
27	Fresh milk (sold instores)	Rolled toilet paper	***Kerosene stoves***	***Vacuum cleaners***	*Whisky B*	Bean-jam buns	Fishes in soybean paste
28	Facial tissue	Fresh milk (sold in stores)	*Knitted suits*	***Cameras***	*Tyres*	***Video tape recorders***	*Quilts*
29	*Women's suits (for winter)*	*Men's sweaters*	***Electric rice-cookers***	Facial tissue	***Video cameras***	Salted cod roe	"Shirasu-boshi", dried young sardines
30	*Dog foods*	Facial tissue	***Automobiles (661cc-1500cc)***	Liquid detergent, kitchen	*Foundation*	***Cameras***	Pork (shoulder)

Notes: 1. The year-to-year percentage change as of December each year (figures for March 2000 are compared to the previous March) in each item is calculated and the top 50 items with large negative contribution rates are chosen. The above Figure shows the number of items included in the top 50 items while the bottom Figure indicates the names of the top 30 declining items. 2. The following goods are indicated as: "clothes", shaded; "durable", bold, "imported/import competitive goods", italics. 3. Deregulation-related items are petroleum products (Provisional Measures Law on the Importation of Specific Petroleum Refined Products, abolished in April 1996) and rice (Staple Food Control Act, abolished in November 1995).

Source: Management and Coordination Agency, *Consumer Price Index*.

Figure 21

Streamlining of distribution channels



<Calculation method>

$\frac{W}{R}$ ratio = $\frac{\text{sales (wholesale industry)}}{\text{sales (retail industry)}}$

ratio of the retail industry to the wholesale industry

$\frac{W}{W}$ ratio = $\frac{\text{total amount of sales (wholesale industry) – inter-office transactions}}{\text{sales to retailers + sales to industries other than wholesale and retail + sales to overseas + sales to consumers}}$

= sales of wholesale industry/sales of wholesale industry to users

Presence of primary and secondary wholesalers within the wholesale industry.

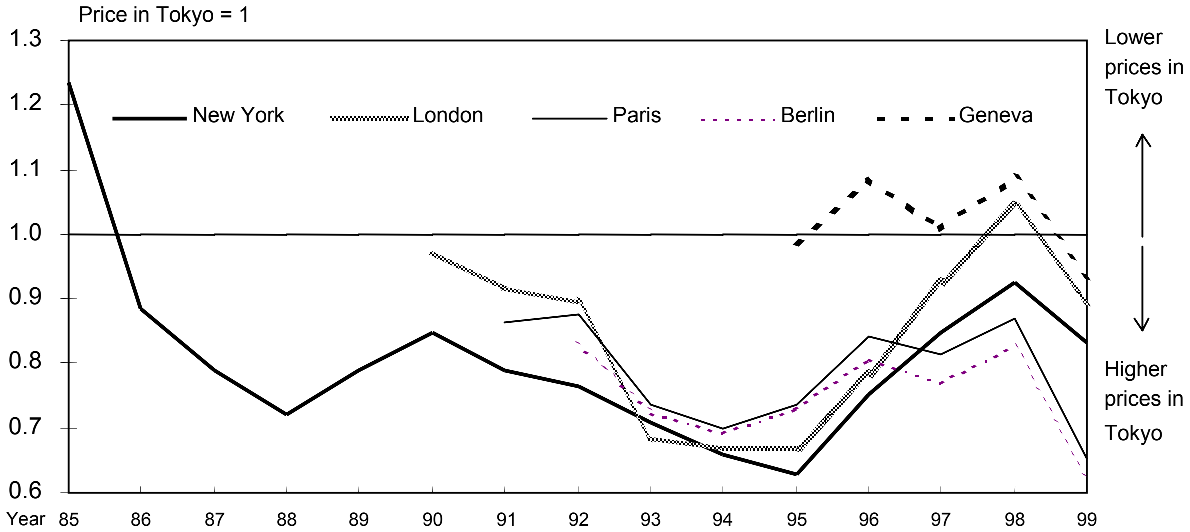
Notes: 1. Data for sales are seasonally adjusted. These figures have been adjusted for discontinuity of data based on firms of all scales in the *Financial Statements Statistics of Corporations by Industry, Quarterly*. 2. Total amount of sales (wholesale industry) based on data in the *Census of Commerce*.

Sources: Ministry of Finance, *Financial Statements Statistics of Corporations by Industry, Quarterly*; Ministry of International Trade and Industry, *Census of Commerce*.

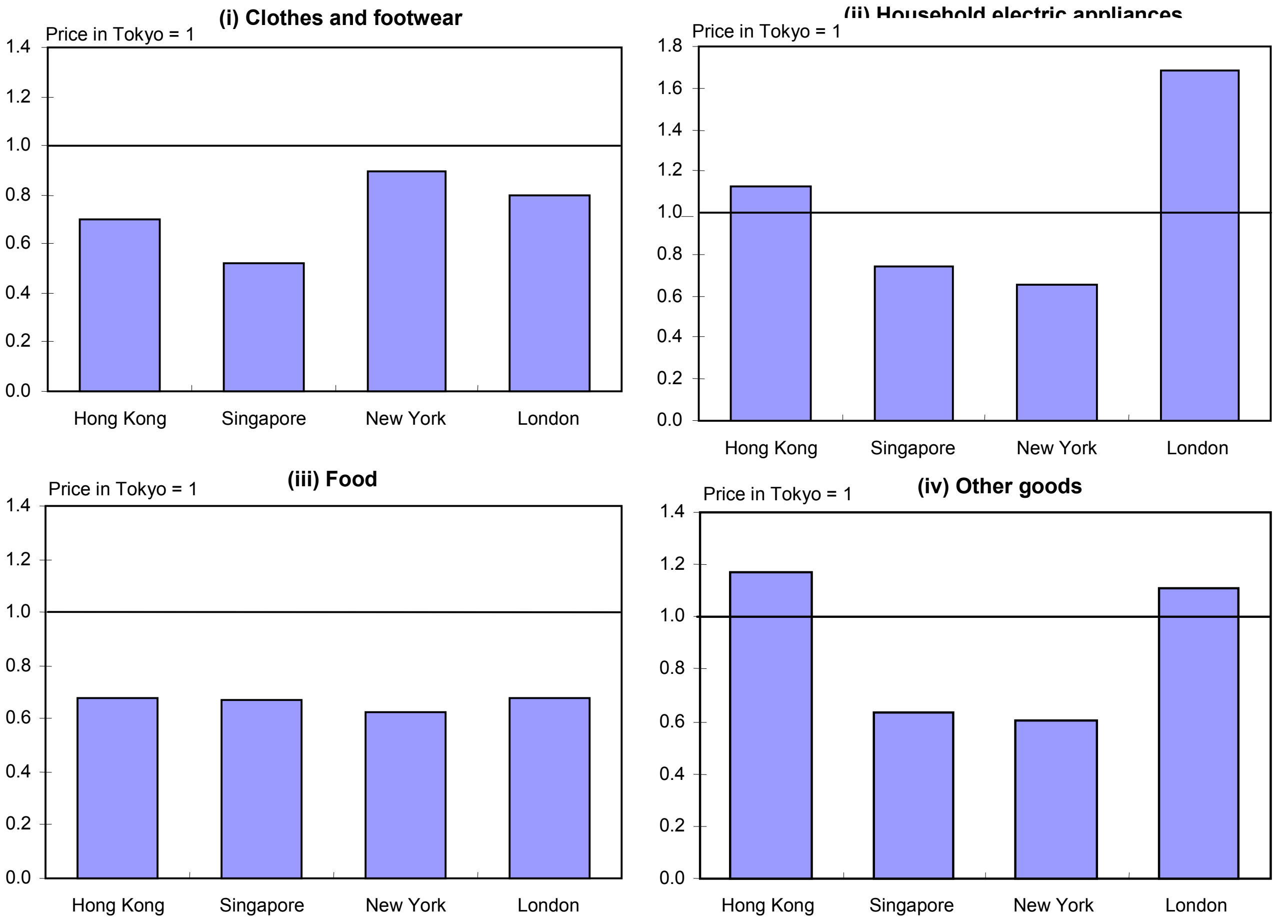
Figure 22

Gap between domestic and foreign prices

1. Changes in price gaps between Japan and overseas; living expenses



2. Price gaps between Japan and overseas (1999); final goods



Note: Price gaps between Japan and overseas for final goods are based on the *Shuyona shohizai oyobi sabisu ni kakaru naigai kakakusa chousa kekka (1999 nen) ni tsuite* (Economic Planning Agency; see source). Each component is weighted by using the weight of the CPI of Japan (for "television", 1998 figures are used). The breakdown of each component is as follows: clothes and footwear: mens' suits (for winter), mens' slacks (for winter), skirts (for winter), mens' business shirts, mens' briefs, mens' shoes (leather). Foods: rice, white bread, spaghetti, salmon, fresh milk, hens' eggs, onions, oranges, bananas, sugar, black tea, cola drinks, beer. Household electric appliances: television, video tape recorders. Other goods: facial tissues, gasoline, films, magazines, newspapers, lipsticks, compact discs.

Source: Economic Planning Agency, *Shuyona shohizai oyobi sabisu ni kakaru naigai kakakusa chousa kekka (1999 nen) ni tsuite (Survey Results on the Price Gap of Major Consumer Goods and Services between Japan and Overseas <1999>)*, *Seikeihi chousa ni yoru koubairyoku heika oyobi naigaikakakusa no gaikyo (Summary Report on Purchasing Power Parity and Price Gaps between Japan and Overseas According to the Living Expense Survey)*; Management and Coordination Agency, *Consumer Price Index*.

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A New Phillips Curve for Spain[1]

Jordi Galí and J David López-Salido[2,3]

Abstract

In this paper we provide evidence on the fit of the New Phillips Curve (NPC) for Spain over the most recent disinflationary period (1980-98). Some of the findings can be summarised as follows: (a) the NPC fits the data well; (b) however, the backward-looking component of inflation is important; (c) the degree of price stickiness implied by the estimates is plausible; (d) the use of independent information about the price of imported intermediate goods (which is influenced by the exchange rate) affects the measure of the firm's marginal costs and thus also inflation dynamics; and finally, (e) labour market frictions, as manifested in the behaviour of the wage markup, appear to have also played a key role in shaping the behaviour of marginal costs.

1. Introduction

In recent years much research has been devoted to the integration of Keynesian features into the class of dynamic stochastic general equilibrium models generally associated with Real Business Cycle theory. Two important ingredients of the resulting New Keynesian models are the presence of imperfect competition and nominal rigidities. The resulting framework has implied a new view on the nature of short-run inflation dynamics. In particular, these New Keynesian models have given rise to the so-called New Phillips Curve (NPC). Two distinct features characterise the relationship between inflation and economic activity in the NPC: first, the forward-looking character of inflation, which is a consequence of the fact that firms set prices on the basis of their expectations about the future evolution of demand and cost factors; second, the link between inflation and real activity, which comes through the potential effects of the latter on real marginal costs.

In this paper, we follow recent work by Sbordone (1999), Galí and Gertler (1999), and Galí et al (2000). Those authors have found supporting evidence for the NPC, and have shown that real marginal costs provide important information to understand inflation dynamics in both the United States and the euro area. The objectives of the present paper are twofold. First, we provide evidence on the fit of the NPC for a small open economy like Spain, and use it as a tool to understand the recent Spanish disinflation process (1980-98). That exercise also allows us to compare the characteristics of Spanish inflation dynamics with those observed for the euro area.

The NPC framework assigns a central role to movements in marginal cost as a source of inflation changes. Hence, understanding the behaviour of marginal costs should shed light on the behaviour of inflation itself. This motivates the second part of the paper, in which we characterise the joint behaviour of Spanish inflation, output and marginal cost over the past two decades, in order to assess

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2 Centre de Recerca en Economia Internacional (CREI), Universitat Pompeu Fabra, CEPR and Bank of Spain.

3 Bank of Spain, Research Department.

quantitatively the contribution of different factors to the recent disinflationary period. The structure of the paper is as follows. In Section 2 we describe the main differences between the traditional Phillips curve and the NPC. Section 3 presents the main theoretical ingredients underlying the NPC. In Section 4 we provide extensive evidence supporting the NPC paradigm. Finally, in Section 5 we analyse the factors underlying inflation inertia by examining in detail the determinants of the marginal costs.

2. Phillips curves, old and new

2.1 The traditional Phillips curve

The traditional Phillips curve relates inflation to some cyclical indicator plus lagged values of inflation. For example, let π_t denote inflation and $\hat{y}_t$ the log deviation of real GDP from its long-run trend. A simple, largely atheoretical specification of the traditional Phillips curve takes the form:[4]

$$\pi_t = \sum_{i=1}^{h} \varphi_i \pi_{t-i} + \delta \hat{y}_{t-1} + \epsilon_t \tag{1}$$

where ϵ_t is a random disturbance.

Instead of the direct estimations of expressions like (1), most of the available evidence on a Phillips curve relationship in Spain was based upon the estimation of wages and prices equations. Given the nature of such a relationship, the emphasis of the literature shifted from analysing the link between inflation and unemployment (or output) in terms of a relationship like (1) to a relationship between real wages and unemployment (ie the so-called wage equation).[5] Pioneers working on that analysis in Spain are Sanchez (1977), Espasa (1982), Dolado and Malo de Molina (1985), Dolado et al (1986), De Lamo and Dolado (1991), Andrés and García (1993) and recently Estrada et al (2000).

Nevertheless, it is still possible to find some evidence of a Phillips curve relationship which explicitly emphasises the link between inflation and unemployment and/or inflation and output. Pioneering work is that by Dolado and Malo de Molina (1985), and specially Baiges et al (1987). The latter constitutes a clear example of estimates of a Phillips curve relationship like (1).

Nevertheless, since the mid-1970s, traditional Phillips curves have been the object of intense scrutiny on different grounds. First, their lack of rigorous micro-foundations has made them subject to the Lucas critique, and questioned their validity as a building block of any model used for the evaluation of alternative monetary policies. This issue is of particular concern in Spain, to the extent that the Bank of Spain has switched between different policy regimes in the past two decades.[6]

Second, its empirical performance has been rather unsatisfactory in many instances. Thus, the traditional Phillips curve seemed incapable of accounting for the combination of high inflation and output losses experienced by industrial economies in the 1970s.[7] More recently it failed to explain why the expansion of the late 1990s was not accompanied by any significant inflationary pressures, at least until the recent hike in oil prices. The recent Spanish experience has not been an exception from this point of view. Figure 1 displays the time series for inflation and detrended output over the period 1980-98. As can be easily seen, low and steady inflation characterising the late part of the sample has not been perturbed despite the robust expansion in economic activity (reflected in positive and

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4 For example, Rudebusch and Svensson (1999) show that a variant of equation (1) with four lags of inflation fits well quarterly US data over the period 1980-98. Galí et al (2000) compare this evidence with the one obtained for the euro area.

5 For details on the relationships between the wage equation and the Phillips curve, see the recent paper by Blanchard and Katz (1999). Essentially the Phillips curve analysis for the Spanish economy was pursued under the approach described by Layard et al (1991).

6 For a detailed discussion, see Ayuso and Escrivá (1999).

7 This was already emphasised by Dolado and Malo de Molina (1985) and Baiges et al (1987).

growing detrended output estimates). In such an environment a traditional Phillips curve would over predict inflation.[8]

2.2 The New Phillips Curve

Recent developments in monetary business cycle theory have led to the development of a so-called New Phillips Curve (NPC). The NPC arises in a model based on staggered nominal price setting, in the spirit of Taylor's (1980) seminal work. A key difference with respect to the traditional Phillips curve is that price changes are the result of optimising decisions by monopolistically competitive firms subject to constraints on the frequency of price adjustment.

A common specification is based on Calvo's model (1983) of staggered price setting with stochastic time dependent rules. The first building block is an equation that relates inflation, π_t, to anticipated future inflation and real marginal cost:

$$\pi_t = \beta E_t \{\pi_{t+1}\} + \lambda \hat{mc}_t \tag{2}$$

where $\hat{mc}_t$ is average real marginal cost, in percentage deviation from its steady state level, β is a discount factor, and λ is a slope coefficient that depends on the primitive parameters of the model, and in particular the one measuring the degree of price rigidity. As we will show below, equation (2) can be obtained by aggregating across the optimal pricing decisions of individual firms.

Equation (2) is the first of two building blocks for the NPC. The second is an equation that relates marginal cost to the output gap. Under a number of assumptions typically found in standard optimisation-based models with nominal price rigidities, it is possible to derive a simple relationship between real marginal costs and an output gap variable:[9]

$$\hat{mc}_t = \delta\ (y_t - y_t^*) \tag{3}$$

where y_t and y_t^* are, respectively, the logarithms of real output and the natural level of output. The latter variable has a theoretical counterpart: it is the level of output hat would be observed if prices were fully flexible.

Combining (2) with (3) yields the standard output gap-based formulation of the NPC:[10]

$$\pi_t = \beta E_t \{\pi_{t+1}\} + \kappa \left(y_t - y_t^*\right) \tag{4}$$

where $\kappa \equiv \lambda\delta$

2.3 Implications and criticisms

The NPC, as exemplified by equation (4), has been the subject of considerable controversy.[11] Like the traditional Phillips curve, inflation is predicted to vary positively with the output gap. Yet in the NPC inflation is entirely forward-looking, as can be easily seen by iterating equation (4) forward:

$$\pi_t = \kappa \sum_{k=0}^{\infty} \beta^k E_t \left\{\left(y_{t+k} - y_{t+k}^*\right)\right\} \tag{5}$$

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8 There is extensive evidence on this for the United States. Recent contributions include Lown and Rich (1997) and Gordon (1998).

9 See Rotemberg and Woodford (1997).

10 See Yun (1996), Woodford (1996) and King and Wolman (1997).

11 See also Galí and Gertler (1999) for a discussion of some of the issues involved.

Hence, past inflation is irrelevant in determining current inflation under this new paradigm. As a result, an economy may achieve disinflation without the need for the central bank to engineer a recession, to the extent that it can commit to stabilising the output gap. In other words, there is no longer a trade-off between price and output gap stability. Many authors have pointed to that prediction as being in conflict with the evidence of substantial output losses associated with disinflations (eg Ball (1994)).

Furthermore, and as emphasised by Fuhrer and Moore (1995) and others, the joint dynamics of inflation and output implied by equation (5) appear to be at odds with the empirical evidence. In particular, (5) implies that inflation should anticipate movements in the output gap, but the evidence suggests that the opposite relationship holds: the output gap tends to lead inflation instead, at least when detrended log GDP is used as a proxy for the former variable. In this sense, the evidence is consistent with the traditional Phillips curve.

2.4 Recent evidence

The previous criticisms notwithstanding, recent work by Sbordone (1999), Galí and Gertler (1999), and Galí et al (2000) has provided evidence favourable to the forward-looking nature of inflation, and the link between the latter variable and real marginal cost, and suggested that equation (2) is largely consistent with the data. These results support the idea that it is the failure of equation (3) - the hypothesised link between real marginal cost and the output gap - that may be behind the claimed poor performance of the NPC.

Galí and Gertler (1999) put forward two possible explanations for this finding. One is that conventional measures of the output gap may be poor approximations. To the extent that there are significant real shocks to the economy (eg shifts in technology growth, fiscal shocks, etc), using detrended log GDP as a proxy for y_t^* in expression (4) may not be appropriate. Second, even if the output gap is correctly measured, it may not be the case that real marginal cost moves proportionately to it, as assumed. In particular, as we discuss in Section 5, with frictions in the labour market, either in the form of real or nominal wage rigidities, equation (3) is no longer valid. These labour market rigidities, further, can in principle offer a rationale for the inertial behaviour of real marginal cost.[12] Indeed, in Section 5 we provide evidence that labour market frictions were an important factor in the dynamics of marginal cost in Spain.

In the next section we sketch the derivation of the structural relation between inflation and real marginal cost. This will be the base of our estimates in Section 4. We do so under alternative assumptions regarding the technology available to firms. We also consider a variant of the baseline model which allows for a fraction of backward-looking firms. In Section 4 we estimate the different specifications of the inflation equation using Spanish data. Section 5 provides some evidence regarding the sources of variations in marginal costs.

3. The New Phillips Curve: basic theory and alternative specifications

We assume a continuum of firms indexed by $j \in [0,1]$. Each firm is a monopolistic competitor and produces a differentiated good $Y_t(j)$, which it sells at nominal price $P_t(j)$. Firm j faces an isoelastic demand curve for its product, given by $Y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\epsilon} Y_t$, where Y_t and P_t are aggregate output and the aggregate price level, respectively. Suppose also that the production function for firm j is given by $Y(j)_t = A_t N_t(j)^{1-\alpha}$, where $N_t(j)$ is employment and A_t is a common technological factor. Notice that allowing for decreasing returns to labour will imply on the one hand increasing marginal costs, and on

[12] As we discuss in detail in Section 5, inertial behaviour of marginal cost opens up the possibility of a short-run trade-off between inflation and output. See also Erceg et al (2000).

the other that marginal costs will differ across firms producing different output quantities. This is not the case under constant returns to labour (ie $\alpha = 0$).

Firms set nominal prices in a staggered fashion, following the approach in Calvo (1983). Thus, each firm resets its price only with probability 1-θ each period, independently of the time elapsed since the last adjustment. Thus, each period a measure 1-θ of producers reset their prices, while a fraction θ keep their prices unchanged. Accordingly, the expected time a price remains fixed is $\frac{1}{1-\theta}$. Thus, the parameter θ provides a measure of the degree of price rigidity. It is one of the key structural parameters we seek to estimate.

After appealing to the law of large numbers and log-linearising the price index around a zero inflation steady state, we obtain the following expression for the evolution of the (log) price level p_t as a function of (the log of) the newly set price p_t^* and the lagged (log) price p_{t-1}.

$$p_t = (1-\theta)p_t^* + \theta p_{t-1} \tag{6}$$

Because there are no firm-specific state variables, all firms that change price in period *t* choose the same value of p_t^*. A firm that is able to reset in *t* chooses price to maximise expected discounted profits given technology, factor prices and the constraint on price adjustment (defined by the reset probability 1-θ). It is straightforward to show that an optimising firm will set p_t^* according to the following (approximate) log-linear rule:

$$p_t^* = \mu + (1-\beta\theta)\sum_{k=0}^{\infty}(\beta\theta)^k E_t\left\{mc_{t,t+\kappa}^n\right\} \tag{7}$$

where β is a subjective discount factor, $mc_{t,t+\kappa}^n$ is the logarithm of nominal marginal cost in period *t+k* of a firm that last reset its price in period *t*, and $\mu \equiv \log \frac{\epsilon}{\epsilon - 1}$ is the firm's desired markup. Intuitively, the firm sets price as a markup over a discounted stream of expected future nominal marginal cost. Note that in the limiting case of perfect price flexibility (θ = *0*), $p_t^* = \mu + mc_t^n$: price is just a fixed markup over current marginal cost. As the degree of price rigidity (measured by θ) increases, so does the time the price is likely to remain fixed. As a consequence, the firm places more weight on expected future marginal costs in choosing current price.

The goal now is to find an expression for inflation in terms of an observable measure of aggregate marginal cost. Cost minimisation implies that the firm's real marginal cost will equal the real wage divided by the marginal product of labour. Given the Cobb-Douglas technology, the real marginal cost in *t+k* for a firm that optimally sets price in *t*, $MC_{t,t+\kappa}$, is given by:

$$MC_{t,t+\kappa} = \frac{(W_{t+\kappa}/P_{t+\kappa})}{(1-\alpha)(Y_{t,t+k}/N_{t,t+k})}$$

where $Y_{t,t+\kappa}$ and $N_{t,t+\kappa}$ are output and employment for a firm that has set price in *t* at the optimal value P_t^*. Individual firm marginal cost, of course, is not observable in the absence of firm-level data. Accordingly, it is helpful to define the observable variable "average" marginal cost, which depends only on aggregates, as follows:[13]

[13] Note that this measure allows for supply shocks (entering through A_t in the production). An adverse supply shock, for example, results in a decline in average labour productivity, Y_t / N_t. Also, the specification is robust to the addition of other

$$MC_t \equiv \frac{(W_t / P_t)}{(1-\alpha)(Y_t / N)_t} \quad (8)$$

Following Woodford (1996) and Sbordone (1999), we exploit the assumptions of a Cobb-Douglas production technology and the isoelastic demand curve introduced to obtain the following log-linear relation between $MC_{t,t+\kappa}$ and MC_t:

$$\hat{mc}_{t,t+\kappa} = \hat{mc}_{t+\kappa} - \frac{\in \alpha}{1-\alpha}\left(p_t^* - p_{t+\kappa}\right) \quad (9)$$

where $\hat{mc}_{t,t+\kappa}$ and $\hat{mc}_{t+\kappa}$ are the log deviations of $MC_{t,t+\kappa}$ and $MC_{t+\kappa}$ from their respective steady state values. Intuitively, given the concave production function, firms that maintain a high relative price will face a lower marginal cost than the norm. In the limiting case of a linear technology $(\alpha = 0)$, all firms will be facing a common marginal cost.

We obtain the primitive formulation of the NPC that relates inflation to real marginal cost by combining equations (6), (7), and (9),

$$\pi_t = \beta\, E_t\{\pi_{t+1}\} + \lambda\, \hat{mc}_t \quad (10)$$

with

$$\lambda \equiv \frac{(1-\theta)(1-\beta\theta)(1-\alpha)}{\theta[1+\alpha(\in -1)]} \quad (11)$$

Note that the slope coefficient λ depends on the primitive parameters of the model. In particular, λ is decreasing in the degree of price rigidity, as measured by θ, the fraction of firms that keep their prices constant. A smaller fraction of firms adjusting prices implies that inflation will be less sensitive to movements in marginal cost. Second, λ is also decreasing in the curvature of the production function, as measured by α, and in the elasticity of demand $\in$: the larger α and $\in$, the more sensitive is the marginal cost of an individual firm to deviations of its price from the average price level; everything else equal, a smaller adjustment in price is desirable in order to offset expected movements in average marginal costs.

3.1 A hybrid model

Equation (10) is the baseline relation for inflation that we estimate. An alternative to equation (10) is that inflation is principally a backward-looking phenomenon, as suggested by the strong lagged dependence of this variable in traditional Phillips curve analysis. As a way to test the model against this alternative, we follow Galí and Gertler (1999) and Galí et al (2000) by considering a hybrid model that allows a fraction of firms to use a backward-looking rule of thumb. Accordingly, a measure of the departure of the pure forward-looking model from the data in favour of the traditional approach is the estimate of the fraction of firms that are backward-looking.

All firms continue to reset price with probability 1 - θ. However, only a fraction 1 - ω resets price optimally, as in the baseline Calvo model. The remaining fraction ω chooses the (log) price p_t^b according to the simple backward-looking rule of thumb:

$$p_t^b = p_{t-1}^* + \pi_{t-1}$$

where p_{t-1}^* is the average reset price in t - 1 (across both backward- and forward-looking firms). Backward-looking firms see how firms set price last period and then make a correction for inflation,

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variable factors (eg imported goods), so long as the elasticity of output with respect to labour is constant, firms take wages as given, and there are no labour adjustment costs.

using lagged inflation as the predictor. Note that though the rule is not optimisation-based, it converges to the optimal rule in the steady state.[14]

We defer the details of the derivation to Galí et al (2000) and simply report the resulting hybrid version of the marginal cost-based Phillips curve:

$$\pi_t = \gamma_b \pi_{t-1} + \gamma_f E_t\{\pi_{t+1}\} + \lambda \hat{mc}_t \tag{12}$$

with

$$\tilde{\lambda} \equiv \frac{(1-\omega)(1-\theta)(1-\beta\theta)(1-\alpha)}{\phi[1+\alpha(\in -1)]}; \gamma_b \equiv \omega\phi^{-1}; \gamma_f \equiv \beta\theta\phi^{-1}$$

where $\phi \equiv \theta + \omega[1-\theta(1-\beta)]$.

As in the pure forward-looking baseline case, relaxing the assumption of constant marginal cost (ie $\alpha = 0$) affects only the slope coefficient on average marginal cost. The coefficients γ_b and γ_b are the same as in the hybrid model of Galí and Gertler (1999). In this regard, note that the hybrid model nests the baseline model in the limiting case of no backward-looking firms (ie $\omega = 0$).

3.2 Alternative measures of marginal costs

In this section we keep the assumption that firms face identical constant marginal costs, which greatly simplifies aggregation, while relaxing the linear specification of the technology. We consider various technologies to generate different measures of marginal cost. We take as a baseline technology a simple Cobb-Douglas production function; we then allow for overhead labour, as well as labour adjustment costs. Finally, we consider a CES production function and we also allow for labour adjustment costs. Let Y_t be output, A_t be technology, K_t capital and N_t total labour. Thus output is given by:

$$Y_t = A_t K_t^{\alpha} N_t^{1-\alpha} \tag{13}$$

Real marginal cost is given by the ratio of the wage rate to the marginal product of labour, ie $MC_t = \frac{w_t}{P_t}\frac{1}{\frac{\partial Y_t}{\partial N_t}}$ Hence, given equation (13), we have the following expression for the real marginal costs:

$$MC_t = \frac{(W_t / P_t)}{(1-\alpha)(Y_t / N_t)} = \frac{s_t^n}{1-\alpha}$$

where $s_t^n \equiv \frac{W_t N_t}{P_t Y_t}$ is the labour income share (or, equivalently, real unit labour costs). Equivalently, in terms of percentage deviations from steady state we have:

$$\hat{mc}_t = \hat{s}_t \tag{14}$$

Consider next the case where technology is isoelastic in non-overhead labour: $Y_t = F(K,N) = A_t K_t^{1-\alpha}(N_t - \overline{N}_t)^{\alpha}$ yields the following expression for the marginal costs:[15]

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[14] Note also that backward-looking firms free-ride off optimising firms to the extent that p_{t-1}^* is influenced by the behaviour of forward-looking firms. In this regard, the welfare losses from following the rule need not be large, if the fraction of backward-looking firms is not too dominant.

[15] Overhead labour is represented by $\overline{N}_t$. The technical details of this section are left to a technical Appendix.

$$\hat{mc}_t = \hat{s}_t + \delta \hat{n}_t \tag{15}$$

where $\delta = \frac{\overline{N}/N}{1-\overline{N}/N'}$ depends on the ratio of overhead labour to total labour in steady state. Thus, from expression (15) it is straightforward to see that allowing for overhead labour makes the real unit labour costs more procyclical.

Let us assume next a CES production function:

$$Y_t = F(K,N) = \left[\alpha_k K_t^{1-\frac{1}{\sigma}} + \alpha_N \left(Z_t N_t\right)^{1-\frac{1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

In this case the expression for the real unit labour cost has to be modified as follows:

$$\hat{mc}_t = \hat{s}_t + \eta \hat{yk}_t \tag{16}$$

where $\hat{yk}_t$ is the deviation from its steady state of the productivity of capital, and $\eta = \left(\frac{1-\mu s}{\mu s}\right)\left(\frac{1-\sigma}{\sigma}\right)$, with μ as the steady state markup, s the steady state labour income share and σ the elasticity of substitution between labour and capital.

Finally, we consider the effect of labour adjustment cost on the computation of the real marginal costs. In that case, the marginal costs take the following form:

$$\hat{mc}_t = \hat{s}_t - \hat{\gamma}_t + \xi \left(\hat{gN}_t - \zeta E_t \left\{ \hat{gN}_t \right\} \right) \tag{17}$$

where $\hat{\gamma}_t = -\delta \hat{n}_t, \hat{gN}_t \equiv \log\left(N_t / N_{t-1}\right)$ and ξ is a constant that depends upon the curvature of the adjustment costs (see the Appendix for details).

4. How well does the New Phillips Curve fit Spanish data?

As a first pass on the data, Figure 2 plots the evolution of inflation (based on the GDP deflator), as well as the labour income share which we take as our baseline measure of real marginal costs, $\hat{mc}_t$. Both variables move closely together, at least at medium frequencies. The relation appears to hold throughout the three key phases of the sample: (i) the disinflation of the 1980s; (ii) the steady inflation of the late 1980s and early 1990s; and (iii) the recent disinflationary period and current period of low inflation since the late 1990s. That apparent positive comovement of marginal cost and inflation suggests that, as was the case for the United States (Galí and Gertler (1999)) and the euro area (Galí et al (2000)), the NPC may also fit the Spanish inflation data well, and thus may provide a useful tool for understanding the dynamics of its differential vis-à-vis the rest of Europe.

In order to confirm such an intuition, we now proceed to provide formal reduced-form evidence of this conjecture.[16] The estimated inflation equation for Spain during the period 1980:I-1998:IV is given by:

[16] We begin by presenting estimates of the coefficients in equation (2). We refer to these estimates as “reduced-form” since we do not try to identify the primitive parameters that underlie the slope coefficient λ. In the next section we proceed to relate these coefficients with a structural model with sticky prices. The aim will be to identify the degree of price rigidities behind the observed evolution of inflation and real marginal costs.

$$\pi_t = \underset{(0.077)}{0.760} E_t\{\pi_{t+1}\} + \underset{(0.052)}{0.151} \hat{mc}_t \tag{18}$$

where standard errors are shown in parentheses.[17] The main predictions of the model appear to be satisfied. The slope coefficient on marginal cost is positive, as implied by the theory, and significantly different from zero. The estimate of coefficient affecting expected inflation (the discount factor) is rather low, but has the right sign and order of magnitude. We view Figure 2 and the previous results as prima facie evidence of the potential merits of the new inflation paradigm.

In Figure 3, we plot the real marginal costs under the different assumptions about technology. In particular, in the left-hand panel we plot the Cobb-Douglas case against two cases: the first allows for overhead labour, and the second for adjustment cost in labour. In the right-hand panel we compare the Cobb-Douglas case with the CES and the CES with labour adjustment costs. It is clear that there are few noticeable differences in the evolution of the alternative measures of real marginal costs. The most remarkable feature can be observed in the specification that allows for labour adjustment costs. In that case, the marginal costs present a higher volatility over the period 1984-92, induced by the large fluctuations in employment experienced in Spain after the introduction of fixed-term contracts among other structural reforms.[18]

In a recent paper, Wolman (1999) suggests that allowing for features such as overhead labour, labour adjustment costs and variable capital utilisation would increase the empirical viability of sticky price models. The analysis here tends to suggest that such extensions may have very little impact on the estimates of the degree of price stickiness, as will become clear in the next section.

4.1 Structural estimates

In this section, we present estimates of the structural parameter θ, which measures the extent of price rigidity. As expression (11) indicates, the reduced-form coefficient λ is a function not only of θ and β, but also of the technology curvature parameter α and the elasticity of demand $\in$. Our main aim is to use the model's restrictions to identify only two primitive parameters: β, the slope coefficient on expected inflation in equation (10), as well as one other parameter among θ, α and $\in$. Our strategy is to estimate the degree of price rigidity, θ, and the discount factor β, conditional on a set of plausible values for α and $\in$. Let us define the constant $\xi \equiv \frac{1-\alpha}{1+\alpha(\in -1)} \in (0,1)$, which is conditional on the calibrated values for α and $\in$. Given this definition, we can express the slope coefficient on real marginal cost, λ in equation (10), as follows: $\lambda \equiv \theta^{-1}(1-\theta)(1-\beta\theta)\xi$.

In our baseline we report estimates under the assumption of constant marginal costs across firms, which corresponds to $\xi = 1$. In this case identification of θ does not require the calibration of any parameter. Nevertheless, under increasing marginal cost, to estimate the parameters β and θ, we treat ξ as known with certainty. We obtain measures of ξ, ie of α and $\in$, based on information about the steady values of the average markup of price over marginal cost, μ_t and of the labour income share $S_t \equiv W_t N_t / P_t Y_t$. By definition, the average markup equals the inverse of average real marginal cost (ie, $\mu_t = 1/MC_t$). It thus follows from our assumptions about technology that: $\alpha = 1 - \frac{S_t}{\mu_t}$. We can accordingly pin down α using estimates of steady state (sample mean) values of the labour income

[17] We estimate this equation by GMM. The method will be described in detail in Section 4, where we present our structural estimates of the model. Our instruments set includes four lags of inflation, detrended output, wage inflation and real marginal costs. We performed a number of diagnostic tests to evaluate the regression. To check for potential weakness of the instruments, we perform an F-test applied to the first-stage regression; the results clearly suggest that the instruments used are relevant (F statistic = 15.7, with a p-value = 0.00). Next we test the model's overidentifying restrictions. Based on the Hansen test, we do not reject the overidentifying restrictions (J statistic = 7.59, with associated p-value of 0.91).

[18] See eg Bentolila and Saint-Paul (1992).

share and the markup. Given an estimate of the steady state markup μ we can obtain a value for $\in$ by observing that, given our assumptions, the steady state markup should correspond to the desired or frictionless markup, implying the relationship which allows us to identify $\in$, ie $\in = \frac{\mu}{\mu - 1}$.We estimate the models (10) and (12) by GMM using the following two orthogonality conditions, respectively:

$$E_t\left\{\left(\pi_t - \beta\pi_{t+1} - \theta^{-1}(1-\theta)(1-\beta\theta)\xi \hat{mc}_t\right)z_t\right\} = 0$$

$$E_t\left\{\left(\pi_t - \omega\pi_{t-1} - \beta\theta\pi_{t+1} - \phi^{-1}(1-\omega)(1-\theta)(1-\beta\theta)\xi \hat{mc}_t\right)z_t\right\} = 0$$

where $\phi \equiv \theta + \omega[1-\theta(1-\beta)]$. Notice that in the hybrid model we can estimate an additional parameter: ω, the fraction of backward-looking price setters. As in the 11 previous cases, we use calibrated values of α and $\in$ to calibrate ξ. This again allows us to identify ω, as well as the price rigidity parameter θ.

In our empirical analysis we use instruments dated $t-1$ or earlier for two reasons: First, there is likely to be considerable error in our measure of marginal cost. Assuming this error is uncorrelated with past information, it is appropriate to use lagged instruments. Second, not all current information may be available to the public at the time they form expectations. Our instruments set includes a constant and four lags of price and wage inflation, detrended output and the real marginal costs.

Table 1 reports estimates of the model under constant returns to labour, ie under constant marginal costs across firms, which corresponds to $\xi = 1$, as discussed above. In addition, we proxy the real marginal costs using the real unit labour costs. The first row (labelled (1)) corresponds to the estimates of the structural parameters of the forward-looking model. The row (2) reports the structural estimates for the hybrid model. The first two columns report the estimates of the two primitive parameters, θ and β. The third column reports the implied estimate for λ, the reduced-form slope coefficient on real marginal cost. Next we report the average duration of a price remaining fixed (in quarters), corresponding to the estimate of θ (ie $D = 1/1-\theta)$). Standard errors (with a Newey-West correction) for all the parameter estimates are reported in brackets.

The first row of Table 1 reports the baseline estimates of the purely forward-looking model using Spanish data from 1980.I to 1998:IV. The estimated parameter θ is a bit high leading to an average duration of prices around 10 quarters. The estimate of the discount factor β is again a bit low, but not terribly so is we take into account the uncertainty surrounding the estimates. The combination of these two parameters implies a low value for the slope of the Phillips curve, λ, positive and significant.[19] Thus, although the results suggest that real marginal cost is indeed a significant determinant of inflation, imposing a pure forward-looking model jointly with the assumption of constant returns to labour yields a high estimate of the price stickiness parameter and so a high duration of fixed prices.

In the second row of Table 1 we report estimates for the hybrid model. In this case, we report the estimates for the primitive parameters ω, θ and β, as well as the reduced-form parameters, γ^b,γ^f and λ while the last column again gives the implied average duration of price rigidity.

The estimates imply that backward-looking price setters, measured by the size of ω, have been a relatively important factor behind the dynamics of Spanish inflation. The estimate of ω, the fraction of backward-looking price setters, is around 0.7 leading to estimates of γ^b and γ^f around 0.5. The estimates of the other structural parameters, β and θ are much more plausible under the hybrid specification. Again, after accounting for standard errors, we get sound estimates, being now the

[19] Although not reported to save space, the overidentifying restrictions are not rejected under any specification. The results are available from the authors upon request.

estimated average duration around six quarters, lower than obtained in the purely forward-looking specification. Thus, using the hybrid model prices are more flexible (ie the average duration of price rigidity is shorter), but the backward-looking behaviour is more important.

We have thus far tested our forward-looking model against the hybrid model under the hypothesis of constant marginal costs and using the real unit labour costs as our measure of real marginal costs. In the next two sections we extend our analysis in two directions. First, we analyse the effect of alternative measures of marginal costs on the estimates of the structural parameters. Second, we focus on the effects of allowing for increasing marginal costs in order to estimate our parameters, paying special attention to the degree of price rigidity.

Table 2 presents the results for the constant marginal costs model, ie $\xi = 1$, under alternative specifications of marginal costs. We report, for each definition of marginal costs, the estimates of the forward-looking model (row (1)) as well as the hybrid model (row (2)). Overall, it appears that the previous results hold. Thus, as anticipated from Figure 3, alternative specification of the marginal costs have no significant effects on the estimation of the structural parameters. The forward-looking specification tends to overestimate the degree of price rigidity. The hybrid model seems to work better. The estimates confirm that backward-looking price setting, measured by the size of ω, is around 0.7, and that this corresponds to estimates of γ^b and γ^f of around 0.5. The duration is estimated at around six quarters.

We now extend the analysis to the model where we allow for increasing marginal costs (ie $\xi \neq 1$). Table 3 reports the structural parameters under two different calibrations of the labour income share. In the first two rows we set *s* = 0.75, while in the second we set *s* = 0.70 corresponding to the average over the estimation period. We fix the steady state markup μ = 1.2 within the range of the empirical estimates (see, for instance, Rotemberg and Woodford (1995) and Basu and Fernald (1997)). Below we will show how the structural estimates depend upon the calibration of those parameters. From Table 3 two main features are worth noting. First, as anticipated in the theoretical Section 3, the existence of increasing marginal costs allows us to estimate a more plausible degree of price stickiness. This value leads to a estimated duration between three and four quarters, in line with the estimates for the United States and the euro area (see Galí et al (2000)). Moreover, these estimates are quite robust to the existence of backward-looking firms (ie the estimation of the hybrid model yields only slightly lower values). Second, allowing for decreasing returns to labour yields lower estimates of both the degree of price rigidity and the fraction of backward-looking price setters than those obtained under the constant returns assumption (corresponding to $\xi = 1$).

These latter estimates, although theoretically appealing, render its identification to the calibration of the parameters α and $\in$ using information on the steady state labour income shares, *s*, and the markup, μ. We have carried out a robustness check of the increasing marginal costs model, by analysing how the estimates of the parameter of price stickiness, θ, depends upon changes in the steady state of both *s* and μ. Thus, we have estimated the parameters of the model for different values of *s* and μ, both in the purely forward-looking model and in the hybrid model. The results are presented in Figures 4a and 4b.

The top panels of Figure 4a present the estimates of the parameter θ with the 95% confidence intervals, for both the forward-looking and the hybrid model under different values of the steady state labour income share (the values ranged from 0.61 to 0.75, which cover the evolution of the variable over the sample period we use in our analysis; see the right-hand scale of Figure 2). For these exercises we keep μ = 1.2 as in the estimates of the previous Table 3. The bottom panels present the estimates (and the 95% confidence interval) of the duration associated to the values of θ. These figures tend to support the results previously discussed. Overall, changes in the labour income share of 15 percentage points slightly affect the estimates of the parameter θ, so the estimated duration ranges from three to four quarters. Nevertheless, a higher steady state labour income share leads to a higher estimates of the price stickiness parameter. In the hybrid model, the differences, across different values of the labour share, in the point estimates of θ are even lower than in the forward-looking model. In addition, under the hybrid model we tend to estimate a lower degree of price rigidity.

Figure 4b carries out a similar exercise. Now we fix *s* = 0.7, but allowing changes in the steady state markup, μ. Values of the steady state markup near one (perfect competition) tend to reduce significantly the estimates of the price stickiness. Nevertheless, for values of the markup between 20%

to 50%, there is no significant effect on the estimation of parameter θ, and so on the duration. Again this is true for both models, although under the hybrid specification we tend to estimate a lower degree of price rigidities across different values of μ.

4.2 A measure of fundamental inflation

In this section we follow Galí and Gertler (1999), Sbordone (1999) and Galí et al (2000), to assess the extent to which our estimates of the model constitute a good approximation to the dynamics of inflation in Spain. We consider both the pure forward-looking and the hybrid model given by equations ((10) and (12)), since the hybrid model yields estimates that are slightly different.

The above-mentioned authors define the concept of fundamental inflation π_t^*, as the one obtained by iterating equations (10) and (12). For simplicity, we focus on the pure forward-looking case. In this case, solving forward yields:[20]

$$\pi_t = \lambda \sum_{k=0}^{\infty} \beta^k E_t \left\{ \hat{mc}_{t+k} \right\} \equiv \pi_t^* \tag{19}$$

Fundamental inflation π_t^* is a discounted stream of expected future real marginal costs, in analogy to the way a fundamental stock price is a discounted stream of expected future dividends.

To the extent that our baseline model is correct, fundamental inflation should closely mirror the dynamics of actual inflation. The question we address in this section is: to what extent can observed fluctuations in inflation be accounted for by our measure of fundamental inflation, ie how far is our model from reality?

Figure 5a displays our measure of fundamental inflation for Spain together with actual inflation in the forward-looking model. The measure of fundamental inflation is constructed using the estimated structural form presented in Table 3. Overall, fundamental inflation tracks the behaviour of actual inflation quite well, especially at medium frequencies. In particular, it seems to succeed in accounting for the high inflation in the early 1980s and the subsequent disinflation in the mid-1980s and 1990s. Nevertheless, the recent episode of low inflation, in the late 1990s, is overestimated. Thus, as expected, the purely forward-looking model fails to fully capture the short run movements of inflation. In Figure 5b we present the fundamental inflation calculated for the hybrid model. In this case, the model seems to work very well both at the medium and high frequencies. Again, as expected allowing for such an inertial behaviour (backward-looking price setters) in inflation improves the previous model so as to capture the short-term movements of inflation over the sample period.

4.3 Measuring marginal costs in an open economy: the role of imported materials

Openness of the economy may affect the dynamics of inflation, because movements in the exchange rate can fuel domestic inflation behaviour through import prices. It is important to stress here, however, that neither the derivation of equation (10), relating domestic inflation to real marginal costs, nor the relationship between the latter variable and the labour income share (given a Cobb-Douglas technology), relied on any assumption on the degree of openness of the economy. But, as we will show next, once we depart from the assumption of a constant elasticity of output with respect to labour, the labour income share may no longer be a suitable indicator of real marginal costs when other non-labour inputs are used. In particular, if some of the intermediate inputs are imported, information about their relative price (which is influenced by the exchange rate) may be needed to measure the firm's marginal costs.

For concreteness, let us assume the following CES production function:

[20] The hybrid case can be found in Galí and Gertler (1999). We leave all the technical details of this section to the previous paper.

$$Y_t = F(N,M) = \left[\alpha_N \left(Z_t N_t\right)^{1-\frac{1}{\sigma}} + \alpha_N \left(M_t\right)^{1-\frac{1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

where M_t represents imported materials (ie intermediate goods), and σ is the elasticity of substitution between the two inputs. From cost minimisation we know that the following equilibrium condition holds:

$$\frac{N_t}{M_t} = \left(\frac{P_{M,t}}{W_t} \right)^{\sigma} \tag{20}$$

where $P_{M,t}$ is the price of imported materials, and W_t is the nominal wage. In that case, and as described in the Appendix, one can derive the following expression for the real marginal costs as:

$$mc_t = \frac{s_t}{1 - \kappa \left(\frac{Y_t}{M_t} \right)^{\frac{1}{\sigma} - 1}} \tag{21}$$

Substituting expression (20) into expression (21) and log-linearising the resulting expression yields the following specification for the real marginal costs:

$$\hat{mc}_t = s_t + \phi\left(p_{M,t} - \omega_t\right) + const \tag{22}$$

where $\phi = \left(\frac{1-\mu s}{\mu s} \right)(\sigma - 1)$. Notice that now real marginal costs depend upon real unit labour cost and an additional term related to the relative price of the two inputs. The parameter ϕ determines how changes in the ratio of relative prices would translate into movements in the marginal costs, and so in inflation. Thus, when $\sigma > 1$ an increase in the prices of imported materials below the increase in the nominal wage will increase the marginal costs.[21] Finally, it is worth pointing out that movement in the exchange rate would affect the evolution of the import prices, and so the dynamic of the marginal costs.

In Figure 6 we plot the evolution of the (log) relative price of imports ($p_{M,t} - \omega_t$) together with domestic annual inflation. As the figure makes clear, the two variables display a similar pattern. This evolution suggests that this component can be an additional and independent source of movements in the marginal costs that is relevant to understand the recent Spanish disinflation. But, what is behind this downward trend in the relative prices? To answer that question we have decomposed this variable in terms of real import prices and real wages:

$$p_{M,t} - \omega_t = \left(p_{M,t} - p_t\right) - \left(\omega_t - p_t\right)$$

Figure 6b presents the evolution of these two components. As can be seen from that figure, the downward trend that dominates the behaviour of relative input prices during the 1980s was the result of a decrease in real import prices (ie a real exchange rate appreciation), as well as an increase in real wages. Interestingly, the nominal depreciation of the peseta in 1992 and subsequent years was not fully translated into real import prices and, in addition, it was offset by a reduction in real wages. These two factors are behind the evolution this second component of the marginal cost.

As a first approximation we proceed to estimate the importance of the open economy factor as a source of variations in marginal cost and, thus, in the dynamics of inflation by estimating the following reduced-form equation:

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21 Notice that when $\sigma \rightarrow 1$ the production function is Cobb-Douglas so the marginal costs are independent of the movements in the relative prices of labour and imported materials.

$$\pi_t = \beta\ E_t\{\pi_{t+1}\} + \lambda \hat{mc}_t$$
$$= \beta\ E_t\{\pi_{t+1}\} + \lambda_1 s_t + \lambda_2(p_{M,t} - \omega_t)$$

where parameters λ_1 and λ_2 are functions of the structural parameters. The GMM estimate of the previous equation is:[22]

$$\pi_t = \underset{(0.058)}{0.561}\ E_t\{\pi_{t+1}\} + \underset{(0.009)}{0.032}\, s_t + \underset{(0.083)}{0.442}\,(p_{M,t} - \omega_t)$$

Notice that the estimated sign of the relative import price coefficient is positive and highly significant. Given the observed behaviour of that variable, we can conclude that the Spanish disinflation of the past two decades can be partly accounted for by the decrease in the relative price of imported inputs (as we describe in Figures 6a and 6b).

Given (22), the estimates also imply an elasticity of substitution between employment and imported materials that is significantly larger than one $(\sigma > 1)$. Finally, the coefficients on expected inflation and real unit labour costs are still clearly significant, as predicted by the theory.

We now turn to estimate our structural parameters for different values of the elasticity of substitution. In particular, in Figure 7 we plot how different values of σ affect the behaviour of the marginal costs. Thus, in the three panels of Figure 7 we plot the evolution of inflation and three measures of marginal costs that have been obtained for: σ = 0.8, $\sigma \to 1$ (the Cobb-Douglas case), and σ = 1.5. Overall, the medium-run behaviour of the marginal costs is very similar to the baseline case, ie the Cobb-Douglas. Nevertheless, in the short run there are some differences, especially during the period 1989-94. In particular, it is worth noting that a higher elasticity of substitution leads to a less volatile behaviour of the marginal cost, ie the marginal costs remain essentially flat over that period, hence contributing to the reduction in inflation. Finally, in Table 4 we present the corresponding structural estimates for these two values of σ. The estimates confirm the previous assessment that accounting for the movements in the relative price of inputs in a non-Cobb-Douglas setting does not affect appreciably the basic results of the paper regarding the value of the structural parameters (θ and ω).

5. Marginal cost dynamics: the role of labour market frictions

5.1 Measuring wage markup

In this section we decompose the movement in real marginal cost in order to isolate the factors that drive this variable.[23] Our results suggest that labour market frictions are likely to play a key role in the evolution of real marginal cost in Spain. Our decomposition requires some restrictions from theory. Suppose the representative household has preferences given by $\Sigma_{t=0}^{\infty}\beta^t U(C_t, N_t)$, where C_t is non-durables consumption and N_t is labour, and where usual properties on the utility are assumed to hold. Without taking a stand on the nature of the labour market (eg competitive versus non-competitive, etc), we can without loss of generality express the link between the real wage and household preferences in the following log-linear way:

$$(\hat{\omega}_t - p_t) = \hat{mrs}_t + \hat{\mu}_t^w \qquad (23)$$

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[22] In the GMM estimation we add four lags of the relative price of inputs as instruments. The coefficient affecting the relative price of inputs has been multiplied by 100. These reduced-form estimates correspond to the model with constant marginal costs across firms.

[23] We follow here the analysis of Galí et al (2000).

where $\hat{mrs}_t = \log(-\frac{U_{N,t}}{U_{C,t}})$ is the log of the marginal rate of substitution between consumption and labour. Because that variable is the marginal cost to the household in consumption units of supplying additional labour, the variable $\hat{\mu}_t^w$ can be interpreted as the wage markup (in analogy to the price markup over marginal cost, $\hat{\mu}_t$). Assuming that the household cannot be forced to supply labour to the point where the marginal benefit $(\hat{\omega}_t - p_t)$ is less than the marginal cost $\hat{mrs}_t$ we have $\hat{\mu}_t^w \geq 0$.

Conditional on measures of $(\hat{\omega}_t - p_t)$ and $\hat{mrs}_t$, equation (23) provides a simple way to identify the role of labour market frictions in the wage component of marginal cost. If the labour market were perfectly competitive and frictionless (and there were no measurement problems), we should observe $\mu_t^w = 0 \left(\hat{\mu}_t^w = 0 \right)$ ie the real wage adjusts to equal the household's true marginal cost of supplying labour. With labour market frictions present, we should expect to see $\mu_t^w > 0$ and also possibly varying over time (ie $\hat{\mu}_t^w \neq 0$). Situations that could produce this outcome include: households' having some form of monopoly power in the labour market, staggered long-term nominal wage contracting, distortionary taxes, and informational frictions that generate efficiency wage payments.

Using equation (23) to eliminate the real wage in the measure of real marginal cost yields the following decomposition:

$$\log\left(MC_t\right) = \log \frac{(W_t / P_t)}{(1-\alpha)(Y_t / N_t)} = \log\left(-\frac{U_{N,t} / U_{C,t}}{(1-\alpha) Y_t / N_t} \right) + \mu_t^w \tag{24}$$

According to equation (24), real marginal cost has two components: (i) the wage markup μ_t^w, and (ii) the ratio of the household's marginal cost of labour supply to the marginal product of labour, $\frac{-U_{N,t} / U_{C,t}}{(1-\alpha) Y_t / N_t}$. In this section, we analyse in detail the 20 determinants of the wage markup, leaving to the next section the analysis of the ratio of the marginal rate of substitution to the marginal product of labour, $\frac{-U_{N,t} / U_{C,t}}{(1-\alpha) Y_t / N_t}$, and its implications for measuring the "output gap" in a economy with both price and wage rigidities.

In this paper, we extend the analysis of Galí et al (2000) considering a type of preferences that imply the absence of income effect on the labour supply decisions.[24] This model has proved useful in gaining an understanding of some monetary business cycle features. In particular, we use the following specification for preferences

$$U\left(C_{it}, N_{it}\right) = \log\left(C_t - \frac{A_t}{1+\varphi} N_t^{1+\varphi} \right) \tag{25}$$

As anticipated, this specification implies that the MRS_t is independent of consumption. Following King and Wolman (1997) A_t can be understood as a random preference shifter that also acts as a productivity shock, so guaranteeing balanced growth. Log-linearising equation (24) and ignoring

[24] Among others, see Christiano et al (1997) and Dotsey et al (1999).

constants yields an expression for marginal cost and its components that is linear in observable variables:

$$\hat{mc}_t = \hat{\mu}^w_t + \left[\left(\hat{a}_t + \varphi \hat{n}_t\right) - \left(\hat{y}_t - \hat{n}_t\right)\right] \qquad (26)$$

with the wage markup defined as follows:

$$\hat{u}^w_t = \left(\hat{w}_t - \hat{p}_t\right) - \left(\hat{a}_t + \varphi \hat{n}_t\right)$$

Figure 8 presents the evolution of the marginal costs and the wage markup for Spain under alternative parameterisation of the labour supply elasticity, respectively. We take three values for φ, namely 1, 5 and 10, implying a labour supply elasticity ($1/\varphi$) of 1, 0.2 and 0.1.[25] The top panel in each case illustrates the behaviour of the (log) inefficiency wedge relative to (log) real marginal cost and the bottom panel does the same for the (log) wage markup.

In general a robust feature is that over the whole period there is a steady decline in the wage markup behind the decline in marginal cost. This circumstance is robust across the different values we use for the labour supply elasticity. Perhaps most striking feature is the change in the wage markup, from the high values at the beginning of the 1980s to an apparent downward drift from 1985 to 1999. This behaviour seems consistent with the popular notion that labour union pressures produced a steady rise in the real wage in the late 1970s and during the beginning of the 1980s. The impact of this labour market distortion is mirrored in the steady increase in the inefficiency wedge over the same period.

The increase in the wage markup during the latest recession is consistent with the idea that workers change their expectations slowly in response to changes in economic conditions. Finally, the reduction in the marginal costs we observe during the 1990s is mostly due to the reduction in the wage markup.

6. Conclusions

In this paper we provide evidence on the fit of the New Phillips Curve (NPC) for Spain over the most recent disinflationary period (1980-98). Some of the findings can be summarised as follows: (a) the NPC fits the data well; (b) however, the backward-looking component of inflation is important; (c) the degree of price stickiness implied by the estimates is plausible; (d) the use of independent information about the price of imported intermediate goods (which is influenced by the exchange rate) affects the measure of the firm's marginal costs and so inflation dynamics; and finally, (e) labour market frictions, as manifested in the behaviour of the wage markup, appear to have also played a key role in shaping the behaviour of marginal costs.

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[25] A low value of the labour supply elasticity is more in line with the microeconomic empirical evidence (see eg Pencavel (1986)). In the analysis, the variable z_t is a measure of the productivity trend obtained from a regression of productivity on a time trend.

Appendix:
Derivation of various marginal cost measures

The purpose of this appendix is to derive alternative measures of firm's marginal costs. In this case, real marginal costs, mc_t, (ie the inverse of the markup) are given by: $mc_t = \frac{\omega_t}{F_{Nt}}$, where ω_t is the real wage and F_{Nt} is the partial derivative of the production function (ie of output) with respect to labour. Under the previous assumptions, the real marginal costs can be expressed as follows:

$$mc_t = \frac{w_t}{F_{Nt}} = \frac{s_t}{\gamma_t}$$

where s_t is the labour income share, and γ is the elasticity of output with respect to labour. In log-deviations from steady state ($mc = \frac{1}{\mu} = \frac{s}{\gamma}$, where μ is the steady state markup), the previous expression is just:

$$\hat{mc}_t = \hat{s}_t - \hat{\gamma}_t \qquad (27)$$

The benchmark case used in this paper is based upon the assumption of no adjustment costs, and a Cobb-Douglas production function $\left(ie\ Y_t = F(K,N) = Z_t K_t^{1-\alpha} N_t^{\alpha}\right)$. In this case, $\gamma_t = \alpha$, thus expression (27) collapses to: $\hat{mc}_t = \hat{s}_t$.

Assuming a CES production function: $Y_t = F(K,N) = \left[\alpha_K K_t^{1-\frac{1}{\sigma}} + \alpha_N (Z_t N_t)^{1-\frac{1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$, the elasticity of output with respect to labour can be written as a function of the average productivity of capital $\left(YK_t \equiv Y_t / K_t\right)$: $\gamma_t = 1 - \kappa (YK_t)^{\frac{1}{\sigma}-1}$. Log-linearising around steady state this yields to: $\hat{\gamma}_t = -\eta\, \hat{yk}_t$, with $\eta = \left(\frac{1-\mu s}{\mu s}\right)\left(\frac{1-\sigma}{\sigma}\right)$.

Using expression (27) we get:

$$\hat{mc}_t = \hat{s}_t + \eta\, \hat{yk}_t \qquad (28)$$

We calibrate the model following Rotemberg and Woodford (1999). Thus, s = 0.7, μ = 1.25, $\frac{1}{\sigma}$ = 2, which implies a value of η = 0.14. Rotemberg and Woodford (1999) also consider the case where technology is isoelastic in non-overhead labour: $Y_t = F(K,N) = Z_t K_t^{1-\alpha}\left(N_t - \overline{N}_t\right)^{\alpha}$. In this case, $\gamma_t = \alpha \frac{N_t}{N_t - \overline{N}}$, and in log-deviations from the steady state: $\hat{\gamma}_t = -\delta\, \hat{n}_t$, where $\delta = \frac{\overline{N}/N}{1-\overline{N}/N}$, so the new expression for the marginal costs is:

$$\hat{mc}_t = \hat{s}_t + \delta\, \hat{n}_t \qquad (29)$$

To calibrate the model we follow Rotemberg and Woodford (1999) using a zero profit condition in steady state. In particular, it can be shown that the ratio of average costs to marginal costs can be written as follows: $\frac{AC_t}{MC_t} = \left[X + \alpha \left(\frac{\overline{N}}{N_t - \overline{N}} \right) \right]$. This implies the following steady state relationship: $AC = \frac{x}{\mu} + \frac{\delta}{1+\delta} s$. Non-negative profits require $AC_t \leq 1$, implying that $0 \leq \delta \leq \frac{\mu - x}{x - \mu(1-s)}$. We calibrate δ in expression (29) following Rotemberg and Woodford (1999). Under zero profits, and using s = 0.7, μ = 1.25, and X = 1, this implies δ = 0.4.

Finally, we consider the effect of including the cost of adjusting labour. These costs take the form: $U_t N_t \phi(N_t / N_{t-1})$, where U_t is the price of the input required to make the adjustment. In this case, the real adjustment cost associated with hiring an additional worker for one period is given by:

$$(U_t / P_t)\{\phi(N_t / N_{t-1}) + (N_t / N_{t-1})\phi'(N_t / N_{t-1})\} - E_t\left[q_{t,t+1}\left\{(U_{t+1} / P_{t+1})(N_{t+1} / N_t)^2 \phi'(N_{t+1} / N_t)\right\}\right]$$

Letting $\zeta_t \equiv \frac{q_{t-1,t}(U_t / P_t)}{(U_{t-1} / P_{t-1})}$, and $g_{Nt} \equiv (N_t / N_{t-1})$, we can approximate the previous expression by:

$$(U_t / P_t)\phi''(1)\left\{\hat{g}_{Nt} - \zeta E_t\left[\hat{g}_{Nt+1}\right]\right\}$$

Assuming that the ratio U_t / W_t is stationary, the real marginal costs are given by:

$$mc_t = \left(\frac{s_t}{\gamma_t}\right)\left[1 + (U / W)\phi''(1)\left\{\hat{g}_{Nt} - \zeta E_t\left[\hat{g}_{Nt+1}\right]\right\}\right]$$

which in terms of deviations from steady state yields:

$$\hat{mc}_t = \hat{s}_t - \hat{\gamma}_t + \xi\left\{\hat{g}_{Nt} - \zeta E_t\left[\hat{g}_{Nt+1}\right]\right\} \qquad (30)$$

where $\xi = \mu^{-1}(U / W)\phi''(1)$. Under the assumption that the employment follows a random walk, then

$$\hat{mc}_t = \hat{s}_t - \hat{\gamma}_t + \xi\{\hat{g}_{Nt}\}.$$

Figure 1

Inflation and Detrended Output

Figure 2

Inflation and Marginal Cost

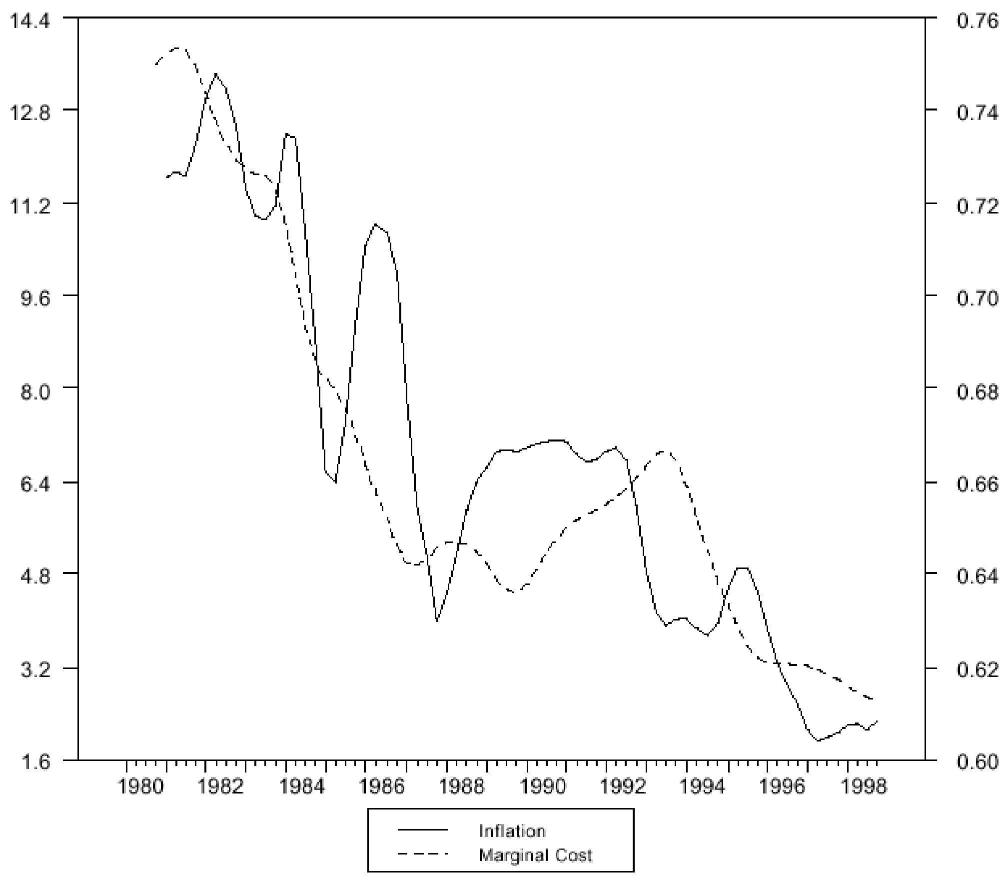

Figure 3

Comparing alternative marginal costs

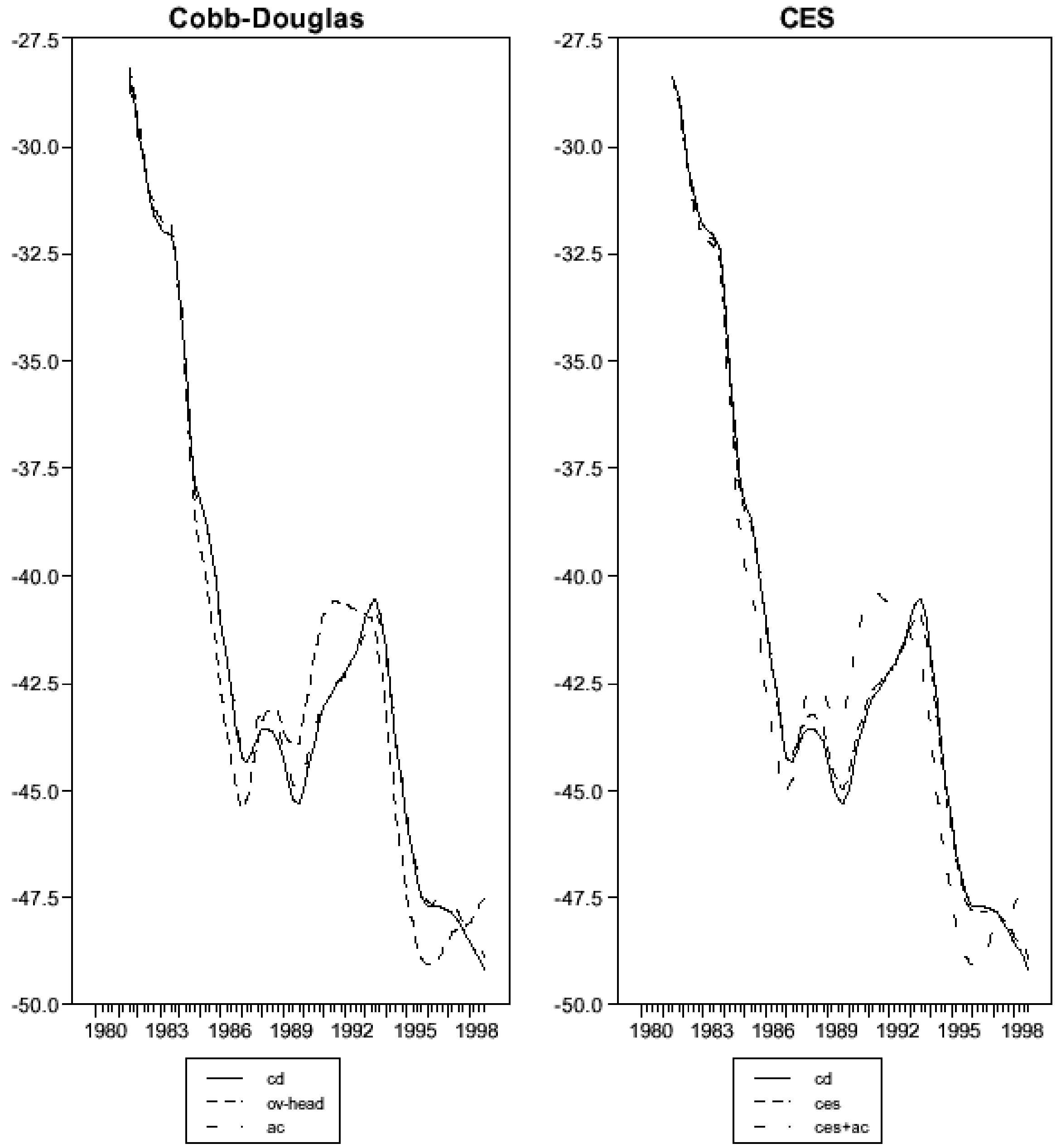

Figure 4a
Inf luence of labour share on estimated price stickiness

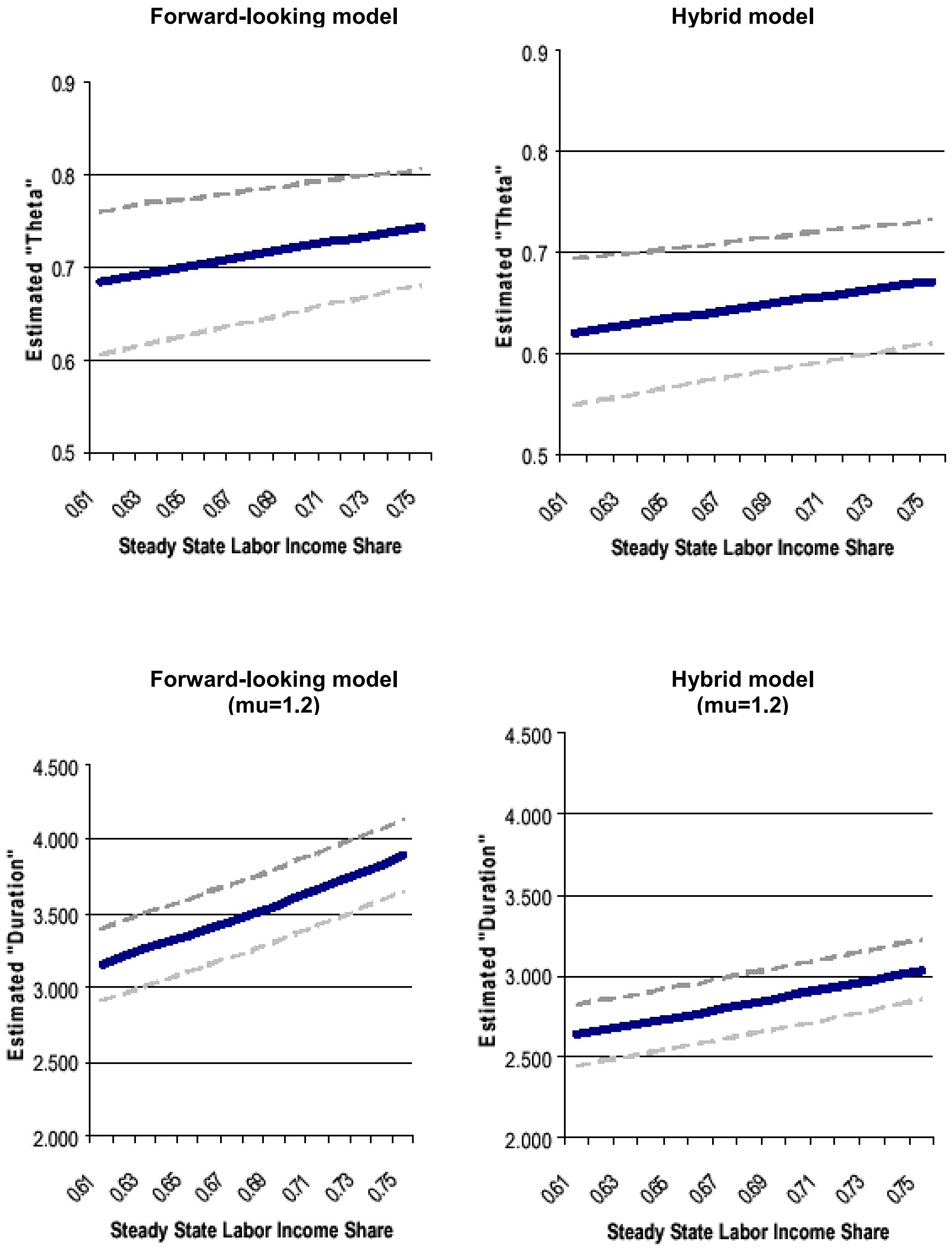

Figure 4b

Influence of markups on estimated price stickiness

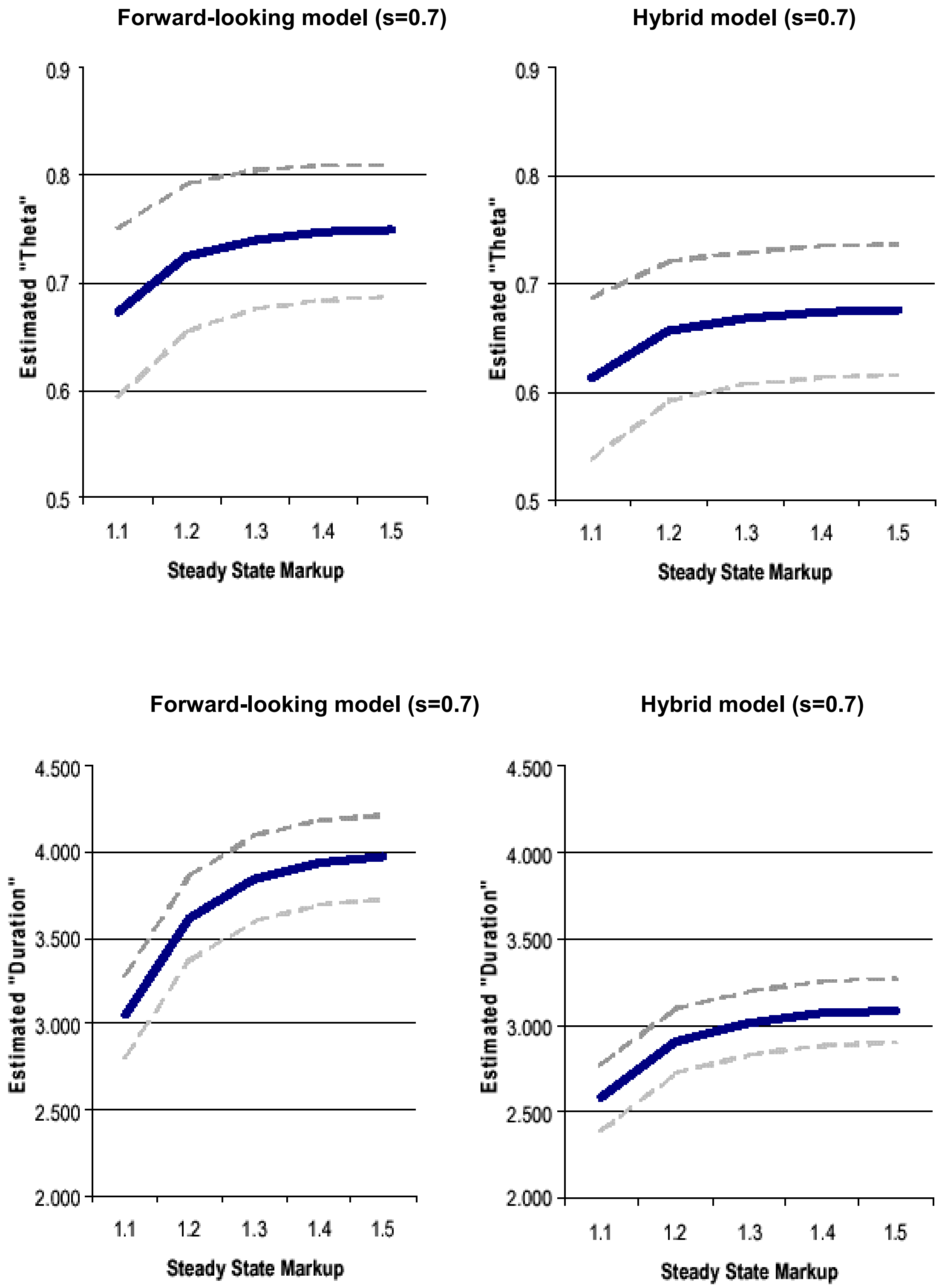

Figure 5a

Inflation: Actual vs Fundamental

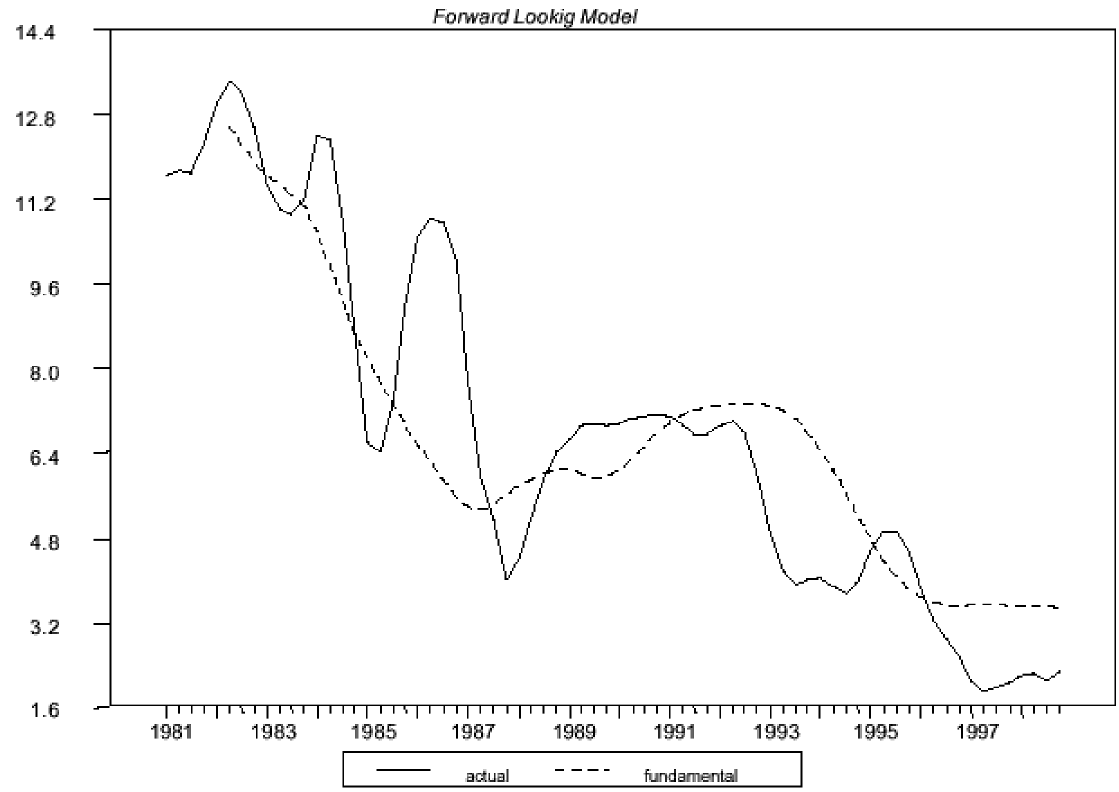

Figure 5b

Inflation: Actual vs Fundamental

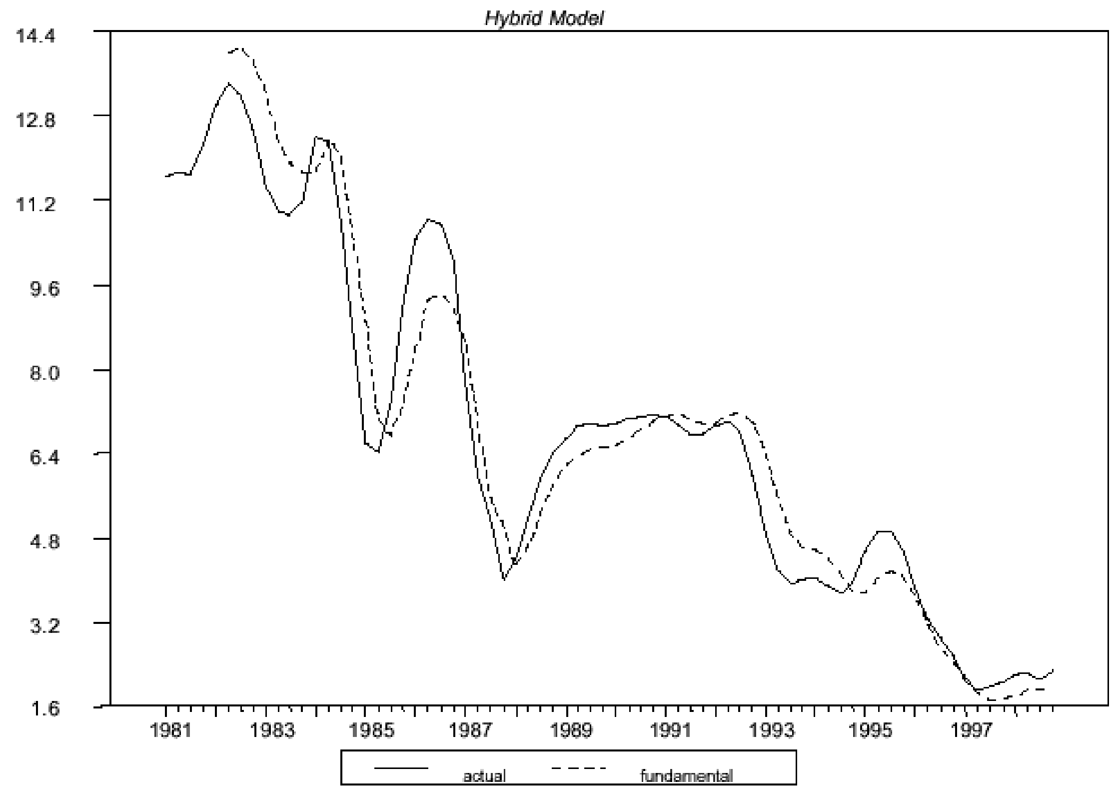

Figure 6a

Inflation and Relative Imput Prices

Figure 6b

Real Wages and Import Prices

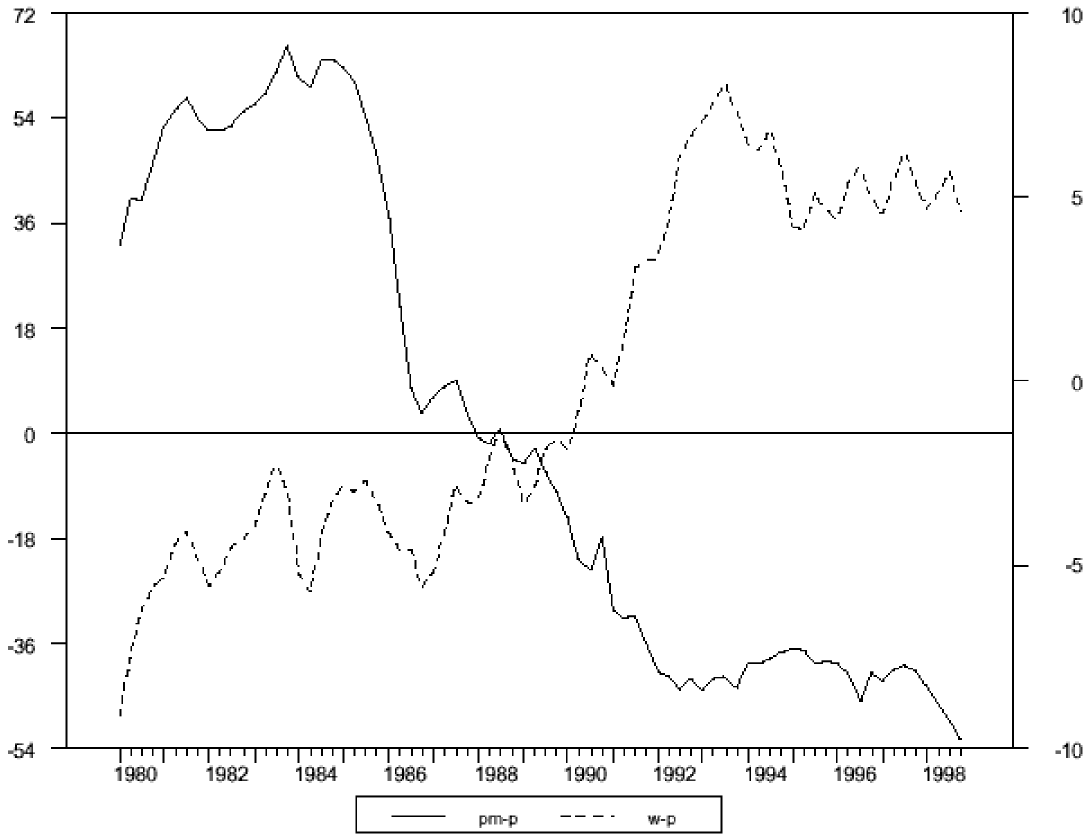

Figure 7

Inflation and alternative marginal
The effect of substitutability between imported materials

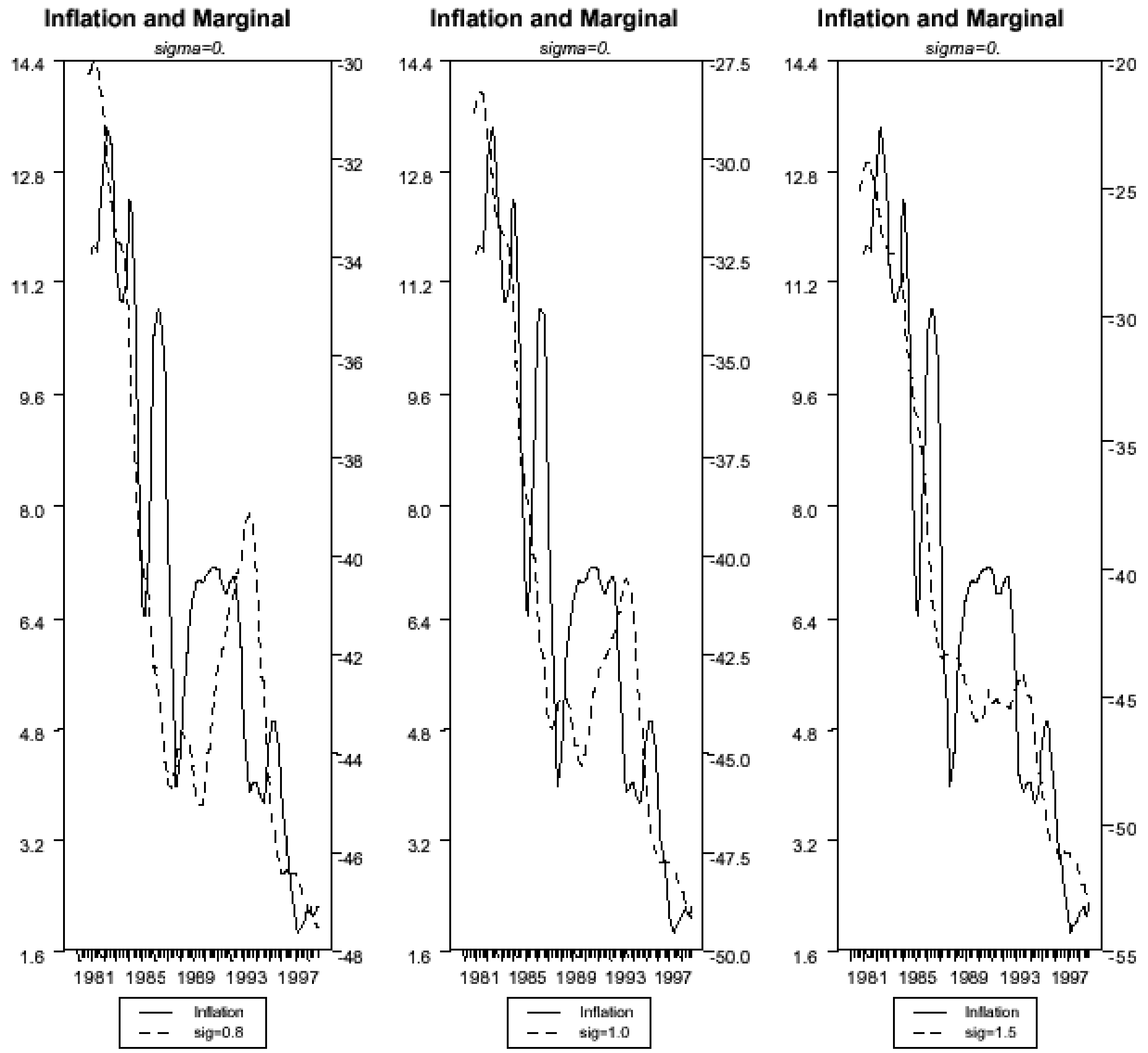

Figure 8
Marginal cost and wage markup

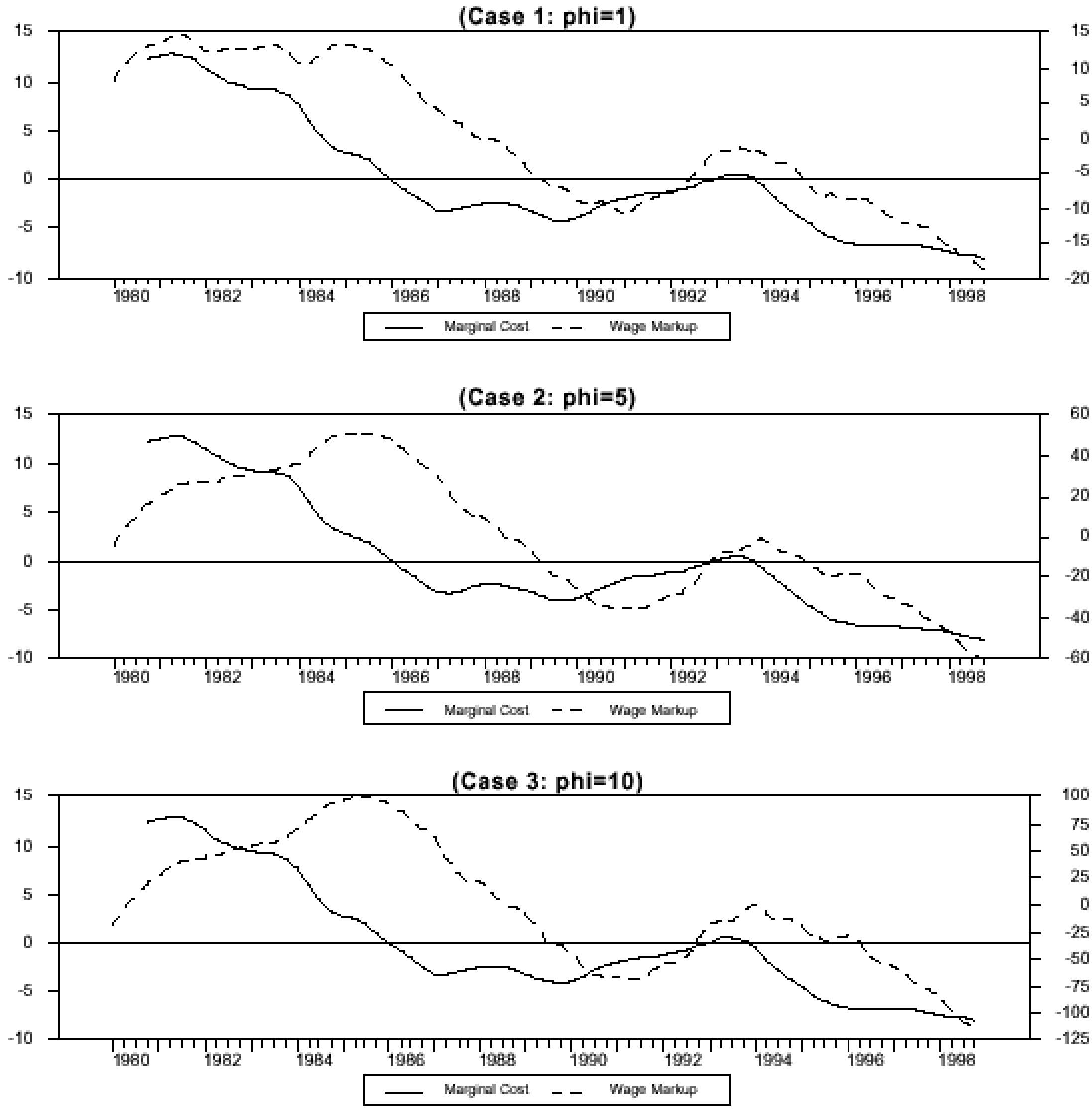

Table 1
Structural estimates: baseline marginal costs

	θ	β	λ	ω	γ_b	γ_f	*D*
$\xi = 1$							
(1)	0.905	0.759	0.033	-	-	-	10.5
	(0.011)	(0.077)	(0.011)				(0.116)
(2)	0.835	0.850	0.010	0.709	0.487	0.487	6.1
	(0.029)	(0.124)	(0.005)	(0.065)	(0.017)	(0.037)	(0.176)

Sample period: 1980-98. Instruments include: a constant term, inflation, wage inflation, detrended output and marginal costs from *t-1 to t-4*.

Table 2
Structural estimates: alternative marginal costs

$\xi = 1$ Technology	θ	β	λ	ω	γ_b	γ_f	D
Cobb-Douglas (CD)							
(1)	0.905	0.759	0.033	-	-	-	10.5
	(0.011)	(0.077)	(0.011)				(0.116)
(2)	0.835	0.850	0.010	0.709	0.487	0.487	6.1
	(0.029)	(0.124)	(0.005)	(0.065)	(0.017)	(0.037)	(0.176)
CD with overhead labour							
(1)	0.912	0.781	0.028	-	-	-	11.1
	(0.012)	(0.064)	(0.010)				(0.133)
(2)	0.839	0.846	0.009	0.725	0.493	0.483	6.2
	(0.032)	(0.161)	(0.005)	(0.085)	(0.017)	(0.047)	(0.200)
CES							
(1)	0.902	0.745	0.035	-	-	-	10.2
	(0.011)	(0.078)	(0.012)				(0.112)
(2)	0.835	0.829	0.011	0.700	0.488	0.482	6.1
	(0.027)	(0.0129)	(0.005)	(0.067)	(0.017)	(0.041)	(0.165)
CD with labour adjustment costs							
(1)	0.904	0.757	0.034	-	-	-	10.4
	(0.011)	(0.074)	(0.011)				(0.114)
(2)	0.835	0.859	0.009	0.719	0.489	0.488	6.1
	(0.027)	(0.120)	(0.004)	(0.068)	(0.017)	(0.036)	(0.164)
CES with labour adjustment cost							
(1)	0.912	0.788	0.027	-	-	-	11.1
	(0.013)	(0.058)	(0.009)				(0.144)
(2)	0.836	0.860	0.010	0.737	0.496	0.483	6.1
	(0.038)	(0.189)	(0.006)	(0.098)	(0.017)	(0.053)	(0.227)

Table 3

Structural estimates: increasing marginal costs

$\xi = 1$	θ	β	λ	ω	γ_b	γ_f	D
μ =1.2, α =0.375							
(1)	0.743 (0.032)	0.759 (0.078)	0.151 (0.052)	-	-	-	3.9 (0.125)
(2)	0.671 (0.031)	0.887 (0.102)	0.044 (0.022)	0.596 (0.063)	0.488 (0.017)	0.487 (0.034)	3.0 (0.094)
μ =1.2, α =0.417							
(1)	0.723 (0.035)	0.759 (0.077)	0.173 (0.060)	-	-	-	3.6 (0.126)
(2)	0.654 (0.033)	0.890 (0.100)	0.051 (0.025)	0.582 (0.064)	0.487 (0.017)	0.487 (0.034)	2.9 (0.095)

Note: The parameter α was calibrated so (1-α) is equal to the average labour income share divided by the chosen markup (μ). The average labour income share takes two values 0.75 and 0.70.

Table 4

Structural estimates: the effects of imported materials

$\xi = 1$ **Technology**	θ	β	λ	ω	γ_b	γ_f	D
σ = 0.8							
(1)	0.915 (0.018)	0.855 (0.065)	0.020 (0.010)	-	-	-	11.7 (0.21)
(2)	0.810 (0.036)	0.906 (0.131)	0.010 (0.005)	0.724 (0.067)	0.490 (0.018)	0.496 (0.035)	5.3 (0.19)
σ =1.5							
(1)	0.919 (0.004)	0.557 (0.069)	0.043 (0.007)	-	-	-	12.3 (0.114)
(2)	0.877 (0.028)	0.819 (0.117)	0.007 (0.003)	0.719 (0.066)	0.485 (0.017)	0.484 (0.037)	8.1 (0.23)

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Forecast-based monetary policy in Sweden 1992-98: a view from within

Per Jansson and Anders Vredin[1]

Abstract

The use of explicit inflation targets has meant that monetary policy has become more transparent and also easier to evaluate. The analysis in this paper is based on forecasts by Sveriges Riksbank (the Central Bank of Sweden) on real output and inflation. Our purpose is to separate the effects on the interest rate instrument of (i) discretionary changes in the rule for monetary policy and (ii) judgments in forecasting. We first feed the Riksbank's forecasts into two different simple rules for interest rate policy. The differences between the interest rates implied by these benchmark rules and the actual policy rate are interpreted as measures of "policy shocks". Second, we compare the Riksbank's forecasts with alternative forecasts. Using a benchmark rule for the setting of the policy rate, we can use the differences between the forecasts to define measures of the effects of the Riksbank's "judgments" on its interest rate policy.

1. Introduction

In order to understand the effects of monetary policy, we have to be able to identify, among other things, movements in interest rates and monetary aggregates that are induced by changes in policy (as opposed to changes in other factors, eg money demand). Attempts to describe central banks' monetary policies have been undertaken by researchers using different methods. One common approach has been to use time-series models, such as vector autoregressions (VARs), to estimate "shocks" to interest rates using a minimum of a priori restrictions. Christiano et al (1998) provide a review of this literature. A quite different approach has been to single out specific episodes when monetary policy is believed to have been especially active and effective and to scrutinise both policy documents and macroeconomic data from those episodes. Although such studies can hardly provide strong statistical evidence, it is clear that careful studies of specific events can yield useful information about the design and effects of monetary policy. The study by Milton Friedman and Anna Schwartz (1963) is probably the most well known example. Christina and David Romer have applied a similar approach in a number of more recent studies (eg Romer and Romer (1989)).[2]

A serious evaluation of policy requires rather detailed information about policy objectives and rules and about the information policymakers have at their disposal when they make their decisions. This type of information is not readily available, either for external economists or economists at the central banks themselves. One reason for this is that policy decisions are made on the basis of many different kinds and sources of information, which in the policy process are weighed together in complicated and informal ways. Policy is to a large extent based on judgments and discretionary decisions. It is not

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[1] Corresponding author: Anders Vredin. E-mail: anders.vredin@riksbank.se; per.jansson@riksbank.se. We would like to thank Peter Lundkvist, Hanna Widell, Stefan Wredenborg and Göran Zettergren for collecting data and providing research assistance. The paper has benefited from comments by seminar participants at Sveriges Riksbank, the EEA meeting in Bolzano, Bank for International Settlements, Uppsala University and Umeå University. In particular, we would like to thank Jeffery Amato, Claes Berg, Fabio Canova, Paolo Giordani, Nils Gottfries, David Gruen, Michael Hutchison, Marianne Nessén, Stefan Norrbin, Torsten Persson, Lars Svensson, Paul Söderlind, Ulf Söderström, Staffan Viotti and Tony Yates. The views expressed in this paper are solely the responsibility of the authors and, in particular, are not to be regarded as representing the view of the Executive Board of Sveriges Riksbank.

[2] Both time-series approaches and Friedman-Schwartz-type studies have of course been criticised; see eg Rudebusch (1998) and Leeper (1997).

simply the result of model forecasts that are plugged into policy rules to which the central banks have committed themselves in advance.

During the last decade, however, many central banks have started to follow policies that have been characterised as "constrained discretion" (Bernanke and Mishkin (1997)). These central banks have defined explicit inflation targets and have also obtained increased independence to achieve their goals. This development has been associated with an increased demand for information about, and analyses of, monetary policy. It has also provided incentives for central bankers to explain their policies to the general public. Examples of this can be found in Australia, Canada, New Zealand, Sweden, the United Kingdom and the European monetary union, although the approaches to inflation targeting differ somewhat between these countries.

The use of explicit inflation targets has meant that monetary policy has become more transparent and also easier to evaluate. For instance, many of the inflation targeting central banks claim that their policies are forecast-based. If the forecasts are also actually published, then interesting insights into the central banks' reaction functions can be gained from investigating the effects of forecasts on policy. On the other hand, if there is a close relation between a published forecast and decisions on monetary policy, then policy considerations may also influence the forecast. A comparison of a central bank's forecasts with some alternative sets of forecasts may thus yield useful information about monetary policy.

In this paper we analyse monetary policy in Sweden during the first six years of the inflation targeting regime, 1992-98. More precisely, our purpose is to investigate if it is possible to describe this monetary policy in terms of a simple reaction function that relates the interest rate instrument to reasonable forecasts of macroeconomic conditions. We try to separate the effects on the interest rate of (i) discretionary changes in the rule for monetary policy and (ii) judgments in forecasting.

In undertaking our study we combine time-series methods with information from policy documents. Specifically, we look at the forecasts of inflation and GDP growth produced by the Riksbank in connection with its Inflation Reports 1992-98. Our study is (to our knowledge) unique in the sense that it constitutes a first attempt to comprehensively analyse actual real-time forecasts undertaken by an inflation targeting central bank. Given such forecasts, it is possible not only to evaluate the forecasts per se but also to relate them to the policy decisions that were actually made. We hope that this exercise is interesting not only for economists inside central banks, but also to market participants and politicians (who may want to evaluate and better understand monetary policy) and researchers (who may be interested in realistic estimates of "policy shocks").[3] We furthermore believe that analyses of this kind are important and necessary to support the mandate and the increased operational independence recently given to many central banks.

We first feed the Riksbank's forecasts into two different simple rules for interest rate policy - one forward-looking Taylor-type rule suggested by Rudebusch and Svensson (1999), the "RS rule", and another which seems to lie closer to the rule suggested by the Riksbank itself in its Inflation Reports, the "RB rule". The differences between the actual policy rates and the interest rates implied by these benchmark rules are interpreted as measures of "policy shocks". These reflect changes of the policy rate that, given the rules, are not motivated by the Riksbank's own forecasts.

Second, we compare the Riksbank's forecasts with alternative forecasts on which the bank could very well have chosen to base its monetary policy: real-time forecasts produced by a VAR model and by other analysts. Using a benchmark rule for the setting of the policy rate, we can then use the differences between the forecasts to define measures of the effects of the Riksbank's "judgments" on its interest rate policy. One of our measures of the impact of "judgments" is thus the calculated change in the policy rate that, given a policy rule, does not appear to be motivated by forecasts derived from a formal model-based approach (in our case a VAR). Our second measure is obtained through a similar calculation where forecasts by other institutions are substituted for the model-based forecasts. The latter measure presumably reflects not only judgmental adjustments of model forecasts, since other institutions' forecasts are not entirely model-based but are also affected by judgments. The differences between the Riksbank's forecasts and those of other institutions may also reflect "informational

3 We think that our estimates of the effects of "judgments" and "policy shocks" come close to the "modest policy interventions" Leeper and Zha (1999) have in mind.

advantages" - or "disadvantages" - that the Riksbank may have, eg about the state of the economy or the effects of monetary policy.

The paper is organised as follows: the Riksbank's forecasts from 1992-98 are presented in Section 2; Section 3 discusses the simple rules for the policy rate that serve as our benchmarks; in Section 4 we present our estimates of "policy shocks"; Section 5 compares the different sets of forecasts of the arguments that enter the simple rules and presents the effects of the Riksbank's "judgments"; Section 6, finally, gives conclusions and includes some suggestions for further research.

A quick summary of the results is as follows: (i) the Riksbank has followed a forecast-based policy rule quite closely, ie "policy shocks" in the sense of deviations from such a rule have been small; (ii) actual policy has been less activist, in particular in response to output fluctuations, than predicted by the theoretical RS rule; (iii) deviations between the Riksbank's forecasts and those of other institutions have been small; and (iv) "judgments" nevertheless seem quantitatively important, since there are large deviations between the Riksbank's forecasts and forecasts produced by a VAR model.

2. Forecasts vs outcomes

Not all central banks (even inflation targeters) publish their forecasts of inflation and other macroeconomic variables. In the case of the Riksbank approximate numerical inflation and GDP growth forecasts (for calendar years) started to emerge during 1996. Around the end of 1997 and the beginning of 1998 approximate annual inflation forecasts appeared on a quarterly basis. Numerical forecasts of inflation and GDP growth to one decimal place were introduced in the Inflation Reports in March 1998 and March 1999 respectively. The inflation and GDP growth forecasts made in 1992-96 were first published in connection with the Inflation Report in June 2000.

The Riksbank's forecasts for 1992-98 are reported in Figures 1 and 2 together with the actual outcomes for annual CPI inflation and GDP growth. To facilitate our discussion and analysis, the same data are also reported in Tables 1 and 2.[4] At each forecast occasion, forecasts of inflation and real GDP growth are produced for the current year and, at most, the two following calendar years.[5] The forecast occasions are quarterly. The actual outcomes of inflation and GDP growth each year *t* can thus be compared with at most 12 earlier forecasts of these figures - four forecasts per year from years $t-2$, $t-1$ and *t*. The actual development of consumer prices is reported by Statistics Sweden on a monthly basis and GDP figures on a quarterly basis.

Figure 1 shows that the Riksbank's inflation forecasts are systematically higher than the actual outcomes for the corresponding years. There is only one exception to this rule (the forecast for 1994 undertaken in April 1994). As can be seen from Figure 2, the same systematic pattern does not obtain for the Riksbank's forecasts of GDP growth.

Several further observations can be made in relation to Figures 1 and 2:

(i) *The Riksbank's inflation forecasts are conditioned on the assumption of an unchanged policy rate.* They are thus not intended to be optimal forecasts in a mean-squared-error sense.[6] It is not clear, however, that this can explain the systematic overpredictions. One reason is that the Riksbank's forecasts (like those of most other central banks) are largely determined by judgments. The conditioning of the forecast on a constant interest rate assumption is obviously extremely difficult without the use of a formal model. Thus, it cannot be ruled out that these forecasts have to some extent been implicitly conditioned on a policy rate that changes over time.

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4 The months reported in these tables (and Table 5) refer to the dates of the final forecasts and hence do not always coincide with the months in which the Inflation Reports were published.

5 Since 1998 the Riksbank also reports forecasts of CPI inflation on a monthly basis. Unpublished monthly forecasts of inflation are available from approximately mid-1997 only. The forecasts of GDP growth are, however, still only given on a calendar year basis.

6 For a discussion of this principle, which is also followed by the Bank of England, see Goodhart (2000).

There is one property of the CPI index, however, which can perhaps explain, at least partly, the forecast errors when the forecast is conditioned on an unchanged interest rate. A lower short-term interest rate implies an autonomous negative effect on the housing cost component in the CPI, which - at least temporarily - puts downward pressure on the CPI. The initial effect of a more expansionary monetary policy, aimed at eventually raising inflation, may thus be a fall in the registered rate of inflation. How much of the forecast errors can be explained by such mechanisms cannot, however, be determined without an explicit structural model which also includes other channels between monetary policy and inflation.[7]

(ii) *The forecast errors become smaller as the forecast horizon is approached.* The typical pattern of inflation forecasts, apparent from Figure 1, is that they start at a higher level than the eventual outcome (often more than 1 percentage point higher) and then gradually converge to the outcome. For example, according to the figures in Table 3, two-years-ahead forecasts for inflation (eight steps ahead in the table) have a root mean-squared error (RMSE) that is almost twice as large as that for inflation forecasts with a one-year horizon (four steps ahead in the table).[8] On some occasions, however, the inflation forecast has temporarily moved in the "wrong" direction. Two of these (October 1994 and August 1997) were - as shown in Figure 3 - followed by increases in the policy rate. This suggests that expectations of higher inflation caused the Riksbank to deviate from the downward interest rate trend that characterised the sample period. That inflation eventually turned out to be lower than expected may of course partly have been the result of the temporary contractions in monetary policy. However, again, some model is needed to evaluate such propositions.[9]

(iii) *The forecasts of GDP growth are on average more accurate than the inflation forecasts.* This is somewhat surprising, since information about actual GDP growth becomes available with a considerable lag, approximately two quarters, and revisions occur frequently. That inflation forecast errors become smaller as the forecast horizon is approached is less surprising. New information about actual inflation becomes available on a monthly basis, with a lag of approximately two weeks, and the CPI figures are only subject to very small revisions on an annual basis.[10] This explains why GDP growth forecasts show less tendency to converge to the actual outcomes than inflation forecasts (cf Figure 2 and Table 3); but it does not explain why GDP growth forecasts have been more accurate than inflation forecasts.

(iv) *There was a regime shift in Swedish monetary policy in 1992-93*, from an exchange rate target to an explicit inflation target. Such changes make forecasting even more difficult than it is under more stable circumstances. That inflation was lower than expected during the 1990s is furthermore something that was experienced in many other countries.[11] It can be noted, however, that there is no tendency for the inflation forecasts to become more accurate over time, something one might perhaps have expected, if forecasters learn about the effects of the regime shift over time. As shown in Table 1, the RMSEs were eg much smaller for the forecasts of inflation of 1994 and 1995 than for the forecasts of 1996-98. The reason is that the first forecasts for 1994 and 1995 started at a level much closer to the eventual outcome than the corresponding forecasts for 1996-98. Another way to express the same thing is to say that actual inflation has come down quite dramatically, but forecasts have not responded to that development to the same degree. The RMSEs for forecasts of

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7 One such model has been presented by Apel and Jansson (1999). This model suggests that a 1 percentage point increase in the nominal interest rate (three-month Treasury bill rate) on average is associated with an initial 0.2 percentage point increase in inflation.

8 Note that the number of available forecasts for a particular horizon is sometimes very small. Hence, the RMSEs of Table 3 need to be interpreted with great care.

9 If the assumption about a constant interest rate can explain part of the forecast errors, then the differences between the Riksbank's inflation forecasts and those of other institutions should contain information about future interest rate changes. In the Inflation Report from June 2000 it is argued that this is indeed the case.

10 Revisions of the official Swedish data on *monthly* CPI are prohibited by law. The annual consumer price change used by the Riksbank to guide its monetary policy is, however, not exactly identical to the annual change of the official CPI. The measures of annual inflation take account of the fact that the composition of the CPI changes over time. The index used by the Riksbank is, however, also published by Statistics Sweden.

11 This can, for example, be seen in the large international database of Consensus Forecasts.

GDP growth have, on the other hand, become smaller over time. The RMSE was much larger for the forecasts of GDP growth of 1994 and 1995 than 1997 and 1998 (Table 2).

3. Simple rules for monetary policy

3.1 The case for simple rules

Central banks with explicit inflation targets (and some without) repeatedly stress that their interest rate policy has to be forward-looking and pre-emptive. One reason for this is that it is believed that the effects of changes in monetary policy (or at least some of the effects) occur with a considerable lag. But even if the central bank could already control inflation perfectly in the short run, policy might have to be forward-looking for other reasons. High ambitions to stabilise inflation in the short run would imply considerable volatility in short-term nominal interest rates, which presumably would be transmitted into high volatility in real variables such as GDP growth and unemployment (see eg Svensson (2000)). In practice, monetary policy is characterised by interest rate smoothing, which may reflect that central banks, in addition to price stability, are concerned with financial stability, or real stability, or both.

It is quite common for central banks with an explicit inflation target also to indicate that they aim to close the gap between the inflation target and the inflation forecast at a certain forecast horizon, typically around two years. This principle, or rule of thumb, can be interpreted in two different ways. The inflation forecast two years ahead may be an *optimal intermediate target* for monetary policy if it takes two years before a change in the interest rate can have any significant effect on inflation. This is the case in Svensson's (1999) model of an inflation targeting central bank. Alternatively, one may view a rule-of-thumb relation between the interest rate and the inflation forecast as a *simple rule* that the central bank has to follow (in order to be transparent and accountable, for instance). The central bank's problem is then to find what the forecast horizon of such a suboptimal rule should be, given its preferences for inflation stabilisation (and possibly other objectives). Such models of inflation targeting have been analysed by eg Amato and Laubach (1999), Batini and Haldane (1999), Batini and Nelson (1999) and Leitemo (1999). Numerical examples suggest that neither very short nor very long forecast horizons are desirable, but that the optimal horizon may very well be around two years.

Another guide to understanding the links between forecasts and monetary policy has been offered by Rudebusch and Svensson (1999). They compare different simple rules and calculate the "social loss" associated with them under different assumptions about the central bank's preferences for price, output and interest rate stability (given certain assumptions about crucial relations in the economy). Their analysis suggests that forward-looking Taylor-type rules (Taylor (1993)) of the following form are quite robust, in the sense that they perform relatively well under different objective functions:[12]

$$i_t^* = \alpha_0 + \alpha_1[E(\pi_{t+s,t+s-j}|I_t;\ i_{t-1}) - \pi^*] + \alpha_2 E(y_{t+h,t+h-i} - y^P_{t+h,t+h-i}|I_t;\ i_{t-1}) + \alpha_3 i_{t-1}, \qquad (1)$$

where i_t^* denotes a benchmark level of the short-term interest rate that is the central bank's policy rate; $E(\pi_{t+s,t+s-j}|I_t;\ i_{t-1})$ is the forecast of inflation between $(t+s)$ and $(t+s-j)$, conditional on the information available at time *t* and on the assumption of an unchanged interest rate; and $E(y_{t+h,t+h-i} - y^P_{t+h,t+h-i}|I_t;\ i_{t-1})$ is the corresponding conditional forecast of the level of the "output gap" (ie the deviation between (log) actual and potential output) accumulated between periods $(t+h)$ and $(t+h-i)$. The parameter π^* is the central bank's (constant) inflation target. Note that information lags may imply that actual values in *t* and (conditionally) expected values at *t* are not the same. The information set I_t may thus not include all information on the outcome of all variables in period *t* and earlier.

12 For a different view, see the paper by Levin et al (1999), where the practice of forecast-based rules is questioned.

We will use (1) as one benchmark interest rate rule for our analysis of Swedish monetary policy. This is justified not only by the results reported by Rudebusch and Svensson (1999), but also because rules of this type seem to be able to describe monetary policy in other countries where price stabilisation has been an important goal (cf Clarida et al (1998, 1999)).[13] We will use coefficients suggested by Rudebusch and Svensson (1999) to define a benchmark rule which we label the "RS rule".[14] There is, however, no self-evident first candidate for a simple rule and sensitivity analyses are of course needed. In particular, it may be interesting to compare the actual interest rate also with a rule that puts zero weight on the output gap, since the Riksbank has repeatedly stressed that its interest rate decisions are mainly based on an assessment of future inflation. Concerns for output stabilisation have not been expressed as often, although it has been explicitly declared that certain temporary deviations from the inflation target may be accepted if a more aggressive monetary policy would imply unacceptably large swings in interest rates and real economic activity; see eg Berg (1999), Heikensten and Vredin (1998) and Heikensten (1999). How much weight the Riksbank has put on output stabilisation in practice is thus an open question. We will therefore derive data-based estimates of the coefficients in (1) that capture the empirical relation between the Riksbank's forecasts and its policy rate. This version of (1) is labelled the "RB rule".

3.2 Defining the arguments in the simple rule

Irrespective of whether we want to define the coefficients of (1) on theoretical or empirical grounds, we first have to define the forecasting horizons *s* and *h* and the time spans of the forecasted inflation rate $(s-j)$ and output gap $(h-i)$. The time spans must be equal to one year, since the forecasts that we have access to cover only the annual frequency (and the inflation target is defined in terms of annual inflation). The maximum forecast horizon in Tables 1 and 2 is 12 quarters, so with *t* denoting quarters, $s \leq 12$ and $h \leq 12$. In the Inflation Reports, the Riksbank declares that the forecast horizon which governs monetary policy lies 12 to 24 months ahead, which suggests that $4 \leq s \leq 8$. In our applications, we have to use a time-varying forecast horizon, because forecasts are made quarterly but only for annual inflation rates. The inflation forecasts by the Riksbank which we feed into the benchmark rule are underlined in Table 1. The benchmark interest rate is thus calculated using only a subset of the available inflation forecasts. We do this partly to make our analysis easier to perform and explain, but also because a simple rule with a forecast horizon of about six to eight quarters seems reasonable in view of actual statements made by central bankers.[15]

The choice of the value of *h* is more difficult, but given the standard view on the transmission mechanism of monetary policy it seems reasonable that $h < s$. We have chosen to base our benchmark rules on the current output gap.[16] It still has to be forecasted, however, since neither the level of potential GDP nor that of current GDP can be observed within the current quarter. The former is unobservable and the latter is reported with a considerable lag. Another problem is that we do not have access to forecasts of the output gap, but only of the growth rates of GDP. Taking the first difference of (1), we obtain:

$$\Delta i_t^* = \alpha_1 \Delta_t E(\pi_{t+s,t+s-j} | I_t;\ i_{t-1}) + \alpha_2 \Delta_t E(y_{t+h,t+h-i} - y_{t+h,t+h-i}^P | I_t;\ i_{t-1}) + \alpha_3 \Delta i_{t-1}, \tag{2}$$

[13] It may be argued that an "optimal" reaction function for a central bank in an open economy should include more arguments than (1), eg exchange rate shocks (see eg Svensson (2000) and Walsh (1999)). On the other hand, one reason why central banks may want to stick to some simple rule is that the "optimal" rule is not feasible. In practice, rules like (1) can be supported by official policy statements and also seem to capture actual monetary policy quite well.

[14] Since (1) has been used and advocated by many researchers, it would perhaps have been more appropriate to use eg the label "FT rule" instead (forward-looking Taylor-type rule). To our knowledge, however, no one has presented such convincing normative arguments for (1) as Rudebusch and Svensson (1999). Furthermore, our choices of coefficient values and lag lengths have also been directly inspired by these authors.

[15] For discussions about problems that policymakers face in practice when trying to implement forecast-based inflation targeting, see eg Heikensten (1999) and Apel et al (1999). Certain problems discussed in those papers, eg whether the inflation target should be defined in terms of CPI inflation or some measure of "core" (or "underlying") inflation, are absolutely crucial for evaluations of monetary policy, but nevertheless beyond the scope of the present paper.

[16] The "top-performing" rules in Rudebusch and Svensson's (1999) analyses use $s = 8$ and $h = 0$.

where Δ_t means that first differences are taken with respect to subscript *t*. If we thus are willing to make assumptions about the forecasted growth of potential output and approximate the change in the forecast of (log) GDP with the forecast of the change in (log) GDP, then we can feed the forecasts of current GDP growth and of the change in the inflation forecast (between two successive forecast occasions) into (2) and calculate the *change* in the benchmark interest rate. The forecasts of GDP growth that we use are underlined in Table 2.

Furthermore, we do not have time-series observations of inflation and GDP growth forecasts made by the Riksbank each quarter, but only the forecasts made on the 21 occasions reported in Tables 1 and 2. This makes it hard to decide what measures of Δi_t^* and Δi_{t-1} we should use. Consider eg the forecasts of GDP growth 1998 and inflation 2000 made in May 1998. Should we use the simple rule to calculate what the benchmark interest rate change Δi_t^* should be between 4 June and 3 June 1998, since the Inflation Report was published on 4 June? Or should we look at the interest rate change between the May forecast and the immediately preceding forecast in February the same year, ie for the period between, say, mid-May 1998 and mid-February 1998? In the former case, the lagged interest rate change in rule (2) should (perhaps) be the change between 3 June and 2 June, whereas in the latter case the change between mid-February 1998 and mid-November 1997 may seem a natural measure of Δi_{t-1}. We have chosen to divide the time period that the sample spans into 21 shorter periods that together cover all interest rate changes made during the whole sample period. Each forecast round is thus assumed to be associated, via the simple rule, with interest rate changes made from the day halfway back to the previous forecast round and up until halfway towards the next forecast round. For instance, the forecasts from May 1998 are used to calculate a benchmark interest rate change between 1 April 1998 and 15 July 1998. The lagged interest rate change in this case is the change between 1 January 1998 and 30 March 1998.[17]

3.3 The RS rule

The first benchmark rule we will look at sets $\alpha_1 = 1.5$, $\alpha_2 = 0.5$ and $\alpha_3 = 0.6$. This is (almost) the best simple rule reported by Rudebusch and Svensson (1999) in their Table 3; in this case the central bank's loss function, which is used to define the optimal policy, puts equal weight on inflation and output stabilisation and the weight on interest rate smoothing is half as large.

In the calibration of the benchmark interest rate implied by the RS rule, the Riksbank's forecast of the potential growth of output has been set to 2.2% per year. We have no data on the assumptions about the potential growth of output that should be associated with the inflation and GDP forecasts in Table 1 and Table 2, and hence are forced to make a guess. We know that the potential growth of output has typically been assumed to lie in the interval 1.5-2.5%, and that the figure 2.2% has been used at least some of the time.

3.4 The RB rule

As noted in the introduction, the purpose of this paper is not to find the rule which best captures the Riksbank's actual policy in the period 1992-98. If, however, the RS rule is very far from the Riksbank's own desired rule, then the use of (2) as a benchmark rule would be quite meaningless. This has led us to investigate how well (2) empirically tracks the actual policy rate changes.

Using the data on inflation and GDP growth forecasts underlined in Tables 1 and 2 respectively and the definition of Δi discussed above, we get the following ordinary least-squares regression:

$$\begin{aligned}&\Delta \hat{i}_t = \underset{(0.29)}{0.81}\Delta_t E(\pi_{t+s,t+s-j} | I_t;\ i_{t-1}) + \underset{(0.14)}{0.05}\Delta_t E(y_{t+h,t+h-i} | I_t;\ i_{t-1}) + \underset{(0.21)}{0.62}\Delta i_{t-1} - \underset{(0.35)}{0.09},\\ &R^2 = 0.65, \qquad \sigma = 0.53,\end{aligned} \qquad (3)$$

[17] Alternatively, we could have calculated a benchmark interest rate change for each day, month or quarter, by assuming that the forecasts which enter the simple rule are the most recent forecasts. This is something we recommend for future work.

wherei the numbers within parentheses are standard errors, R^2 is the multiple coefficient of determination and σ is the standard error of regression.

The residual diagnostics indicate that the error terms are close to white noise.[18] Hence, the arguments on the right-hand side of (3) seem on average to have good explanatory power for the systematic changes in the policy rate over the sample period.

Some features of (3) are especially noteworthy. First, the coefficient on GDP growth is not significantly different from zero. When we compare the residuals from (3) with the "policy shocks" implied by the theoretical RS rule (rule (2) using the coefficient values given in Section 3.3) we see that the theoretical rule produces particularly large shocks for the first two observations in our sample (see Section 4 below). One may of course argue that the Riksbank's policy may have changed during the sample period, eg because a particularly contractionary policy was needed in the beginning of the new regime to establish credibility for the inflation target. The full-sample estimates are compared with various subsample estimates in Table 4. We have deleted observations both from the beginning of the sample and from the end. All results (even (3)) must of course be interpreted with great care, because of the limited number of observations that are available to us (at most 18). There are no significant differences between the coefficient estimates from any of the subsamples and those reported from the analysis of the full sample. Still, it can be noted that the point estimates of the coefficient on the output gap increase steadily as more and more observations from the beginning of the sample are deleted. It may be tempting to conclude that the Riksbank was a more "strict" inflation targeter in the beginning of the new regime and has become more "flexible" over the years; but the statistical evidence from this small sample only provides weak support for this hypothesis.

Another interesting result is that the point estimates of the intercept are roughly consistent with the argument that the constant in (3) approximates $-\alpha_2 \Delta y^P$ with $\Delta y^P = 2.2$, as assumed in Section 3.3.[19] For instance, for the full sample with an estimate of $\alpha_2 = 0.05$ and an assumption of $\Delta y^P = 2.2$ the implied value of the constant is –0.11, while the empirical estimate is –0.09. For the sample using observations 9-19, the estimate of α_2 is 0.49 and the implied value of the constant is –1.08, while the empirical estimate is -1.16. If the true coefficient for the output gap in the Riksbank's policy rule is zero, then the constant in (3) should also be zero. The estimates are indeed not significantly different from zero.

These empirical results strengthen our belief that forward-looking Taylor-type rules serve as a useful benchmark for a study of Swedish monetary policy. The particular form (2), in combination with the coefficient values given in Section 3.3 (the RS rule), can be questioned, however. A rule which restricts the coefficient on GDP growth to zero seems to be at least as relevant a benchmark (in view of the Riksbank's own statements about its reaction function combined with the evidence from (3)). Estimating (2) upon restricting the reaction coefficient on the output component to zero gives:[20]

$$\begin{aligned} \Delta\hat{i}_t &= \underset{(0.28)}{0.81} \Delta_t E(\pi_{t+s,t+s-j} | I_t;\ i_{t-1}) + \underset{(0.14)}{0.67} \Delta i_{t-1} + \underset{(0.14)}{0.02}, \\ R^2 &= 0.65, \qquad \sigma = 0.51. \end{aligned} \tag{4}$$

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[18] $F_{AR}(2,\ 12) = 5.3 \quad (0.02)$, $\chi^2_{NORM}(2) = 3.1 \quad (0.21)$, $F_{ARCH}(1,\ 12) = 0.2 \quad (0.67)$, $F_H(6,\ 7) = 0.6 \quad (0.74)$, $F_{HC}(9,\ 4) = 0.4 \quad (0.90)$. F_{AR} is an *F* test against serial correlation of order two; χ^2_{NORM} is a normality test; F_{ARCH} tests for conditional heteroscedasticity of order one; F_H and F_{HC} are *F* tests for heteroscedasticity with and without regressor-cross products respectively (see Doornik and Hendry (1997) for further details). Numbers within parentheses are *p* values.

[19] This argument is based on the assumption that α_0 in (1) is indeed constant. It has been argued that it should vary with eg changes in the equilibrium real interest rate (see Hall (2000)).

[20] The residual diagnostics are similar to those obtained using the unconstrained specification and are for expository convenience not reproduced here.

In the next section we will use this empirical rule, which we label the RB rule, as another benchmark, besides the theoretical RS rule which is based on coefficient values adapted from Rudebusch and Svensson (1999).[21]

4. "Policy shocks"

The differences between the actual change in the interest rate and the change predicted by the simple benchmark rules - the theoretical RS rule (rule (2) using the coefficient values from Section 3.3) and the empirical RB rule (4) - may be interpreted as different measures of "policy shocks" created by discretionary deviations from the rules. Formally, let $\Delta i_t^* \big| (s, f)$ be the policy rate change computed conditional on rule *s* and forecasts *f*. The "policy shocks" then are $\Delta i_t - \Delta i_t^* \big| (s_{RB}, f_{RB})$ and $\Delta i_t - \Delta i_t^* \big| (s_{RS}, f_{RB})$ for the RB and RS rule respectively. Here, s_{RB} and s_{RS} denote the RB and RS rules respectively and f_{RB} the Riksbank's forecasts of inflation and output growth.

The actual policy rate is compared with the rates implied by the benchmark rules in Figure 4. The difference between the thick solid line (the actual rate) and the dotted line is the "policy shock" compared with the RS rule, while the difference between the thick and thin solid lines is the "policy shock" using the RB rule as the benchmark. In order to understand this figure, it is useful to consider eg the increase in the interest rate between 15 June and 30 November 1995 (ie the increase in the interest rate which we associate with the forecasts made in October 1995). During this period the policy rate was raised by 0.25 percentage points, from 8.66% to 8.91%. Had the Riksbank followed its own simple RB rule (4) exactly, it would have raised the interest rate by 8 basis points more, to 8.99%. If the Riksbank had instead followed the theoretical RS rule then it would have raised the interest rate by another 16 basis points, to 9.15%. In this case there thus seems to have been a negative "policy shock" to the interest rate, irrespective of our choice of benchmark rule.

The deviations between the actual interest rate and the benchmark rates, in most cases (all except two), have the same sign for both benchmark rules. The deviations from the estimated RB rule are of course, on average, smaller than the deviations from the theoretical RS rule. The differences between the two estimates of "policy shocks" are nevertheless surprisingly small, in view of the fact that the RS rule has been defined without any reference to how monetary policy in Sweden has actually been conducted. As noted already in Section 3 above, the differences between the RS and RB rules are larger at the beginning of the sample than towards the end.

Another interesting result is that although the RS rule often suggests a change in the policy rate in the same direction as the actual change, it implies a more aggressive policy than the one actually followed. The Riksbank has thus chosen a smoother path for the policy rate than it would have chosen had it followed the theoretical RS rule. There are, however, some exceptions to this pattern, in particular the decreases of the policy rate during the first half of 1996; here the Riksbank lowered the interest rate by more than the simple RS rule implies.

An interesting topic for future work is to look at the "policy shocks" more carefully, to see if they can be systematically related to other macro variables, or if they can be understood through the official explanations of policy given in eg the Riksbank's Inflation Reports.[22]

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21 As noted above, there may be reasons to also restrict the constant in the RB rule (4) to zero. However, because the coefficient estimate is very close to zero this restriction is of no empirical importance.

22 This would thus follow Romer and Romer's (1989) and Leeper's (1997) analyses of monetary policy in the United States.

5. Alternative forecasts and the Riksbank's "judgments"

There are several reasons why the forecasts published by central banks may differ from those made by other analysts or derived directly from models. One reason is that it cannot be ruled out, of course, that there is an element of policymaking involved also in the construction of the forecasts (as opposed to reacting differently to *given* forecasts). Another is that a central bank may hold the view that it has an "informational advantage" (over both other analysts and models), eg in its understanding of the effects of monetary policy. Relative to purely model-based forecasts, it may also be the case that professional forecasters believe that they can do better by making use of special information that is difficult to incorporate in standard macro forecasting models, eg high-frequency information from survey data or financial markets.

In order to shed light on the nature of judgments made at the forecasting stage, we will now compare the Riksbank's forecasts with two alternative sets of forecasts on which the bank could very well have chosen to base policy. One set is derived from a VAR model (the purely model-based alternative), the other simply consists of averages (medians) of other Swedish institutions' forecasts. Below, we start out by briefly describing the VAR model. We then turn to some practical problems that need to be addressed when undertaking and interpreting ex post forecasting. After having compared the various forecasts using standard measures of forecasting accuracy, we feed them into the benchmark rules and translate the differences in forecasts into differences in policy rate changes. These are our two measures of the Riksbank's "judgments".

5.1 Constructions of alternative forecasts

The VAR model that we consider is a version of the open economy quarterly VAR proposed by Jacobson et al (2000).[23] The model is a seven-variable VAR with four lags. The endogenous variables are: the Swedish CPI; Swedish real GDP; the short-term (three-month) nominal Treasury bill rates for Sweden and Germany; a foreign CPI; foreign real GDP; and a nominal effective exchange rate. To handle various deterministic breaks and regime shifts in Sweden and foreign countries, the model is augmented by a set of dummy variables.

We do not believe that this VAR framework necessarily constitutes the best possible forecasting tool for Swedish inflation and GDP growth.[24] Rather, we wish to derive some model forecasts of inflation and GDP growth that the Riksbank could very well have made, as alternatives to the actual judgmental forecasts. Our ambition has been to identify some simple empirical model with reasonable statistical properties that contains approximately the sort of information that policymakers and other analysts use when discussing monetary policy. The evaluation of the statistical properties of the VAR model undertaken by Jacobson et al (2000) shows that the model fulfils the criterion of being reasonably specified from a statistical point of view (see Tables 1 and 3 in their paper).

The specification of the VAR model implies that the real exchange rate and the short-term interest rate differential are stationary (I(0)). In addition, the foreign variables are not driven by three independent trends but share common trends and thus are cointegrated.

There are some important practical problems involved in ex post forecasting. A first problem is related to the input data that are used when deriving the forecasts. It is well known that published data on many macro variables are frequently revised and that the "final observation" on a particular series is often only available after a considerable lag, which may sometimes be several years. This means that the real-time forecasts of the Riksbank are sometimes not conditioned on the observations on macro variables available today but rather on preliminary figures that were later revised. A completely realistic real-time scenario would hence require the use of (some) macro series that are revised over time. While this is possible in principle, if one is willing to carefully reconstruct all revisions that were undertaken and recursively update the database that is used in the econometric analysis, the revisions

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[23] A detailed description of the data is given in Jacobson et al (2000). Estimations are undertaken using PcFIML version 9.0. The full sample length of our updated data set is 1970:1-1998:4.

[24] It seems that the forecasting performance of VARs may be improved by imposing Bayesian prior restrictions on estimated parameters; see Robertson and Tallman (1999) for a recent review and Villani (1999) for an analysis of the VAR model that we explore.

in the case of Swedish data do not appear to be of such a magnitude that such a cumbersome approach is warranted (at least not as concerns the revisions undertaken during the sample period that we consider). Our analyses will thus be based on the most current observations on the variables that are available.[25]

While data revisions in our case do not seem to be quantitatively important, there is still the problem that data on many macro variables are available only after a considerable time lag. This publication lag implies that a forecast of a certain variable made at, say, time *t*, may not be based on information up to and including *t* but rather on $(t-k)$. The problem becomes particularly ticklish since for our VAR model the value of *k* is not the same for all variables. In particular, for interest rates and exchange rates the publication lag is zero, for consumer prices it is almost zero, whereas quarterly GDP is published with a lag of approximately two quarters. The approach that has been chosen here - and which is summarised in Table 5 - is to make the simplifying assumption that inflation forecasts from the VAR model always make use of more recent information on all variables than the GDP growth forecasts from the same model. The model-based forecasts of inflation have an informational advantage over the Riksbank's inflation forecasts in that they use more information than was actually available in real time. In the case of forecasts of the growth rate of GDP, the opposite holds true.

A third issue that deserves comment concerns the updating of the parameters in the cointegration space. The cointegration matrix depends on two estimated parameters (in the normalised cointegration relation between the foreign variables). The updating (re-estimation) procedure that we have chosen implies that these parameters are recursively re-estimated with an interval lag of approximately four forecasts (see Table 5). Looking at the details of the estimations (not shown to save space) it can be seen that the estimates of the parameters in the cointegration space only vary very little over time.[26] This indicates that the exact design of the updating procedure for the cointegration space is probably not very important, but we still believe that our recursive interval-lag procedure is rather reasonable as a description of a situation forecasters would face in practice.

The issue of the real-time use of the deterministic dummy variables is presumably more important. The problem concerns one particular dummy variable that represents the introduction of the floating exchange rate, inflation targeting regime in Sweden in 1992:4. This dummy variable deserves special mention because its dating implies that it will become effective *during* the forecasting sample period. The procedure adopted in our exercises assumes that the hypothetical real-time model forecaster would immediately have interpreted the float of the Swedish krona in the fourth quarter of 1992 as a permanent "exogenous" policy regime shift to his VAR model.

The medians of forecasts by other analysts are computed as follows: for each month in which the Riksbank has produced new forecasts, the medians of the latest available forecasts (including forecasts made that same month) from nine other Swedish institutions have been calculated. The institutions that are included are: the Ministry of Finance; the Wholesale & Retail Research Institute (Handelns Utredningsinstitut); the National Institute of Economic Research (Konjunkturinstitutet); the Federation of County Councils (Landstingsförbundet); the Trade Union Confederation (Landsorganisationen, LO); Handelsbanken; Nordbanken; SE-banken; and Sparbanken (the latter four are commercial banks).

5.2 Comparisons of the different forecasts

In Figures 5 and 6 Sveriges Riksbank's forecasts (RB) are depicted along with the forecasts from the VAR model, the medians of the other institutions' forecasts and actual outcomes.[27,28] In addition, the

[25] During the summer of 1999 Statistics Sweden undertook a more fundamental revision of the Swedish national accounts system (the new system is called SNA93/ESA95). Since the forecasts from the Riksbank used in this paper are all conditional on the data available before this revision, our calculations and analyses throughout are based on data according to the earlier system of national accounts (called SNA68).

[26] Details of these results are available from the authors upon request.

[27] Details on how the alternative forecasts have been constructed are available from the authors upon request.

[28] Note that the dates on the horizontal axes in Figures 5 and 6 refer to the year for which the forecasts have been made. For instance, the three data points for the Riksbank inflation forecast for 1998 (the dotted (RB) line) show the three "two-years-ahead" forecasts of inflation 1998 made in June 1996-February 1997.

bottom lines of Table 3 summarise the overall forecasting accuracy of the different forecasts using RMSEs.

Looking first at the forecasts of inflation (Figure 5) it can be seen that all two-years-ahead forecasts persistently overpredict inflation over the four years of the sample period. The Riksbank's forecasts are quite close to the medians of the forecasts from other institutions and, accordingly, their RMSEs are also similar. The forecasts from the VAR model are not very different either, if we look at forecasts for 1996 (ie forecasts made in October 1994) and onwards. The initial forecasts from the VAR model display very large differences to the other two sets of forecasts, however. The VAR model first (December 1992) severely underestimates inflation two years ahead, then overestimates it by an even larger margin. Indeed, if one excludes the first two forecasts for 1994, then the RMSE for the VAR forecasts decreases to approximately 2.01 whereas the RMSE for the Riksbank's forecasts increases to 2.02 (the corresponding numbers if one also excludes the forecasts for 1995 are 2.11 and 2.41 respectively). The VAR forecasts thus appear to have a quicker "error correction mechanism" than the Riksbank's forecasts, but perform very badly in the beginning of the sample period.

The forecasts of GDP growth are displayed in Figure 6. In contrast to the inflation forecasts, there is no clear bias tendency for these forecasts. In general, the prediction errors are much smaller than for the inflation forecasts, which may be related to the fact that we look at current-year forecasts as opposed to two-years-ahead forecasts in the case of inflation. From Table 3, it can again be seen that the VAR model overall performs worse than the Riksbank's forecasts and that the performance of the other institutions' forecasts is similar.

In conclusion, the judgmental forecasts made by the Riksbank (possibly with the aid of forecasting models) have been rather successful compared with forecasts generated by the VAR model. Although there have been systematic overpredictions of inflation by the Riksbank, the forecasts are very close to the medians of other institutions' forecasts. More interestingly, the forecast errors could have been even larger if VAR models had been used, at least in the early period after the shift to the inflation targeting regime. The performance of the VAR model, however, improves over time, and in some cases even becomes better than the judgmental forecasts towards the end of the sample period. These results are perhaps not so surprising. In 1993 and 1994 the inflation targeting regime was still quite young and thus backward-looking model-based forecasts (like VAR forecasts) tended to be too heavily influenced by the previously higher average inflation rate. Policymakers and other forecasters therefore had reasons to use their own judgments to adjust the models' forecasts. Recently, however, it seems as if model-based forecasts have adjusted more rapidly to the large decline in inflation while the judgments have had a larger bias towards higher inflation.[29] One lesson from this is perhaps that model-based forecasts can be expected to be less biased than judgmental forecasts in stable (or at least less unstable) environments, while judgments should be particularly useful after regime shifts.[30]

5.3 The effects of "judgments" on the interest rate

Equipped with a set of alternative (real-time) forecasts we are able to estimate the effects of the Riksbank's "judgments" on its interest rate policy. We do this by feeding the three sets of forecasts - the Riksbank's, the other institutions' and the VAR model's - into the RB rule used in Sections 3 and 4. Algebraically, we compute $\Delta i_t^* |(s_{RB}, f_{RB}) - \Delta i_t^* |(s_{RB}, f_{ALT})$, where f_{ALT} is either the VAR forecast or the median forecast from other analysts of inflation and output growth. The different pictures of the effects of "judgments" that we get by plotting these quantities are presented in Figure 7.

The estimates of the effects of "judgments" differ both in size and sign depending on whether we choose to contrast the Riksbank's forecasts with model-based (VAR) forecasts or the medians of other

29 It must of course be remembered that our model forecasts are conditioned on a regime-shift dummy in 1992:4. Furthermore, there are more general reasons for interpreting the comparisons between the Riksbank's forecasts and the alternative forecasts with care. As emphasised previously, the Riksbank's forecasts are intended to be conditioned on the assumption of an unchanged interest rate. But, as also noted above (see Section 2), this difference may not be quantitatively important in practice.

30 We have experimented with alternative specifications of the VAR model and also made comparisons with a simple random-walk model. These models have typically produced larger forecast errors (and larger estimates of the influence of "judgments") than the VAR model presented here.

institutions' forecasts. Even abstracting from the first two observations in our sample - when the VAR model produced extreme forecasts - the estimates of the Riksbank's "judgments" are much larger if the VAR model is used as a norm than if we make the comparisons with other institutions' forecasts. The differences between the Riksbank's forecasts and the medians of other institutions' seldom correspond to interest rate effects larger than 0.5 percentage points. Compared to the VAR model's forecasts, however, the effects of the Riksbank's judgmental forecasts are more often close to, and sometimes even larger than, 1 percentage point.

It is likely that the use of the medians of other institutions' forecasts involves an underestimation of the effects of "judgments" in forecasting, since individual institutions' forecasts presumably deviate more from the Riksbank's forecasts than the medians. It is less obvious that the comparison with the VAR model involves an overestimation of the Riksbank's "judgments". As noted above, the VAR model's forecasts are quite close to the Riksbank's, except during the early part of the sample, and both sets of forecasts involve systematic overestimations of inflation two years ahead. It is conceivable that a VAR model with better forecasting properties could have been constructed. If so, our estimates of the Riksbank's "judgments" could very well have been larger.

Comparing Figures 4 and 7, our results suggest that the *quantitative* effects of "judgments" may be at least as important as the effects of "policy shocks".[31] There does not, however, appear to be any systematic relation between the ***signs*** of the effects of "policy shocks" and "judgments".[32] Sometimes these different aspects of policymaking seem to affect the interest rate in the same direction, but just as often their effects seem to go in opposite directions.

6. Conclusions

We have found that, for the first six years of the floating exchange rate, inflation targeting regime, it is possible to describe Swedish monetary policy quite well by a forward-looking Taylor-type rule. According to the estimated "RB rule" there has been a significant response by the Riksbank to its own inflation forecasts. On the other hand, interest rate policy does not seem to have been significantly affected by the Riksbank's forecasts of GDP growth (at least not on average). Nevertheless, the size of the deviations from the theoretical "RS rule", suggested by Rudebusch and Svensson (1999), which puts some weight on the output gap, does not seem particularly large either. It is also noteworthy that the signs of the estimated "policy shocks" are the same, irrespective of whether we use the RB rule or the RS rule as a benchmark, and that the size of the "policy shocks" has decreased over time.[33] Actual policy has been characterised by a somewhat more gradual adjustment of the interest rate than the RS rule prescribes, but there does not seem to have been any positive or negative bias; in most cases the policy rate has been changed in the direction suggested by the RS rule.

The deviations between the Riksbank's forecasts and the medians of other institutions' forecasts have been relatively small, which suggests that the Riksbank's judgmental adjustments of its forecasts have not been larger than those of other institutions. An alternative (or perhaps equivalent) interpretation of this result is that the Riksbank has (had) no large "informational (dis)advantage" compared to other professional forecasters. However, the difference between the Riksbank's forecasts and the forecasts of a VAR model are occasionally quite large. In the beginning of the sample period, immediately after the regime shift in monetary policy, the VAR model severely overestimated inflation. The Riksbank's judgmental forecasts presumably took more account of the effects of the regime shift, which led to smaller forecast errors. Towards the end of the sample period, however, the Riksbank's forecasts were "more conservative" than the VAR forecasts and were associated with somewhat larger errors.

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31 A comparison based on the RS rule reinforces this result. In this case, "judgments" are quite considerably larger than "policy shocks". The results are available upon request.

32 The sample correlations range between –0.31 and 0.15. A correlation larger than 0.46 or smaller than –0.46 is approximately significant at the 5% test level.

33 "Policy shocks" have become smaller in terms of percentage points, but since the level of the interest rate has also decreased, they may have been quite stable in some relative sense. However, since it is the level of nominal interest rates and inflation in percentage points that plays an economic role (just as in the case of tax rates), it is the first feature that is important.

That there may sometimes be a rather sizeable judgmental element in the central bank forecasts suggests that it may not always be very easy to replicate (or even come close to) them using reasonable forecasting models and thus points to the need to supplement central bank forecasts with explanations concerning how the forecasts are derived. Inflation Reports or similar official policy documents appear to be natural forums for that purpose.

It would be interesting, at least in principle, to feed the estimated “policy shocks” and “judgments” into a macroeconomic model to investigate whether these interventions seem to have had positive (stabilising) effects or not. Of course, Lucas’s critique of policy evaluations with econometric models forcefully spells out the problems associated with such an exercise. There are reasons to expect, however, that the estimated effects of “policy shocks” and “judgments” will be quite small. This is a common result in the literature on the effects of shocks to monetary policy more generally, partly because most models of the transmission mechanisms suggest that changes in nominal interest rates have rather little impact, but also because the typical interest rate “shocks” appear to be quite small.[34] It has been argued in connection with previous studies (see eg the discussion between Leeper (1997) and Romer and Romer (1997)) that many earlier estimates may have shown misleadingly large (or small) effects of monetary policy, because of difficulties in distinguishing between exogenous and endogenous interest rate movements. In this paper we have tried to handle such problems by making use of the Riksbank’s own forecasts, ie by using information which the bank has claimed that policy really has been based upon (rather than eg ex post data on inflation and output). It should be worthwhile, therefore, to exploit this data on the central bank’s information set further, eg by integrating our analysis with the approach suggested by Leeper and Zha (1999).

To our knowledge, our study constitutes the first comprehensive attempt to evaluate Swedish monetary policy during the inflation targeting regime. The use of the central bank’s own forecasts distinguishes our study from eg studies of UK monetary policy by McCallum (2000) and Nelson (2000). Nevertheless, more work is obviously needed in this area. As suggested by Orphanides (1999), the use of real-time data on the output gap may affect the interpretation of monetary policy, so one interesting task for future research is to make an attempt to more carefully reproduce the Riksbank’s estimates of actual and potential output (although we emphasise that this is difficult for reasons previously discussed; see Section 3).

A further extension is to compare our estimates of “policy shocks” and “judgments” with official explanations of monetary policy in the Inflation Reports and other policy documents. Is there a systematic pattern in the deviations from the simple policy rules and/or in the deviations between the Riksbank’s forecasts and alternative forecasts? This would thus involve the same type of analyses as Romer and Romer (1989) and Leeper (1997) have applied to US data.

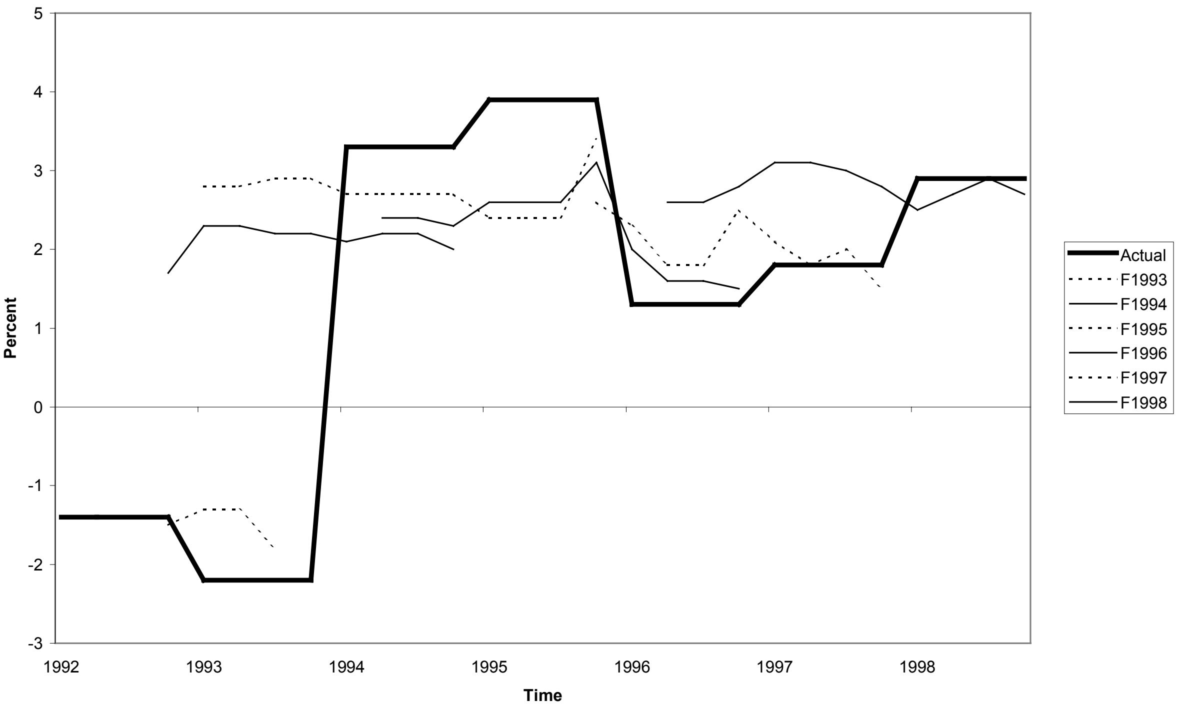
Ellingsen and Söderström (1998), inter alia, have pointed out that the market responses to changes in the central bank’s instrument interest rate depend on whether the market interprets a change in the instrument as reflecting new information about eg future inflation, or as a sign of a change in policy. In principle, the data on the Riksbank’s own forecasts used in this paper could also be used to separate “policy shocks” from “new information” (measured by eg changes in forecasts). One could then study how the yield curve responds to such innovations. As pointed out by Rudebusch (1998), among others, the yield curve and futures markets also contain information about the systematic and unexpected parts of monetary policy. There are thus several different ways to derive “policy shocks”, and further work is needed to increase our understanding of the design and effects of monetary policy.

[34] We have added our “policy shocks” and “judgments” into a simple AS-AD model (used by the Riksbank for other purposes) and the results suggest that the effects on inflation and the output gap are indeed small.

Figure 1
Actual inflation and forecasts by Sveriges Riksbank

Note: Inflation is measured as average annual inflation. The series F199X show forecasts for the calendar year 199X available at the quarters indicated by the horizontal axis. Where no new forecast is available in a quarter, the most recent available forecast has been used.

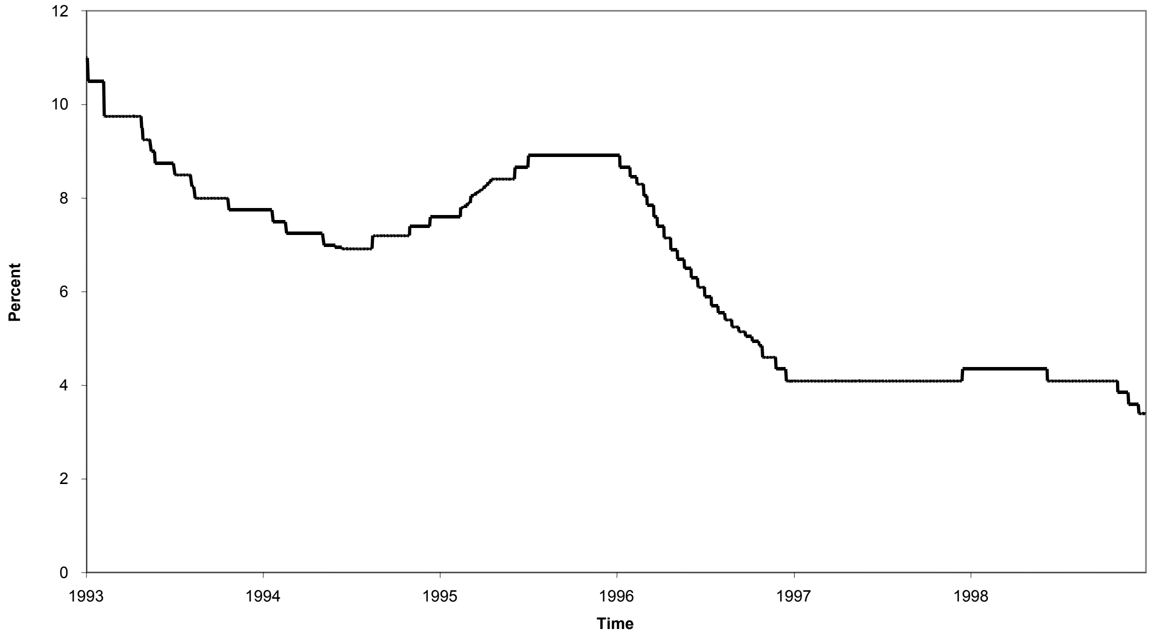
Figure 2
Actual real GDP growth and forecasts by Sveriges Riksbank



Note: GDP growth is measured at an annual rate. The series F199X show forecasts for the calendar year 199X available at the quarters indicated by the horizontal axis. Where no new forecast is available in a quarter, the most recent available forecast has been used.

Figure 3

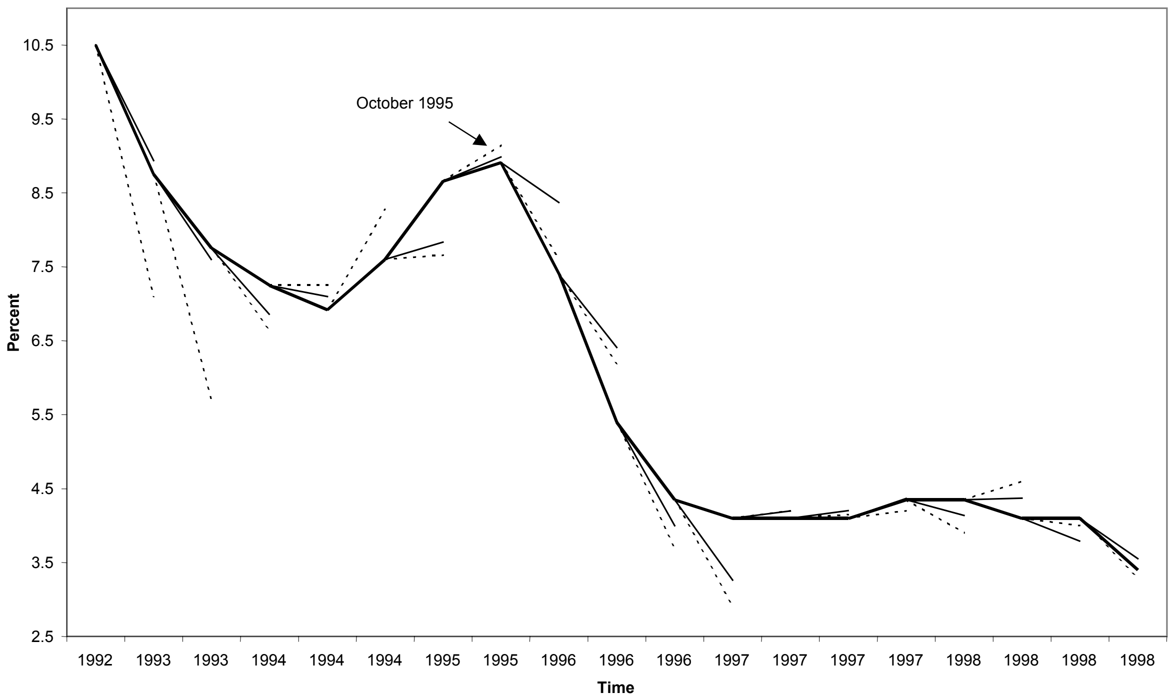
The Riksbank's policy (repo) rate



Note: The series shows the development of the repo rate on a daily basis.

Figure 4

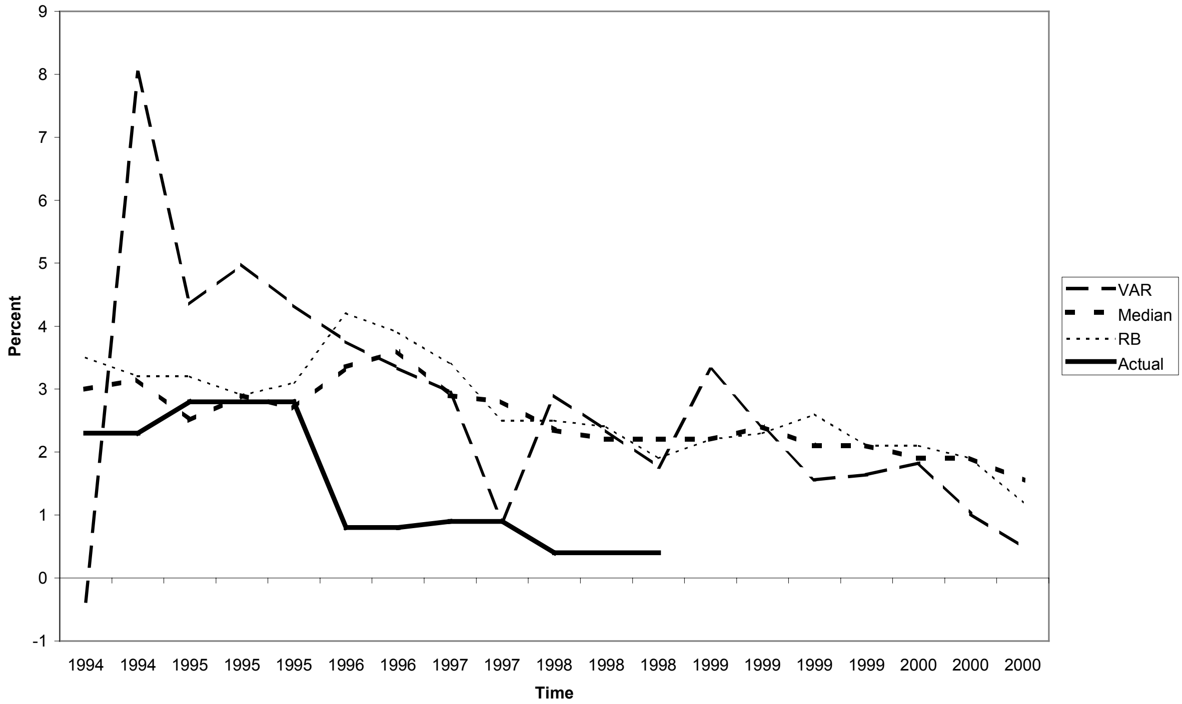
The actual policy rate and the Riksbank's "policy shocks"



Note: The thick solid line denotes the actual policy rate. The thin solid line denotes the changes of the policy rate that should have obtained had the rate been adjusted according to the RB rule using the Riksbank's forecasts. The dotted line denotes the changes of the policy rate that should have obtained had the rate been adjusted according to the RS rule using the Riksbank's forecasts. The horizontal axis has been "truncated" in order to correspond to symmetrically centred time points of the forecast dates (see the discussion in the text for further details).

Figure 5

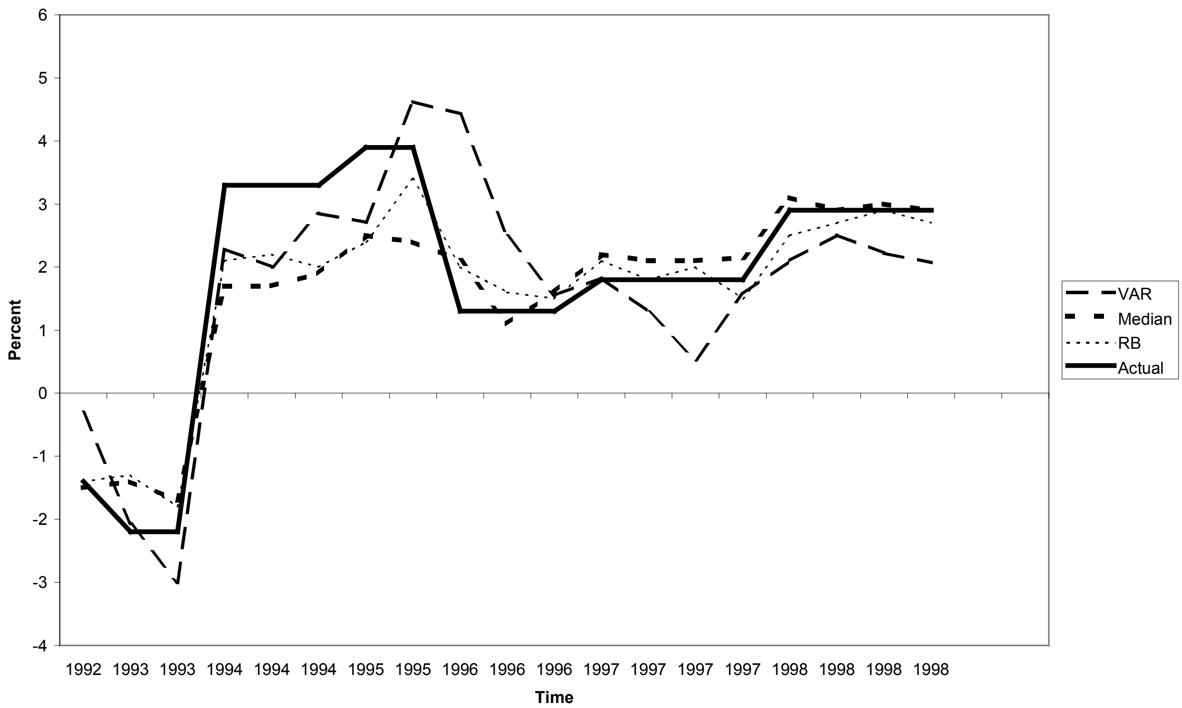
Actual inflation and two-years-ahead forecasts



Note: Inflation is measured as average annual inflation. VAR are the forecasts derived from a VAR model. Median are the median forecasts derived from a set of alternative analysts forecasts. For further details see the text. RB are the forecasts from Sveriges Riksbank. For each year on the horizontal axis the lines show the corresponding forecasts (made approximately two years previously) or actual value for that year.

Figure 6

Actual GDP growth and current-year forecasts

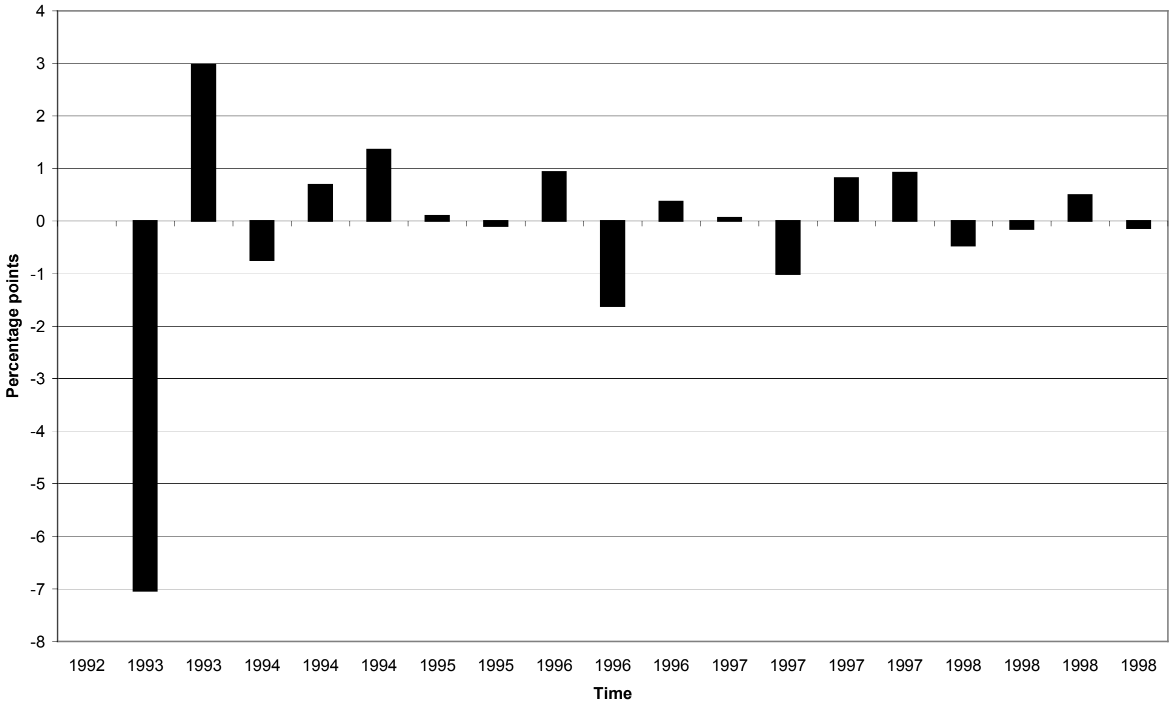


Note: GDP growth is measured at an annual rate. VAR are the forecasts derived from a VAR model. Median are the median forecasts derived from a set of alternative analysts forecasts. For further details see the text. RB are the forecasts from Sveriges Riksbank. For each year on the horizontal axis the lines show the corresponding forecasts (made within the current year) or actual value for that year.

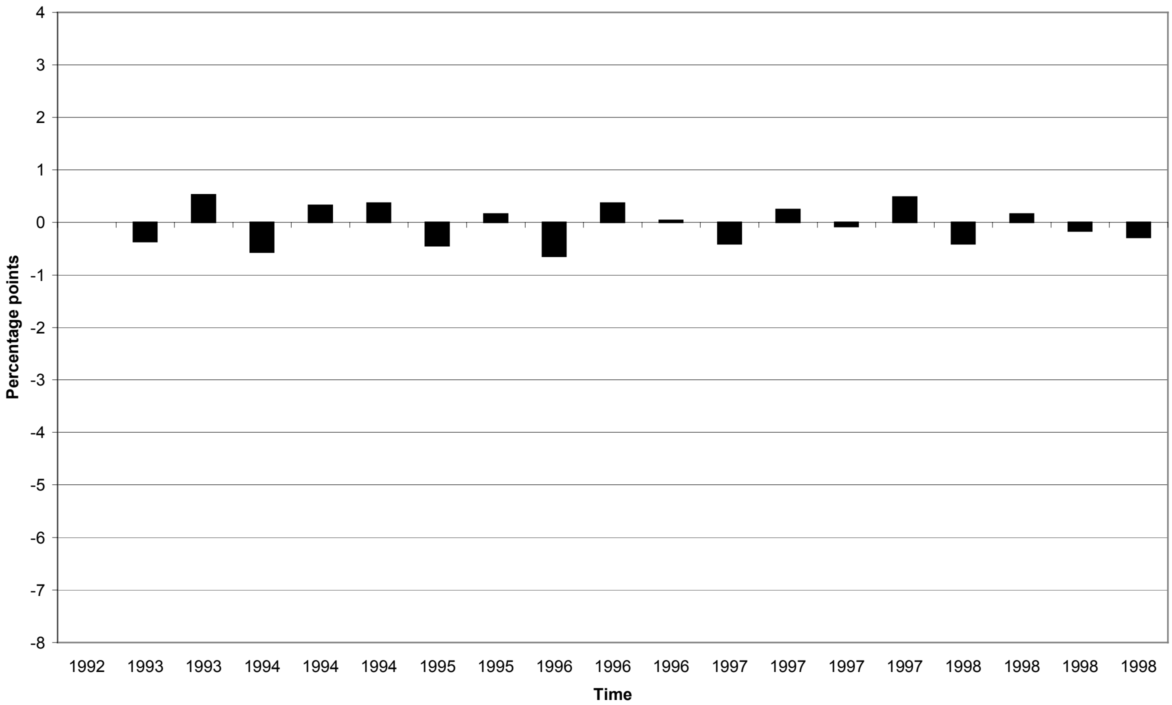
Figure 7

The Riksbank's "judgments"

Comparison with VAR forecasts



Comparison with forecasts from other analysts (medians)



Note: The bars represent the differences between the changes in the policy rate that should have obtained had the rate been adjusted according to the RB rule using the Riksbank's forecasts and the alternative forecasts (VAR, median of other analysts' forecasts) respectively.

Table 1

Actual inflation and forecasts by Sveriges Riksbank

Forecast derived at time	Forecast for year									
	1992	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
1992: Dec		5.2	***3.5***							
1993: Mar		5.6	***3.2***	3.0						
1993: Aug		4.8	3.2	***3.2***						
1994: Jan			2.9	***2.9***						
1994: Apr			2.0	***3.1***	2.9					
1994: Oct			2.4	3.5	***4.2***					
1995: Feb				3.2	***3.9***					
1995: Oct				3.0	3.1	***3.4***				
1996: Jan					2.1	***2.5***				
1996: Jun					1.6	2.3	***2.5***			
1996: Oct					1.0	1.9	***2.4***			
1997: Feb						1.0	***1.9***			
1997: Jun						0.9	1.9	***2.2***		
1997: Aug						0.9	2.1	***2.3***		
1997: Nov						0.9	2.1	***2.6***		
1998: Feb							1.6	***2.1***	2.0	
1998: May							0.5	0.9	***2.1***	
1998: Sep							0.6	0.8	***1.9***	
1998: Nov							0.4	0.6	***1.2***	
1999: Mar								0.3	***1.0***	
1999: May								0.2	1.0	***1.6***
Actual		4.7	2.3	2.8	0.8	0.9	0.4			
RMSE		0.6	0.77	0.38	2.18	1.21	1.42			
Variance		0.16	0.32	0.04	1.39	0.83	0.64			

Note: The forecasts used in the RS and RB rules are bold and italic. RMSE is the root mean-squared error. Variance is the centred sample variance of the forecasts.

Table 2

Actual real GDP growth and forecasts by Sveriges Riksbank

Forecast derived at time	Forecast for year: 1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
1992: Dec	***–1.4***	1.5	1.7							
1993: Mar		***–1.3***	2.3	2.8						
1993: Aug		***–1.8***	2.2	2.9						
1994: Jan			***2.1***	2.7						
1994: Apr			***2.2***	2.7	2.4					
1994: Oct			***2.0***	2.7	2.3					
1995: Feb				***2.4***	2.6					
1995: Oct				***3.4***	3.1	2.6				
1996: Jan					***2.0***	2.3				
1996: Jun					***1.6***	1.8	2.6			
1996: Oct					***1.5***	2.5	2.8			
1997: Feb						***2.1***	3.1			
1997: Jun						***1.8***	3.1	3.6		
1997: Aug						***2.0***	3.0	3.4		
1997: Nov						***1.5***	2.8	3.2		
1998: Feb							***2.5***	2.9	3.0	
1998: May							***2.7***	3.0	2.9	
1998: Sep							***2.9***	2.8	2.6	
1998: Nov							***2.7***	2.1	2.3	
1999: Mar								***2.1***	2.5	
1999: May								***2.5***	3.0	3.0
Actual	–1.4	–2.2	3.3	3.9	1.3	1.8	2.9			
RMSE	0.0	0.70	1.23	1.14	1.05	0.45	0.21			
Variance		0.06	0.05	0.09	0.32	0.29	0.04			

Note: The forecasts used in the RS rule are bold and italic. RMSE is the root mean-squared error. Variance is the centred sample variance of the forecasts.

Table 3

Accuracy of forecasts

Type of forecast	RMSE: Inflation	RMSE: GDP growth	No of forecasts
RB 0-steps ahead	0.17	0.59	6
RB 1-step ahead	0.13 (min)	0.26 (min)	3
RB 2-steps ahead	0.43	0.58	4
RB 3-steps ahead	0.86	0.93	6
RB 4-steps ahead	1.41	1.06	5
RB 5-steps ahead	1.36	0.78	2
RB 6-steps ahead	1.20	0.70	3
RB 7-steps ahead	1.75	0.94	5
RB 8-steps ahead	2.41 (max)	1.03	4
RB 9-steps ahead	0.40	1.00	1
RB 10-steps ahead	2.10	0.81	2
RB 11-steps ahead	0.20	1.10 (max)	1
RB	1.90	0.68	12 (π); 19 (Δy)
VAR	2.59	1.07	12 (π); 19 (Δy)
Median	1.67	0.84	12 (π); 19 (Δy)

Note: The X-step(s)-ahead forecasts are annual forecasts undertaken X quarter(s) in advance. 0-steps ahead means a forecast undertaken in the last three months of a year. VAR are the forecasts derived from a VAR model. Median are the median forecasts derived from a set of alternative analysts' forecasts. For further details see the text. RB are the forecasts from Sveriges Riksbank. Inflation forecasts RB, VAR, Median are two years ahead and GDP growth forecasts RB, VAR, Median are current year. π denotes inflation and Δy GDP growth.

Table 4

Recursive analysis of equation (3)

Recursive sample	Coefficient estimate [standard error] on			
	Constant	**Inflation**	**Output**	**Interest rate**
2-19 (full sample)	−0.09	0.81	0.05	0.62
	[0.35]	[0.29]	[0.14]	[0.21]
3-19	−0.05	0.80	0.03	0.62
4-19	−0.69	0.89	0.31	0.53
5-19	−0.65	0.91	0.29	0.58
6-19	−0.68	0.94	0.31	0.57
7-19	−0.70	1.03	0.33	0.57
8-19	−1.09	1.06	0.45	0.40
9-19	−1.16	1.07	0.49	0.41
2-18	−0.09	0.78	0.05	0.62
2-17	−0.07	0.79	0.04	0.63
2-16	−0.07	0.80	0.05	0.63
2-15	−0.09	0.83	0.05	0.62
2-14	−0.09	0.82	0.05	0.62
2-13	−0.07	0.83	0.05	0.63
2-12	−0.05	0.85	0.04	0.63

Note: None of the recursive-sample estimates in rows two to 15 are significantly different (at the 5% test level) from the full-sample estimates (top row).

Table 5

Setup for alternative forecasters' forecasts

Forecast derived at time	Inflation forecasts		Forecasts of GDP growth	
	Information set up to and including	**Forecast for year (two years ahead)**	**Information set up to and including**	**Forecast for year (current year)**
1992: Dec	1992:4 *♦	1994	1992:2 *	1992
1993: Mar	1993:1	1994	1992:3	1993
1993: Aug	1993:3	1995	1993:1 ♦	1993
1994: Jan	1993:4	1995	1993:3	1994
1994: Apr	1994:1	1995	1993:4	1994
1994: Oct	1994:2 *	1996	1994:2	1994
1995: Feb	1995:1	1996	1994:3 *	1995
1995: Oct	1995:3	1997	1995:2	1995
1996: Jan	1995:4	1997	1995:3	1996
1996: Jun	1996:2	1998	1995:4	1996
1996: Oct	1996:3 *	1998	1996:2	1996
1997: Feb	1997:1	1998	1996:3	1997
1997: Jun	1997:2	1999	1996:4 *	1997
1997: Aug	1997:3	1999	1997:1	1997
1997: Nov	1997:4	1999	1997:2	1997
1998: Feb	1998:1 *	1999	1997:3	1998
1998: May	1998:2	2000	1997:4	1998
1998: Sep	1998:3	2000	1998:1	1998
1998: Nov	1998:4	2000	1998:2 *	1998

Note: * indicates the points in time at which the cointegration-space parameters of the VAR model are re-estimated; ♦ indicates the time from which the regime-shift dummy in Sweden (the floating exchange rate, inflation targeting, regime) is included in the VAR.

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Forecasting Swiss inflation with a structural macromodel: the role of technical progress and the "mortgage rate-housing rent" link

Peter Stalder

1. Introduction

At the beginning of the year 2000, the Swiss National Bank (SNB) adapted its monetary policy strategy. Instead of using a medium-term target path for the monetary base, an inflation forecast now serves as the main indicator for monetary policy decisions. At the operational level, the SNB has adopted three-month Libor (London interbank offered rate) as its new reference interest rate, and the intended stance of monetary policy is communicated to the public in terms of a target range for this interest rate with a width of 1 percentage point.

In view of this adapted concept, a sound foundation for monetary policy decisions requires deeper insights into the process generating future inflation in general and the transmission mechanism from short-term interest rates to long-term interest rates, exchange rates, real economic activity and inflation in particular. Ideally, an econometric model should be available that produces reliable conditional inflation forecasts, thus showing how three-month Libor has to be adjusted in order to keep inflation in conformity with the definition of price stability (CPI inflation below 2%).

The SNB inflation forecast is based on different models and indicators. Among the forecasting models, three approaches may be distinguished. A first approach follows the VAR methodology and identifies the variables that are most relevant for future inflation in Switzerland (Jordan (1999)). A second approach is a small structural model of the Swiss economy, centred on a Phillips curve and an IS relationship (Zurlinden and Lüscher (1999)). The third approach is a medium-size structural model of the Swiss economy with a relatively detailed representation of aggregate demand, a supply block (wage-price dynamics, capacity output, labour market) and a monetary block (interest rates and exchange rates). This latter model forms the basis for the analysis contained in this paper.

In the framework of the adapted concept, the appropriateness of monetary policy is connected in a straightforward manner to the reliability of the inflation forecast. Erroneous inflation forecasts give rise to wrong policy decisions, and wrong policy decisions can in principle be traced back to erroneous inflation forecasts, although performing this task may not be quite as easy in practice due to the overlapping character of updated inflation forecasts and monetary policy decisions. In this context, the paper investigates two issues that are related to (i) uncertainties in the process of forecasting inflation and (ii) institutional changes in the Swiss economy that may affect the monetary transmission mechanism.

Specifically, a first model simulation deals with the question of to what extent the inflation forecast is affected by alternative assumptions with respect to the rate of technical progress. This experiment is motivated by the recent discussion about potential, but so far insecure, productivity gains resulting from the "new economy" in connection with liberalised markets and intensified competition. A second simulation addresses the question of to what extent the link of housing rents to mortgage rates, as established by Swiss legislation on tenancy rights, hampers the monetary transmission mechanism. This is done by carrying out a counterfactual simulation in which the housing rent equation of the model, reflecting current legislation, is replaced by an alternative link of housing rents to the CPI. In fact, proposals going in this direction are currently being discussed in the Swiss parliament.

The second simulation is somewhat different in character from the productivity experiment since it addresses the implications of an institutional change that would be known to the monetary authorities some time in advance. In both cases, however, the change in the economic structure affects inflation and thus - if not taken into account properly in the forecasting model - will give rise to wrong signals for monetary policy. Alternatively, the second simulation can also be viewed as an exercise that sheds some light on the question of whether the current legislation should be changed or not.

All simulations and forecasts presented in this paper refer to a situation comparable to the one faced by the SNB in August 2000. It should be noted, however, that they are made for the purpose of this study only and do not necessarily coincide with the actual SNB forecast. Moreover, although the SNB does not actually pursue a policy of explicit inflation targeting, a strict inflation target of 1.7% is assumed for didactic reasons.

The remainder of the paper is organised as follows. Section 2 outlines the basic structure of the model, with emphasis on those parts that matter most in the following simulation experiments. The sequence of simulations starts - as in the actual monetary policy decision process - with an inflation forecast based on the assumption of an unchanged three-month Libor (Section 3). This baseline forecast is intentionally made somewhat more inflationary than the actual SNB forecast of August 2000 in order to bring it into clear contrast to price stability and to motivate - in Section 4 - the simulation of a more restrictive monetary policy. The role of productivity growth is analysed in Section 5. This simulation is implemented in such a way that, given higher productivity growth, the inflation target is attained without monetary tightening. On this basis, the consequences of two possible errors in the stance of monetary policy can be discussed: (i) tightening because actually higher productivity growth is not taken into account in the inflation forecast, (ii) not tightening because of expected higher productivity growth when in fact it remains unchanged. Section 6 deals with the role of the “mortgage rate-housing rent” link and analyses the extent to which this link affects the monetary transmission mechanism. Section 7 summarises the paper and draws some conclusions.

2. Structure of the model

The model used for the following simulations is a quarterly structural model of the Swiss economy recently developed at the SNB. In its present version, it contains 29 stochastic equations, which may be assigned to an aggregate demand block, a supply block (production function, labour market, wage-price dynamics) and a monetary block (interest and exchange rates).[1] Although the model is rather conventional in many respects, it involves some distinguishing features that should be pointed out. The emphasis in this section is on those aspects of the model that are particularly relevant for the simulations presented below.

2.1 Supply block

2.1.1 Capacity output, factor proportions, investment and scrapping

A rather non-standard approach is taken in the specification of the supply block of the model.[2] The equations for firms’ decisions on investment, production capacity and prices are based on a vintage production function, ie the assumption that “machines” can be designed to combine with an optimal input of labour prior to their installation but that the factor proportions remain fixed thereafter. Further assuming monopolistic competition in the product market, the problem of the firm is to choose on each investment vintage the cost-minimising factor mix, to pursue an optimal policy of replacing old investment vintages by new equipment and to adjust production capacities, output and prices in response to changes in goods demand and factor costs. In this framework, the evolution of capacity output YC_t and capacity labour demand LC_t (ie labour demand corresponding to full utilisation of available equipment) can be described by the following two equations:

$$YC_t = S_t\, YC_{t-1} + B_t I_t \qquad (1)$$

$$LC_t = S_t\, LC_{t-1} + C_t I_t \qquad (2)$$

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1 The developer of the model has previously been responsible for the development of the macroeconometric model at KOF/ETH. Several insights into the mechanism of the Swiss economy gained during this work at KOF/ETH are reflected in the model of this paper.

2 A more detailed description is given in Stalder (1994).

In (1) and (2), S_t is the share of surviving equipment from the previous period (1-S_t is the scrapping rate). B_t is capital productivity and C_t is labour intensity of the new vintage, while I_t is gross investment for the period. Hence B_tI_t is capacity added by the vintage installed at time t and C_tI_t is the corresponding labour requirement. Assuming a Cobb-Douglas production function with labour-augmenting technical progress θ and labour share α, one obtains B_t and C_t as

$$B_t = B_0 q_t^{-\alpha} e^{\theta\alpha t} \qquad \text{and} \tag{3}$$

$$C_t = C_0 q_t^{-1} \qquad \text{where} \quad q_t = w_t / v_t \tag{4}$$

is the ratio of wages to capital cost at the time of investment.

The expected long-term growth rate of q_t theoretically also plays a role in (3) and (4) and at the same time affects the prospective lifetime of vintage t for the following reasons. The replacement of existing by new equipment is determined by a comparison of production costs. On existing vintages, the factor input proportions are fixed and capital costs are "sunk". Existing vintages are thus replaced as soon as the associated unit labour costs exceed total unit costs on new equipment (scrapping rule). Hence, if wages are expected to increase strongly in relation to capital costs, the prospective lifetime of new equipment shortens and firms shift to a more capital-intensive expansion path, ie they choose lower B_t and C_t. Without such a shift, the prospective lifetime would obviously shorten more. In specifications (3) and (4), these considerations are neglected or, put differently, it is assumed that the expected long-term growth rate of q_t is constant. This can be justified by noting that the logarithm of q_t can be represented empirically as a random walk with drift, implying that the innovations of the process affect the actual growth rate of the factor price ratio but leave its expected long-term growth rate unchanged.

With respect to the scrapping decision of each period, it is, however, not the *expected* long-term growth rate but the known *actual* growth rate of q_t that matters (denoted by $\dot{q}_t$). Old equipment is typically more labour-intensive than new equipment and capital costs on old equipment are "sunk". Therefore, if wages increase *strongly* in relation to capital costs in a certain period, a larger share of existing equipment will lose its competitiveness and be scrapped. Hence, the share of surviving equipment is a negative function of $\dot{q}_t$:

$$S_t = S(\dot{q}_t) \tag{5}$$

Investment behaviour can be specified on the basis of the same theoretical considerations. If S_t and B_t are low (because of high $\dot{q}_t$ and q_t respectively), a larger volume of new investment I_t will be needed to adjust production capacity from YC_{t-1} to YC_t. In fact, the investment equation can be derived from (1) by replacing YC_t by some concept of desired capacity, solving for I_t and allowing for adjustment lags (see below).

2.1.2 Price setting and regimes of the firm

On the assumption of monopolistic competition in the goods market, firms set the price as a profit-maximising mark-up over marginal costs *MC*. These can be defined either as total unit costs on new equipment or as unit labour costs on marginal (oldest) equipment. The two concepts are equivalent in equilibrium due to the scrapping rule (old vintages are replaced as soon as the associated unit labour costs exceed total unit costs on the most recent vintage). The normal mark-up price of a firm can thus be written as[3]

$$\bar{p}_t = \left(\frac{\eta}{\eta - 1}\right) MC_t \tag{6.1}$$

where η is the price elasticity of the firm's demand curve and marginal costs are defined, on the basis of the Cobb-Douglas vintage production function, as

[3] The term "normal" is perhaps somewhat misleading. More precisely, $\bar{p}$ is the optimal price neglecting capacity constraints - or the long-term optimal price, since firms can always add new equipment, making the long-run "supply curve" horizontal. The effect of short-run capacity constraints will be introduced below.

$$MC_t = w_t^{\alpha} v_t^{1-\alpha} e^{-\theta\alpha t} \tag{6.2}$$

where α is the labour share and θ is the rate of labour-augmenting technical progress.

Desired production capacity is given by expected demand at $\bar{p}$, $YD(\bar{p})$. In the short run, however, the available set of vintages places an upper bound on output, giving rise to two possible regimes of the firm:[4]

1. If a firm faces a demand curve which, at the normal mark-up price $\bar{p}$, exceeds capacity output *YC*, it will produce at full capacity ($Y = YC < YD(\bar{p})$) and raise the price ($p > \bar{p}$) in order to choke off excess demand. Moreover, effective labour demand *LD* corresponds to capacity labour demand *LC*.

2. If demand at $\bar{p}$ falls short of capacity output *YC*, the firm's output level is constrained by demand ($Y = YD(\bar{p}) < YC$) and the optimal price p is equal to $\bar{p}$. In this case, effective labour demand *LD* falls short of capacity labour demand *LC*.

This theoretical framework, which is somewhat in the spirit of the "disequilibrium" approach of Malinvaud (1980), Benassy (1986) or Sneessens (1990), establishes a straightforward link to business survey data: a firm that reports capacities as being too small (too large) indicates it is in regime 1 (regime 2). Of course, individual firms will generally be in different regimes, and this creates an aggregation problem. Moreover, $YD(\bar{p})$ and YC are not directly observable.

2.1.3 Aggregation and the use of business survey data

A convenient way to deal with both problems at once has been proposed by Lambert (1988). Assuming that the ratio $YD(\bar{p})/YC$ is log-normally distributed in the population of firms and that the output level of each firm *i* is given by the minimum of the two possible constraints, ie $Y_i = \min(YC_i, YD(\bar{p}))_i$, the aggregate relationships can be approximated by

$$Y(1-\pi_G)^{-\kappa} = YD(\bar{p}) \tag{7.1}$$

$$Y\pi_G^{-\kappa} = YC \tag{7.2}$$

where π_G is the proportion of firms reporting capacities as being too small (capacity-constrained firms in regime 1). Equations (7.1) and (7.2) define a one-to-one mapping from the two latent variables $YD(\bar{p})$ and YC to the two observables Y and π_G. In order to see how this mapping works, it is instructive to divide (7.1) by (7.2), yielding a logit-type equation for π_G:

$$\left(\frac{\pi_G}{1-\pi_G}\right)^{\kappa} = \frac{YD(\bar{p})}{YC} \tag{7.3}$$

According to (7.3), the regime mix (π_G, 1-π_G) is endogenously determined in the model by the aggregate demand/capacity ratio, and the "curvature" of this relationship is shaped by parameter κ. If we let $YD(\bar{p})$ increase in relation to YC, π_G converges to its upper bound 1 ("all" firms are capacity-constrained). In such a limiting situation, Y according to (7.2) tends from below to YC, ie aggregate output corresponds to aggregate capacity. If we let $YD(\bar{p})$ decrease in relation to YC, then π_G converges to its lower bound 0 ("all" firms are demand-constrained) so that in the limit - according to (7.1) - Y is bounded from above by $YD(\bar{p})$. Aside from these limiting situations, actual output Y is smaller than YC and $YD(\bar{p})$, increasingly so for large values of κ. Parameter κ can be viewed as a measure of mismatch between the micro structures of aggregate demand and capacity. More precisely, it measures the dispersion of $YD(\bar{p})/YC$ in the population of firms.

4 In the following equations, the time subscripts are omitted.

Firms for which $Y = YC < YD(\overline{p})$ have an incentive to raise the price p above $\overline{p}$ in order to bring demand into line with available capacity. At the aggregate level, this can be formalised as follows:

$$p_t = \overline{p}_t \,(1 - \pi_{G_t})^{-\tau} \tag{8}$$

The aggregate price level p is an increasing function of π_G. The specification implies that p tends from above to its lower bound $\overline{p}$ if π_G converges to 0, which - according to (7.3) - happens if aggregate demand becomes sufficiently low in relation to capacity output ("all" firms demand-constrained). Provided that firms facing excess demand at $\overline{p}$ raise the price enough to eliminate excess demand, one may assume that $Y = YD(p)$. Note, however, that it is always $YD(\overline{p})$ - and not $YD(p)$ - that determines desired capacity and thus investment behaviour.

Substituting (6.1) and (6.2) into (8), one obtains the following aggregate price equation:

$$p_t = \left(\frac{\eta}{\eta - 1}\right) w_t^{\alpha} v_t^{1-\alpha} e^{-\theta \alpha t} \left(1 - \pi_{Gt}\right)^{-\tau} \tag{9}$$

In the empirical model, (9) is dynamically extended into an error correction equation and applied to the GDP deflator (excluding housing rents).

2.1.4 Investment behaviour

By investing in new equipment, firms tend to bring production capacities into line with the development of demand. Demand at the normal mark-up price determines desired production capacity, ie $YC_t^* = YD_t\,(\overline{p}_t)$. After substituting this into (1) one may solve for the desired investment rate:

$$IR_t^* \equiv I_t^* \big/ YC_{t-1} = \left(\frac{YD_t\,(\overline{p}_t)}{YC_{t-1}} - S_t\right) \big/ B_t \tag{10}$$

This equation defines the investment rate that would just close the gap between demand at $\overline{p}_t$ and the surviving capacity from the previous period. To allow for adjustment cost and other factors that may cause inertia in investment behaviour, a simple partial adjustment scheme is introduced:

$$IR_t = \lambda\, IR_t^* + (1 - \lambda) IR_{t-1} \quad \text{where } IR_t = I_t / YC_{t-1} \tag{11}$$

The role of capacity output in the model differs from the more commonly used concept of potential output in two respects. First, capacity output acts as a strict upper bound for actual output ($Y \leq YC$), ie the output gap is never positive, whereas potential output is usually defined as output at a normal utilisation rate so that actual output may exceed potential output in boom periods. Second - and also in contrast to the usual concept of potential output - capacity output refers to technical capacities only. The tension situation on the labour market is taken into account separately, as shown next.

2.1.5 Labour market and wage formation

On the labour market, the aggregate relationships can be formalised in a similar way. As outlined above, in capacity-constrained firms (regime 1, proportion π_G) we have $LD = LC$ while in demand-constrained firms (regime 2, proportion 1-π_G) we have $LD < LC$. At the aggregate level, this spillover from insufficient goods demand to effective labour demand can be represented by

$$LD = LC \pi_G{}^{\kappa} \tag{12}$$

where *LC* is given by (2). Apart from the limiting situation where π_G tends to 1 (ie as soon as some firms are demand-constrained in the goods market), effective labour demand *LD* falls short of capacity labour demand *LC*. To allow for labour hoarding, π_G is expanded into a lag structure in the empirical model. Employment *L* is determined in connection with aggregate labour supply *LS* as

$$L(1 - \pi_L)^{-\upsilon} = LD = LC \pi_G^{\kappa} \tag{13.1}$$

$$L \pi_L{}^{-\upsilon} = LS \tag{13.2}$$

where π_L, endogenously determined by *LD/LS*, is the proportion micro labour markets in excess demand (measured by the share of firms reporting labour shortages). The implied unemployment rate is

$$URATE = 1 - L/LS = 1 - \pi_L{}^{\upsilon} \tag{14}$$

If *LD* = *LS*, we have π_L = 0.5. This can be regarded as an aggregate equilibrium. The associated unemployment rate (structural rate of unemployment at equilibrium) is

$$SURE = 1 - 0.5^{\upsilon} \tag{15}$$

SURE is an increasing function of parameter υ, which can be viewed as a measure of demand/supply "mismatch" (dispersion of the demand/supply ratio across micro labour markets).[5]

In the empirical application, econometric equations are substituted on the right-hand side of (7) and (13), and the parameters of these equations are estimated jointly with the parameters υ and κ, which shape the transformation from the latent variables *YD*, *YC*, *LC* and *LS* to the observable variables *Y*, *L*, π_G and π_L.

The equation substituted for labour supply makes *LS* dependent on the exogenous potential labour force and involves a partial adjustment scheme with respect to actual employment. This can be seen as kind of a "discouraged worker" mechanism in the sense that low (high) employment entails a retreat from (re-entry into) the labour market. In addition, it may also reflect a cyclical buffer role of seasonal and frontier workers, who are not included in the potential labour force.

The proportion π_L enters the wage equation of the model in the following way:

$$w_t = p_t^{k_1} pc_t^{(1-k_1)} \left(\frac{Y_t}{L_t} \right)^{k_2} \left(\frac{\pi_{Lt}}{1 - \pi_{Lt}} \right)^{k3} \tag{16}$$

The development of the nominal wage thus depends on a weighted average of the GDP deflator *p* and consumer prices *pc*, labour productivity *Y/L* and π_L, reflecting tension in the labour market. In the empirical model, equation (16) is brought into an error correction form as well.

Equation (16) says that wages increase in relation to prices if the labour market becomes tight (high π_L). Equation (9) says that firms raise prices in relation to wages if capacity utilisation increases (high π_G). Hence, if both the goods and the labour market are tight, the formation of wages and prices may become incompatible in the sense that the income claims of workers and firms add up to more than what is actually available for distribution. The result is accelerating inflation that must continue to the point where real activity is dampened enough to make income claims compatible by lowering π_L and π_G.[6]

Consumer prices *pc,* which enter (16) with a weight of about 0.5, depend on the GDP deflator *p*, import prices *pim* (excluding oil), the price of imported oil *poil* and housing rents *phr*:

$$pc_t = pc(p_t, pim_t, poil_t, phr_t) \tag{17}$$

According to this equation, increasing import prices or housing rents may drive a wedge between the GDP deflator and consumer prices (or between the real producer wage and the real consumer wage) and thereby - since nominal wages are partly adjusted to consumer prices - also set in motion a wage-price spiral. This aspect of the model will become relevant in Section 6, where the impact of the formation of housing rents on the monetary transmission process is discussed.

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5 With regard to the *SURE* concept and some other aspects, the model of this paper is quite similar to the various country models presented in Drèze and Bean (1990).

6 This is in the spirit of the NAIRU model of Layard, Nickel and Jackman (1991).

2.1.6 *Impact of higher productivity growth - theoretical considerations*

Section 5 of this paper presents a model simulation addressing the question to what extent the inflation forecast is affected by higher technical progress. Given the above specifications, it is quite straightforward to carry out this exercise by raising the technical progress parameter θ in equations (3) and (9). In accordance with the adopted vintage framework, this amounts to the assumption that higher technical progress falls exclusively on new equipment:

- In equation (3), a higher θ entails a stronger increase of capital productivity *B* and thus labour productivity on new equipment, which is given as[7]

  $$A_t = B_t / C_t = (B_0 / C_0) q_t^{1-\alpha} e^{\theta\alpha t} \quad (18)$$

- In equation (9), a higher θ lowers the output price in relation to factor prices.

Of course, these are just initial effects. Eventually, all variables of the supply block are affected by higher productivity growth in a rather complex way. The responses also depend on various reaction parameters in the aggregate demand block and the monetary block of the model. A crucial issue is the extent to which the higher growth potential of the economy is actually absorbed by a steeper increase in aggregate demand. If the positive effect of lower prices on aggregate demand is weak, investment and employment will decline as a result of higher capital productivity and labour productivity, respectively. The corresponding underutilisation of resources enhances the direct price dampening effect of productivity growth. If aggregate demand is stimulated strongly by lower prices, negative reactions of investment and employment may be prevented. But then, the price-dampening effect of higher productivity growth will also be smaller.

More technically, consider an increase of θ by an amount of $\Delta\theta$. Initially, this raises the growth rate of both capital productivity and labour productivity by $\Delta\theta\alpha$ but leaves the labour intensity of new equipment unaffected, as can be seen from equations (3), (4) and (18). In the sequel, however, since higher technical progress pushes prices down in relation to wages, there will be an increase in the factor price ratio *q* = *w/v*, shifting the factor input ratio in favour of capital (lower *C*). This process of capital deepening on the one hand raises the growth rate of labour productivity still further. On the other hand, it dampens the growth rate of capital productivity. An illustrative benchmark case obtains if we assume that the growth rate of *q* just rises by $\Delta\theta$ (wages increase in relation to capital costs exactly by the amount of additional labour-augmenting technical progress, thus keeping the factor price ratio in terms of efficiency units constant). In this case, the growth rate of labour productivity *A* rises by $\Delta\theta$ (instead of $\Delta\theta\alpha$), while capital productivity *B* remains constant (instead of rising by $\Delta\theta\alpha$). Empirically, it turns out that the growth rate of *q* increases, but by less than $\Delta\theta$. Nevertheless, the induced process of capital deepening reduces the negative impact of faster technical progress on investment while the negative impact on employment is enhanced. Both negative effects are mitigated or even reversed if aggregate demand shows a large positive reaction to lower prices (which can be expected in the longer run).

The model distinguishes between three concepts *of* labour productivity, namely technical labour productivity on new equipment (*A* = *B/C*), technical labour productivity on the entire production apparatus (*YC/LC*) and measured labour productivity (*Y/L*). The increase in *YC/LC* resulting from a higher value of θ hinges on the speed with which old equipment is replaced by new equipment, ie scrapping and investment. Measured labour productivity *Y/L* additionally depends on cyclical factors like capacity utilisation *Y/YC* and labour hoarding.

Empirically, all three productivity measures show a positive reaction to a higher value of θ. The effect on output *Y* is positive as well, but smaller than the increase in labour productivity. As a result, employment *L* declines and unemployment rises, lowering the tension measure π_L. In the wage equation (16), one thus has two opposing effects, a positive productivity effect and a negative tension effect. Empirically, the productivity effect dominates so that wages decline by less than the GDP deflator and consumer prices. Accordingly, both the real producer wage (*w/p*) and the real consumer wage (*w/pc*) increase. The price of new capital goods, *v*, also declines substantially in relation to the nominal wage so that the factor price ratio *q* = *w/v* increases. The fall in *v* is partly due to the

7 *B* is output per unit of new capital, *C* is labour per unit of new capital, hence *B/C* is output/labour, ie labour productivity.

functioning of the monetary block, where lower domestic prices lead to an appreciation of the Swiss franc, which in turn has a dampening effect on the prices of imported investment goods.

Investment behaviour is influenced by higher technical progress in different ways. First, the stronger increase in the factor price ratio $q = w/v$ lowers S, ie speeds up scrapping and thus stimulates investment. Second, the stronger growth of capital productivity B exerts an opposing negative effect on investment since less investment is needed to attain a certain production capacity. Third, the response of investment depends on the extent to which aggregate demand is stimulated by lower prices. Empirically, it turns out that the response of investment to a higher rate of technical progress is negative in the short run (the effect of higher capital productivity dominates) but positive in the longer run (as the aggregate demand effect gains strength).

In the following, we describe the specification of the aggregate demand part of the model, which is rather conventional.

2.2 Aggregate demand, income determination and sector prices

On the demand side of the goods market, we have the equations for the various components of aggregate demand:

- *Private consumption* depends on real disposable household income, the real long-term interest rate, the share of the non-active population and the unemployment rate.
- *Investment in machinery and equipment* is determined in close connection with the specification of capacity output as a function of tension in the goods market and the level and growth rate of relative factor costs, as described in Section 2.1 above.
- *Business construction* reacts with some delay on investment in machinery and equipment and relative construction prices.
- *Housing investment* responds to the level and the growth rate of GDP, a specific profitability measure (involving long-term interest rates, housing rents and construction prices) and population growth.
- *Inventory investment* is specified according to a buffer-stock stock-adjustment model. The impact of purely short-term demand shocks on GDP is thus buffered by inventory changes, whereas more persistent demand movements are reinforced by the stock adjustment process.
- *Exports* depend on a weighted composite of GDP in Europe, the United States and Japan on the one hand and the Swiss supply price in relation to the prices of competing producers in the world economy (converted into Swiss francs by the trade-weighted external value of the Swiss franc) on the other.
- *Imports* react to all components of aggregate demand with component-specific elasticities (reflecting different import intensities) on the one hand and import prices (excluding oil) in relation to the GDP-deflator on the other.
- *Public construction* and *government consumption* are treated as exogenous or - as an alternative in model simulations - linked in fixed proportions to GDP.

Together, these components define GDP (Y) from the demand side. However, Y is constrained in the supply block of the model by capacity output YC. In a situation where Y tends to its upper bound YC, prices increase, which dampens aggregate demand, in particular via foreign trade (lower exports, higher imports), while investment and capacity growth are stimulated. This mechanism works towards equilibrium in the goods market in the long run.

The goods market and the labour market interact via the production function and wage-price dynamics, as described above. In addition, income generated in the labour market is the most important component of *primary household income* and thus the central determinant of private consumption. The other component of primary household income, business and property income, is linked to non-wage value added, defined as nominal GDP minus total labour costs. The net tax *rate* that enters in the definition of *disposable household income* is treated as exogenous.

The aggregate demand part of the model also collects the equations for those sector prices that are not part of the supply block:

- *Construction prices* depend on the GDP deflator and the share of construction investment in total GDP as a rough indicator of the relative position of the construction sector in the overall business cycle.
- *Housing rents* are determined by construction prices and interest rates, reflecting Swiss legislation that allows house owners to pass changes in the mortgage rate on to tenants. An increase in interest rates by 1 percentage point pushes housing rents up by 4.5% (with a lag), which is less than what is legally allowed but nevertheless hampers the efficiency of monetary policy to a significant degree, as shown in Section 6.
- *Import prices* are linked to world market prices converted into Swiss francs by the trade-weighted external value of the Swiss franc.
- *Export prices* depend on the GDP deflator and import prices as a proxy for the input prices of imported raw materials and intermediate products.

Finally, one should note that equation (9), the central price equation of the model, refers to the GDP deflator excluding housing rents, *p*. The overall GDP deflator is then obtained by a definition equation involving *p* and housing rents *phr*. This distinction is motivated by the following consideration. As noted above, the speed with which tighter monetary policy dampens CPI inflation is hampered by the fact that higher interest rates are passed on to housing rents. However, increasing housing rents not only raise consumer prices and thus depress real wages but also raise non-wage incomes, which mitigates the negative effect on overall real household incomes. This is taken into account by the explicit appearance of housing rents in the equation for the GDP deflator, since it is the difference between nominal GDP and labour costs that determines non-wage household incomes. When simulating a more restrictive monetary policy (Section 4) or when suppressing the impact of interest rates on housing rents (Section 6), taking these income effects properly into account is important.

2.3 Monetary block

The monetary block determines short-term interest rates (three-month Libor), long-term interest rates (government bond rate) and the exchange rate of the Swiss franc, defined as its trade-weighted external value. The specification of this part of the model is based on the following assumptions:

- The orientation of *monetary policy* is reflected in the development of the *short-term interest rate* (three-month Libor), and it is assumed that this interest rate is a “sufficient statistic” for the stance of monetary policy. Put differently, monetary policy affects the economy only through short-term interest rates and there is no additional role for the quantity of money in the model.
- *Swiss long-term interest rates* depend on Swiss short-term interest rates and foreign long-term interest rates.
- The *exchange rate of the Swiss franc* reacts to interest rate differentials and the balance on the external account.

Furthermore, taking into account the orientation of Swiss exports as well as the origin of Swiss imports, it seems likely that monetary policy pays special attention to the exchange rate of the Swiss franc against the euro (historically the Deutsche mark or the currencies of the “DM-block”). Therefore, the model is focused on the Swiss franc/euro (Deutsche mark) exchange rate and the corresponding interest rate and inflation differentials. The overall trade-weighted external value of the Swiss franc is then determined by the endogenous Swiss franc/euro (Deutsche mark) exchange rate and the exogenous external value of the euro (Deutsche mark) against other currencies.

Based on these considerations, monetary policy is assumed to be conducted in such a way that Swiss short-term interest rates (*srate*) go up if real GDP growth ($\dot{y}$) and inflation ($\dot{p}$) rise, whereas an appreciation of the Swiss franc ($\dot{e}$) and increasing unemployment (*URATE*) are counteracted by lowering short-term interest rates. These reactions of *srate* take place in relation to the euro (German) short-term interest rate (*srate**) as a point of reference in the following form:

$$\begin{aligned}\Delta srate_t = {} & S_s \Delta srate_t^* + S_e \log(e_t/e_{t-4}) + S_y \log(Y_t/Y_{t-1}) + S_u URATE_t \\ & - S_\gamma \left(srate_{t-1} - S_0 - srate_{t-1}^*\right)\end{aligned} \tag{19}$$

In the actual process of inflation forecasting, equation (19) is typically removed from the model and three-month Libor is treated as an exogenous instrument. Equation (19) should also not be viewed as the "official SNB policy rule". For certain simulation exercises it is necessary, however, to endogenise three-month Libor. Historically, the behaviour of three-month Libor is captured quite well by (19). Attempts to include the current inflation rate were empirically unsuccessful. This result is not really surprising: on the one hand, in the case of cost-induced inflation, the appropriate policy response is rather to accommodate higher money demand to some extent than to tighten monetary reins. On the other hand, in the case of demand-pull inflation, high GDP growth precedes inflation, so that monetary tightening is already advisable when GDP growth rises. Moreover, *URATE* is the driving force in the wage-price block of the model. Hence, low values of *URATE* can be viewed as a leading indicator of rising inflation as well.

The dependence of *srate* on *srate** in (19) is of an error correction form and involves the assumption that *srate* is cointegrated with *srate**. If *srate** changes, *srate* moves by the same amount in the long run, while the short-term adjustment of *srate* is governed by parameters S_γ and S_s. The dependence of *srate* on the relative change in the external value of the Swiss franc, GDP growth and the unemployment rate is of a simple partial adjustment type. This can be made more apparent by rewriting (19) as:

$$\begin{aligned} srate_t &= S_0 S_\gamma + (1 - S_\gamma) srate_{t-1} + S_e \log(e_t / e_{t-4}) + S_y \log\left(Y_t / Y_{t-1}\right) + S_u URATE_t \\ &\quad + S_s srate_t^* + (S_\gamma - S_s) srate_{t-1}^* \end{aligned} \tag{19}$$

In the case of *URATE*, for example, the short-run impact on *srate* is given by parameter S_u (< 0) and the long-run impact by S_u / S_γ. The exchange rate *e* is defined as euro (Deutsche mark) per Swiss franc (external value), so that an increase in *e* reflects an appreciation.

The long-term interest rate depends on the foreign (German) long-term interest rate and - in a specific form - on Swiss and foreign short-term interest rates:

$$\begin{aligned} \Delta lrate_t &= L_l \Delta lrate_t^* + L_s \left[\Delta srate_t - S_s \Delta srate_t^* + S_\gamma \left(srate_{t-1} - S_0 - srate_{t-1}^*\right)\right] \\ &\quad - L_\gamma \left(lrate_{t-1} - L_0 - lrate_{t-1}^*\right) \end{aligned} \tag{20}$$

The dependence of *lrate* on *lrate** is of an error correction form, involving the assumption of a full pass-through in the long run, while the short-run adjustment of *lrate* to *lrate** is characterised by parameters L_γ and L_s. The response of *lrate* to *srate* is of a partial adjustment type. Note that the term in brackets in (20) is derived from (19). This specification amounts to a distinction between changes in *srate* that result from changes in *e*, *Y* and *URATE* on the one hand and changes in *srate* that reflect changes in *srate** on the other hand. Only the former have an impact on *lrate* (in relation to *lrate**). Consider, for instance, a situation where *srate** increases while *lrate** remains unchanged. In this case, *srate* according to (19) adjusts to the higher *srate*,* but - as the term in brackets in (20) does not change - *lrate* remains unaffected. The spread of Swiss interest rates (*srate-lrate*) thus fully adjusts to the change in the foreign spread (*srate*-lrate**), although with a certain lag. This can be seen as a delayed tightening of Swiss monetary policy in response to a more restrictive course abroad. On the other hand, consider an increase in *srate* that is induced in (19) by an overheating of the Swiss economy. This will be reflected in (20) by a higher value of the term in brackets and hence transmit to *lrate*, but only partly (as $L_s + L_\gamma < 1$ empirically). Such a relative tightening of Swiss monetary policy entails an increase of the spread (*srate-lrate*) in relation to the foreign spread (*srate*-lrate*).*

The equation for the external value of the Swiss franc vis-à-vis the euro (Deutsche mark) is specified as

$$\begin{aligned} \log(e_t / e_{t-1}) &= E_0 + E_\rho \log(e_{t-1} / e_{t-2}) + E_s \left((srate_t - lrate_t) - (srate_t^* - lrate_t^*)\right) \\ &\quad + E_b BAL_t + E_\gamma \log(er_{t-1}) \end{aligned} \tag{21}$$

where *BAL* is the balance on the external account including commodities, services and tourism in relation to nominal GDP and *er* is the real external value, defined as

$$er_t = e \left(\frac{p_t}{p_t^*}\right) \tag{22}$$

According to this specification, the relative change in the external value of the Swiss franc depends on the difference in interest rate spreads (indicating relative tightness of monetary policy) and the external account. In addition, there is a kind of error correction "feedback" from the real external value *er* on the change in *e* ($E_\gamma < 0$), ensuring that persistent inflation differentials, giving rise to a trendlike behaviour of *p/p**, must be accompanied by a compensating trend in *e*. Hence, if the other explanatory variables in (22) were stationary (which is not the case for *BAL,* however), *er* would be stationary as well.

Obviously, this specification of the monetary block has a strong ad hoc flavour. Theoretical considerations like the uncovered interest rate parity condition and the term structure of interest rates are not taken into account explicitly, although the equations involve some rough approximations to these concepts. Empirically, however, the specification works quite well in terms of historical fit, parameter stability and accuracy of ex post forecasts (Stalder (2000)).

3. Baseline forecast (unchanged three-month Libor)

In the baseline forecast, the Swiss short-term interest rate (three-month Libor) is held constant at 3.5% (level prevailing in August 2000). Together with the assumptions for the world economy, the model predicts a strong expansion of the Swiss economy in the year 2000 and a moderate slowdown in the following years. After an increase of 3.3% in 2000, GDP growth falls to 2.2% in 2001. The growth rate is further reduced to 1.8% in 2002-03 and picks up slightly to 1.9% in 2004. Despite this slowdown, the expansion of GDP exceeds productivity growth throughout the forecast period. Accordingly, employment increases - on average by somewhat more than labour supply - so that the unemployment rate falls from 2% in 2000 to 1.7% in 2004.

CPI inflation increases from 0.8% in 1999 to 1.7% in 2000 and reaches 2.5% in the next two years. In 2003-04 the inflation rate falls somewhat, but remains above 2% until the end of the forecast period.[8]

The rise in CPI inflation is caused by:

(i) a sizeable increase in housing rents, due to the delayed adjustment to higher interest rates,

(ii) increasing import prices, caused by the weakness of the Swiss franc against the dollar and higher oil prices,

(iii) higher wage growth and a stronger increase in the GDP deflator resulting from tighter conditions in the labour and product markets (lower unemployment, narrowed output gap).

Factor (i) becomes weaker towards the end of the forecasting horizon. Factor (ii) dies out quickly in 2001 and is even reversed later on. In contrast, factor (iii) remains relevant during the whole forecast period. In other words, the external factors responsible for the current rise in inflation are replaced in the course of the forecast period by higher internal market tension.

The baseline forecast is presented in some more detail in Table 1 (Appendix).

4. The effects of tighter monetary policy (Alternative 1)

The SNB defines price stability as a CPI inflation rate below 2%. This definition is violated in the baseline forecast, implying that monetary policy should become more restrictive. However, one should note in this respect that SNB officials have indicated on several occasions that inflation rates in excess of 2% may temporarily be tolerated, in particular if caused by factors beyond the reach of monetary policy. Moreover, one should also recognise that a sizeable amount of inflationary pressure is already in the pipeline for the year 2001 and could be counteracted only by a radical monetary tightening at excessive cost in terms of real output loss. What monetary policy may reasonably try to control is

[8] What is referred to here as the baseline forecast has been designed for the purpose of this paper and does not fully correspond to the actual assessment of the SNB. In particular, the baseline forecast is intentionally made somewhat more expansionary and inflationary than the official SNB forecast of August 2000.

inflation at longer forecasting horizons. Although the SNB does not pursue a policy of explicit inflation targeting, it is assumed in this paper that the baseline forecast is considered too inflationary and that monetary policy is tightened such as to bring CPI inflation down to a target value of 1.7% in 2004 (instead of 2.2% as in the baseline forecast).

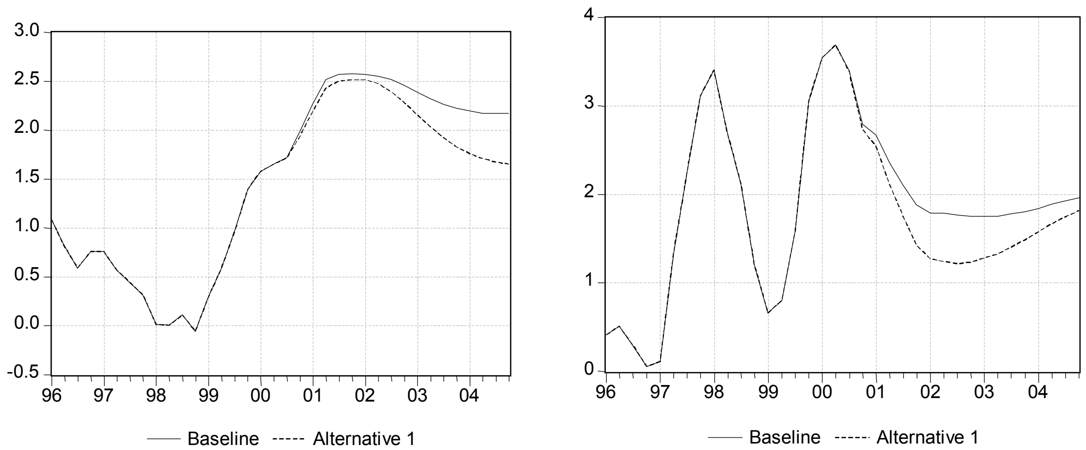
According to the model, this target can be attained by raising three-month Libor from 3.5% to 4.5% at the start of the simulation period (2000 Q3). Of course, other paths of three-month Libor that would produce the same inflation outcome in 2004 are conceivable as well. However, as GDP growth is stronger now than later in the forecast period, an immediate tightening of monetary policy seems preferable with regard to a smooth development of aggregate output.

The forecast with higher short-term interest rates (three-month Libor = 4.5%), referred to as Alternative 1, is documented in Table 2a. Table 2b shows the effects of monetary tightening in the form of differences between Alternative 1 (Table 2a) and the baseline forecast (Table 1). The effects are expressed as differences in growth rates except for the long-term interest rate and the unemployment rate where differences in levels are displayed. Figures 1 and 2 show the dynamic responses of some important endogenous variables of the model on a quarterly basis. Figure 1 compares the two scenarios with respect to CPI inflation and GDP growth in the form of percentage rates of change over the same quarter in the previous year. Figure 2 shows the deviations of Alternative 1 from the baseline path as level effects for interest rates and the unemployment rate and as differences in annualised quarterly growth rates for all other variables.

Figure 1

Effects of tighter monetary policy (baseline and Alternative 1)

(a) CPI inflation (b) GDP growth

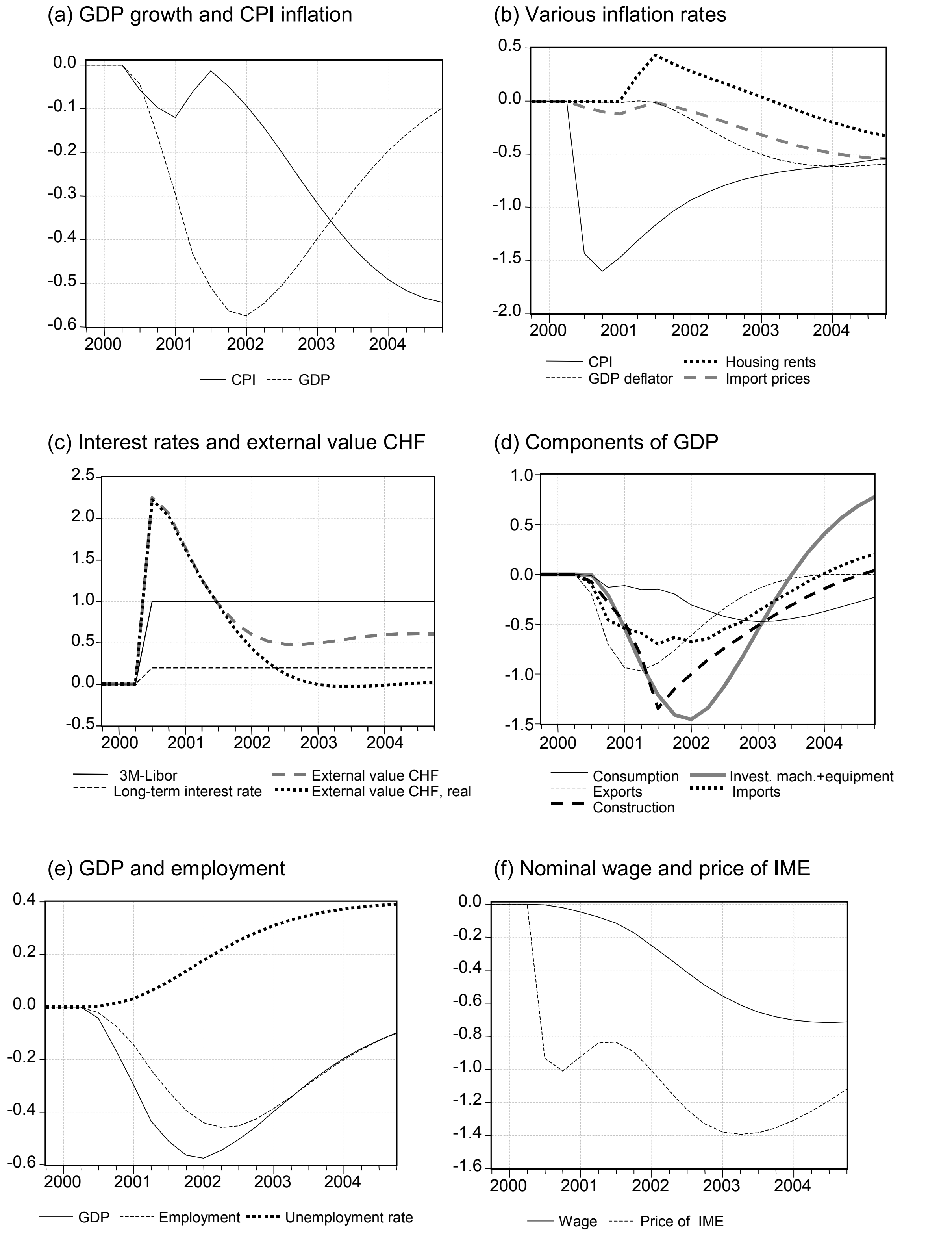


The mechanisms in the model by which monetary tightening dampens CPI-inflation can be assigned to an exchange rate channel and an aggregate demand channel. A temporary countereffect originates from the response of housing rents to higher interest rates. The rise in three-month Libor entails a quick appreciation of the Swiss franc (Figure 2c). This has a dampening impact on CPI inflation via declining import prices (Figure 2b) and reduces aggregate demand via lower export growth. Second, there is a partial pass-through of short-term to long-term interest rates, and this reduces aggregate demand via investment and private consumption (Figure 2d). Both initial effects set in motion a multiplier-accelerator process, by which all income-dependent components of aggregate demand are further reduced. Of course, import growth also declines, which partly offsets the negative impact of lower aggregate demand on GDP. GDP growth falls by a maximum of about 0.6 percentage points six quarters after the rise in three-month Libor. The response of export growth is relatively quick with a maximum loss of about 1 percentage point. The reaction of construction and investment in machinery and equipment is stronger but somewhat delayed. In the case of investment in machinery and equipment, there is a positive response later in the simulation period. This is caused by the dampening effect of the appreciation on (imported) investment goods. As shown in Figure 2f, the price of investment goods (machinery and equipment) falls markedly in relation to wage costs, changing the factor price ratio in favour of capital. The response of private consumption turns out to be relatively weak and slow.

Figure 2

Effects of tighter monetary policy

Alternative 1, deviations from baseline growth rates or levels (interest rates and unemployment rate)



CPI inflation is reduced in two waves (Figures 2a and b). There is a quick downward move already in the first few quarters of the forecast period. This is mainly brought about by the exchange rate channel. In the second year of the simulation, there is a sizeable countereffect coming from increasing housing rents. Due to this mechanism, the inflation dampening record of tighter monetary policy looks quite disappointing one year after action has been taken. CPI inflation is almost back to the baseline path whereas there is a considerable loss in GDP growth of about 0.6 percentage points. Thereafter, however, the dampening effects of lower aggregate demand and higher unemployment (Figure 2e) begin to work, reducing CPI inflation by slightly more than ½ percentage point by the end of the forecast period, while GDP growth rates tend back to the baseline values.

5. The role of productivity growth

5.1 The effects of higher productivity growth (Alternative 2)

Productivity growth is captured in the supply block of the model by the rate of labour-augmenting technical progress on new equipment, θ (see Section 2.1). The historical estimate of θ is 0.003 or 1.2% on an annual basis. The forecasts described in the preceding sections are based on this estimate. Motivated by the outstanding recent development of the US economy (high growth and low unemployment without much indication of rising inflation), many observers have argued that the fast diffusion of new technologies has given rise to productivity growth which is much faster than that suggested by historical estimates. In this paper, we do not try to make an assessment as to the relevance and magnitude of such a "new economy" effect.[9] The purpose of the following simulation is merely to show the sensitivity of the inflation forecast with respect to alternative assumptions about productivity growth.

In the baseline forecast, on the assumption of a continuing historical productivity trend and an unchanged three-month Libor of 3.5%, the CPI inflation rate is 2.2% in 2004. In Section 4, it was shown that a 1 percentage point increase in three-month Libor to 4.5% is required to bring inflation down to 1.7% in 2004. In the following scenario, the technical progress parameter θ is raised to such an extent that the inflation target of 1.7% is attained without any monetary tightening (three-month Libor = 3.5%). According to the model, θ has to be raised from 0.003 to 0.0045, lifting the annual rate of labour-augmenting technical progress from 1.2% to 1.8%. This scenario, denoted as Alternative 2, is documented in Table 3a (Appendix). Table 3b shows the effects of higher productivity growth in the form of deviations of Alternative 2 from the baseline forecast.

The implications of faster technical progress in the adopted vintage framework have already been discussed from a theoretical perspective in Section 2.1.6. The initial effect of a higher θ is a stronger increase in capital productivity and labour productivity on new equipment and a decline in the output price in relation to factor prices. What happens in the sequel is the result of an interaction of various responses in the labour market, on the demand side of the goods market and in the foreign exchange market. The extent to which the higher growth potential of the economy is actually absorbed by a stronger increase of aggregate demand is decisive for the outcome. The larger the stimulation of aggregate demand by lower output prices, the smaller the inflation dampening effect of higher productivity growth becomes.

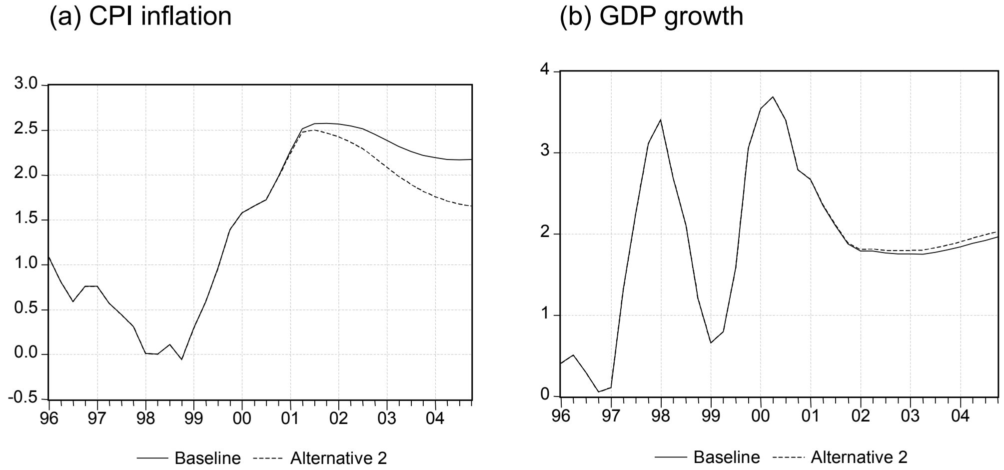
As shown in Figures 3 and 4a, higher productivity growth has a sizeable negative effect on the inflation rate of about ½ percentage point towards the end of the forecast period while GDP growth is stimulated only weakly. Accordingly, employment growth decreases in relation to the baseline path and unemployment rises (Figure 4c). In wage formation, we thus have two opposing forces, namely a stimulating effect of stronger productivity growth and a dampening effect of higher unemployment. The productivity effect dominates. To be sure, the growth rate of nominal wages declines, but by less than both CPI inflation and inflation measured by the GDP deflator (Figure 4d). Hence, real wage growth is

9 A rather sceptical view is advocated for instance by Gordon (2000).

higher than in the baseline forecast. The price of investment goods (machinery and equipment, largely imported) is dampened strongly. This is due to the functioning of the monetary block, where lower inflation reduces the real external value of the Swiss franc but leads to a nominal appreciation in the longer run (Figure 4e).

Figure 3

Effects of higher productivity growth (baseline and Alternative 2)



The decline of investment prices in relation to wages induces a change in the factor price ratio in favour of capital. The resulting process of capital deepening raises the growth rate of labour productivity above the initial effect of higher technical progress (Figure 4b). The initial effect is 0.42 percentage points, corresponding to the increase in θ of 0.6 percentage points (annualised) times $\alpha = 0.7$ (output elasticity with respect to labour). Together with the effect of capital deepening, the growth rate of labour productivity on new equipment is raised by the end of the forecast period by somewhat more than 0.7 percentage points. The effect on technical labour productivity on the whole production apparatus is of course smaller because the higher rate of technical progress is exclusively embodied in new equipment and thus materialises only to the extent that old equipment is replaced by new equipment. In fact, due to the faster increase of relative wage costs, replacement speeds up, but the share of new equipment in the whole production apparatus nevertheless remains small within a time horizon of four years. The growth rate of overall technical labour productivity is raised by about 0.2 percentage points by the end of the simulation period. The effect on measured labour productivity is even somewhat smaller (0.16 percentage points) since employment is reduced by slightly less than what would be technically feasible. The 0.16 percentage point productivity gain is split in roughly equal parts between higher GDP growth and lower employment growth (Figure 4c).

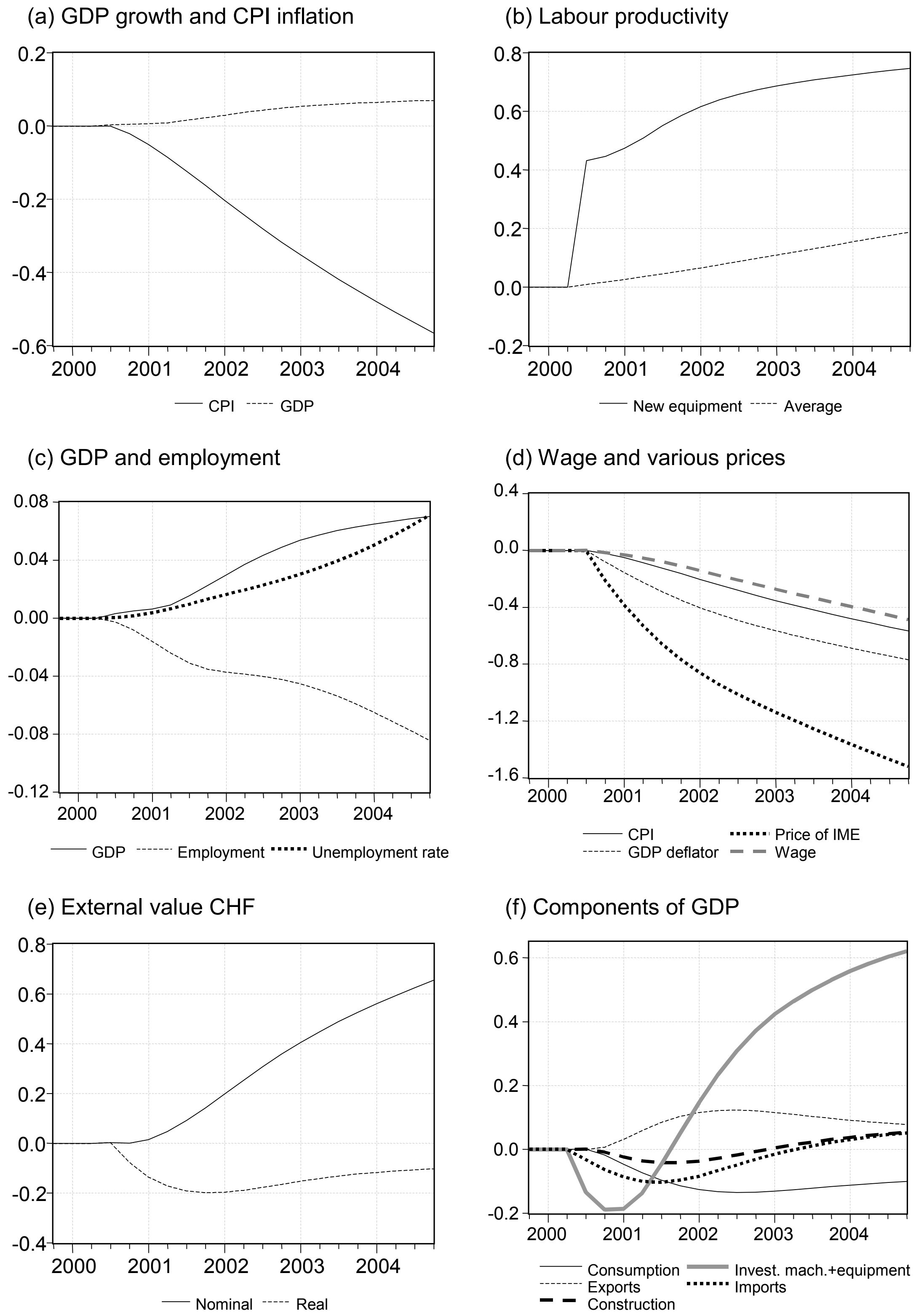
The reactions of the various components of GDP are shown in Figure 4f. Investment in machinery and equipment is first negatively affected by the stronger growth of capital productivity (less investment is needed for a given expansion of production capacity). In the second year of the simulation, the response turns positive as GDP growth increases and the factor price ratio shifts in favour of capital. At the end of the forecast period, the growth rate of investment in machinery and equipment exceeds the baseline values by 0.6 percentage points. Private consumption shows a delayed and weak but long-lasting negative response. The increase in the real consumer wage is smaller than the decrease in employment, so that real household income is negatively affected. In addition, there is a negative impact of higher unemployment on consumption. Construction investment remains practically unaffected. Lower Swiss inflation improves international competitiveness and thus stimulates export growth. However, this effect weakens in the course of the forecast period as the Swiss franc appreciates (Figure 4e). The reaction of import growth is negative in the first half of the simulation period but becomes positive in the second half. This reflects the changes in the various components of aggregate demand on the one hand and improved competitiveness of domestic producers on the other.

To summarise, one can say that the assumption of a higher rate of technical progress dampens future inflation significantly while it stimulates GDP growth only weakly. The two results are connected to each other. The fact that the higher growth potential of the economy is only partly matched by higher growth of actual GDP reinforces the price dampening effect of stronger productivity growth through increased slack in the goods and labour market. The stronger growth of capital productivity temporarily reduces investment in machinery and equipment, and the stronger increase of labour productivity has a long-lasting negative effect on employment.

Figure 4

Effects of higher productivity growth

Alternative 2, deviations from baseline growth rates or levels (interest rates and unemployment rate)



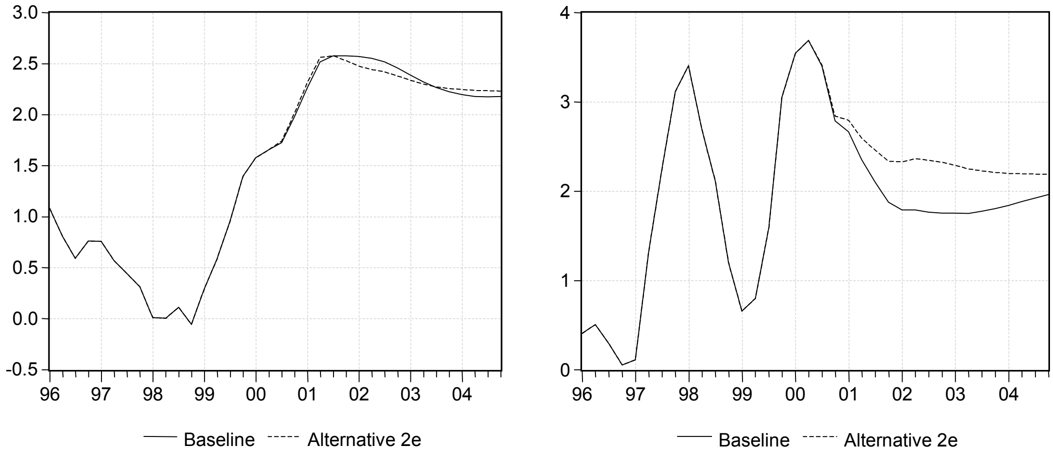
Of course, the split of the productivity effect on lower inflation and higher GDP growth can be influenced by monetary policy. For instance, by cutting three-month Libor from 3.5% to 2.5%, monetary policy would stimulate aggregate demand and thus give more room for actual output to increase. On this assumption, as shown in Figure 5 (to be compared with Figure 3), one obtains an inflation forecast that practically coincides with the baseline forecast whereas GDP growth is notably higher. In other words, given a certain inflation target, the appropriate level of short-term interest rates is lower the more productivity rises. The recent development in the United States can be taken as an illustration of this relationship. Counting on faster technical progress, the Federal Reserve has tightened monetary conditions only gradually although the US economy was expanding for several years at a pace that would have had to be judged as highly inflationary on the basis of historical estimates of productivity growth.

Figure 5

Effects of higher productivity growth

Baseline and Alternative 2e (monetary policy relaxed: three-month Libor = 2.5%)

(a) CPI inflation (b) GDP growth



In other respects, the recent US experience shows that the above simulation exercise captures potential “new economy” effects only in a very limited sense. In particular, in the US economy higher productivity growth was not accompanied by a decline in investment activity and employment. To some extent, this may be due to a lucky coincidence with other factors that *independently* stimulated the economy from the demand side. However, it is probably more appropriate to think of the “new economy” as a phenomenon that simultaneously boosts productivity *and* spurs aggregate demand through the creation of new market opportunities. A related point is made by Gordon (2000). He finds that the productivity effect of the “new economy” is confined to durables manufacturing. The other sectors of the economy invest in new technologies as well, but without much impact on productivity. For instance, firms may be forced by competition to engage in internet activities, to maintain websites and to offer e-commerce services. In many cases, such investments are only duplicating traditional sales promotion activities rather than replacing them by something more productive.

Obviously, such direct demand effects are not taken into account in the scenario of Alternative 2. To be sure, higher productivity growth influences aggregate demand, but only through the adjustment of relative prices like an increase in the real wage, a relative decline in capital costs and a fall in the real exchange rate. Eventually, these adjustments bring about an increase in aggregate demand. The process is slow, however, and is moreover delayed by the initial decline in investment and employment. Against this background, labelling Alternative 2 as a “new economy” scenario would seem rather problematic.

5.2 Implications for monetary policy (Alternative 3)

In this section, we want to illustrate how monetary policy may be led astray by incorrect assessments of future productivity growth. In order to establish a clear basis of comparison, monetary authorities are again assumed to aim at an inflation target of 1.7% in 2004. Accordingly, Alternative 1 (historical productivity growth, three-month Libor = 4.5%) portrays an appropriate stance of monetary policy. This is also the case for Alternative 2 (higher productivity growth, three-month Libor = 3.5%). In both scenarios, three-month Libor is set on the basis of correct assumptions with respect to productivity growth and the inflation target is therefore attained (Figure 6a). Of course, as shown in Figure 6b, GDP growth is higher in Alternative 2 since the reduction in the inflation rate is brought about by stronger productivity growth instead of monetary tightening. In contrast, two other scenarios are conceivable in which monetary authorities either underestimate or overestimate future productivity growth:

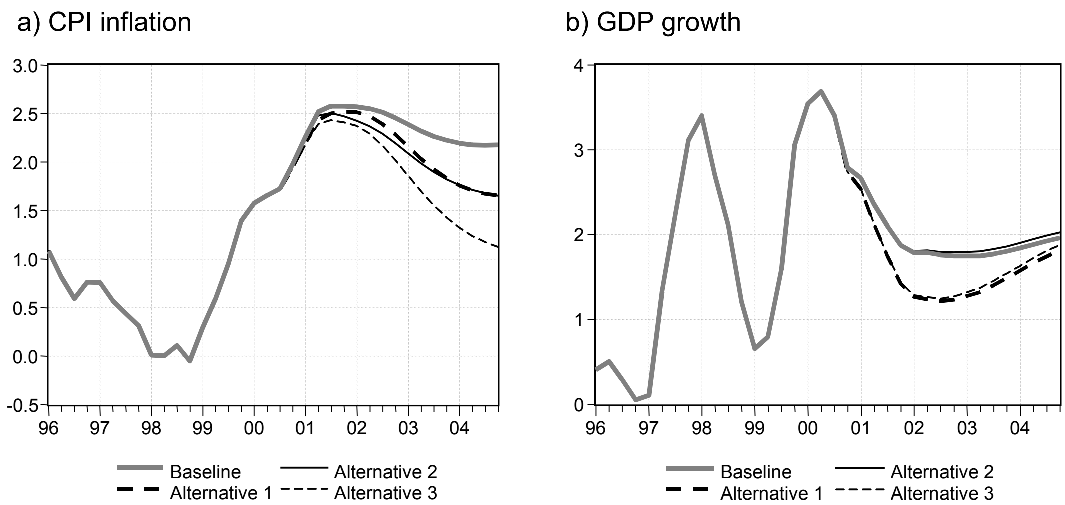
- The inflation forecast is based on the assumption of an unchanged productivity trend (θ = 1.2%) and three-month Libor is therefore raised to 4.5%. In fact, however, productivity growth accelerates (θ = 1.8%). In this scenario, referred to as Alternative 3 (Table 4, Appendix), monetary policy turns out to be too restrictive. The inflation rate falls to 1.2% (0.5 percentage points below the target), at the cost of an unnecessary depression of GDP growth as compared to Alternative 2, where the acceleration of productivity growth is correctly anticipated and three-month Libor is therefore left unchanged at 3.5% (Figure 6). The cumulative loss in GDP growth associated with the excessive tightness of monetary policy is 1.5 percentage points.
- Monetary authorities may expect an increase in productivity growth but in fact productivity proceeds on the historical trend. Simulating such a scenario is not really necessary since the baseline forecast (Table 1) can be interpreted this way. It combines unchanged productivity growth (θ = 1.2%) with a three-month Libor of 3.5%, which would be appropriate with regard to the inflation target in case of increased productivity growth (θ = 1.8%). However, as productivity growth actually remains unchanged, monetary policy turns out to be too lax. The inflation rate in 2004 is 2.2% (0.5 percentage points above the target), as shown in Figure 6.

In this latter case, there is a cumulative gain in GDP growth of 1.7 percentage points as compared to Alternative 1, where the three-month Libor is raised to 4.5%. However, one should refrain from weighing this GDP gain against the deviation from the inflation target because, by doing so, one would call the target itself into question. Moreover, as can be seen from Figure 6, the loss in GDP growth associated with monetary tightening in Alternative 1 is largely temporary, whereas not tightening in case of unchanged productivity growth has inflationary consequences of a longer-term nature.

Figure 6

Baseline (three-month Libor = 3.5%), Alternative 1 (three-month Libor = 4.5%)

Alternative 2 (higher productivity growth, three-month Libor = 3.5%)
Alternative 3 (higher productivity growth, three-month Libor = 4.5%)



6. The role of the "mortgage rate-housing rent" link

As already noted in Section 4, monetary tightening reduces inflation via the exchange rate channel and the aggregate demand channel, but there is a sizeable temporary countereffect resulting from the dependence of housing rents on mortgage rates. In this section, we want to quantify the importance of this countereffect by means of a model simulation in which housing rents are alternatively linked to the overall CPI.

6.1 The effects of linking housing rents to CPI (Alternative 4)

The equation for housing rents in the model does not explicitly include the mortgage rate as an argument but takes the long-term interest rate as a proxy. Using the mortgage rate would require an additional equation in the model, linking mortgage rates with a certain lag to market interest rates. However, a simple error correction equation for housing rents (*phr*) with a three-quarter lag on the long-term interest rate (*lrate*) and construction prices (*picnstr*) actually works better than the alternative approach. The equation reads as

$$\Delta \log(phr_t) = b_0 + b_1 \Delta lrate_{t-3} + b_2 \Delta \log(picnstr_{t-3}) - \gamma\left[\log(phr_{t-1}) - \beta_1 lrate_{t-4} - \beta_2 picnstr_{t-4}\right] \quad (21a)$$

Estimation of (21a) shows that the pass-through of interest rates to housing rents is significant. However, as an analysis of parameter stability reveals, the pass-through has become somewhat weaker over time (decreasing values of b_1 and β_1). Taking this into account, the equation used in the above simulations implies that a 1 percentage point increase in long-term interest rates pushes housing rents up by about 4.5% (β_1), although with a substantial degree of inertia (γ = 0.15). This is less than what would be allowed according to Swiss legislation on tenant protection, permitting a 3% rise of housing rents per ¼ percentage point rise in mortgage rates. A plausible explanation of the reduced impact is that an increasing share of apartments are nowadays rented at market prices and no longer at cost-determined rents below market prices. Nevertheless, the impact of interest rates on housing rents is still strong enough to hamper the efficacy of monetary policy to a considerable degree.

In the following simulation, (21a) is replaced by an alternative "rule" that links housing rents (*phr*) to the overall CPI (*pci*). Proposals for such a change in the legislation are currently being discussed in the Swiss parliament. From an economic point of view, linking housing rents to the CPI is rather problematical since it amounts to fixing the relative price of a sector that probably differs from the rest of the economy with respect to the development of production costs and demand. In fact, in the period 1980-99 housing rents increased more than the CPI, on average by 0.23 percentage points per quarter. Accordingly, when a CPI rule for housing rents is fitted to the data, one needs to include a constant term, which assumes a significant positive value of 0.0023:

$$\Delta \log(phr) = 0.0023 + \Delta \log(pci) \quad (21b)$$

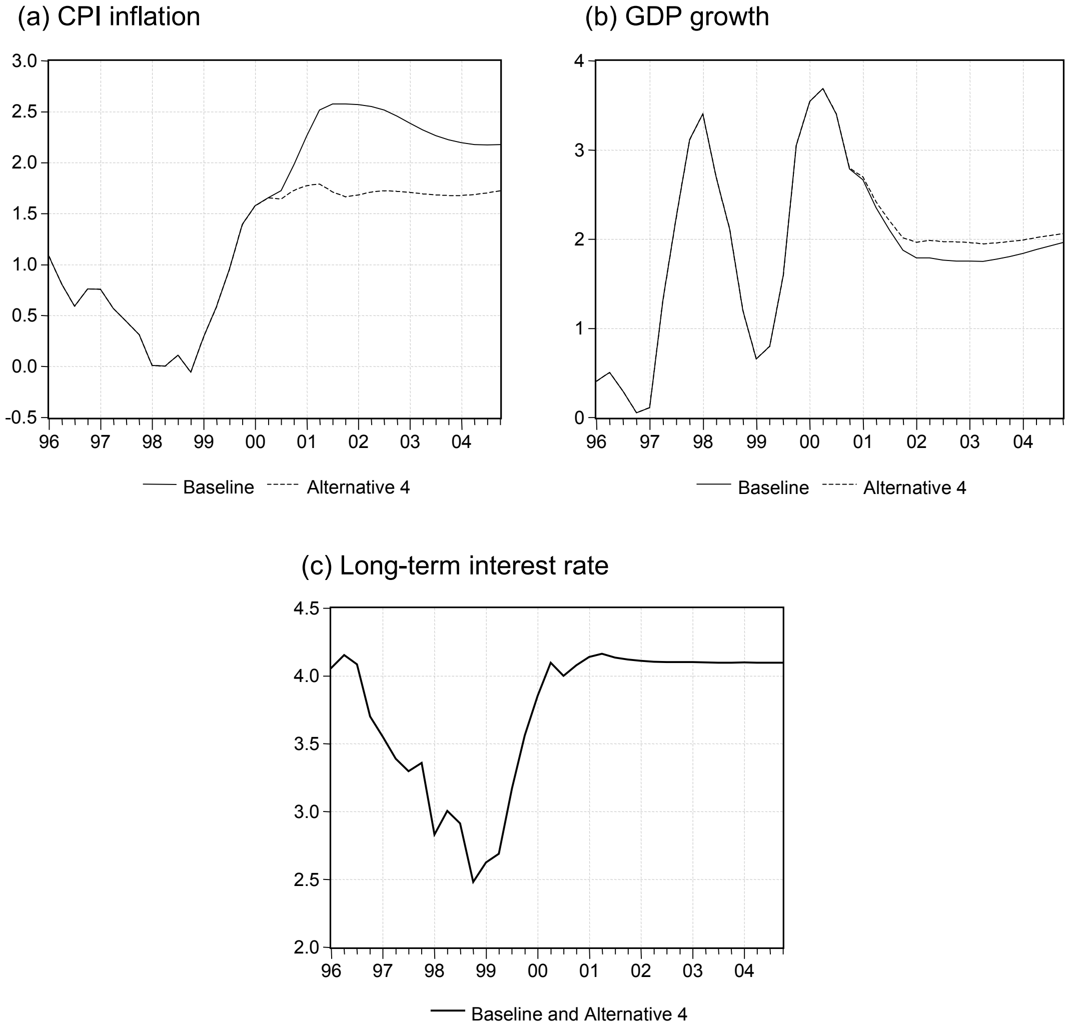
Longer-run simulations without such a constant term would entail a continuous decline of housing investment. This outcome is due to the fact that the equation for housing investment involves a measure of profitability, and this measure deteriorates if *phr* is prevented from increasing in relation to *pci*. In the following simulation, the interest rate rule for housing rents, (21a), is therefore replaced by a CPI rule in the form of (21b). The constant term in (21b) ensures that the long-term development of housing rents is the same on average as for (21a). In periods of increasing interest rates, (21b) will, however, produce smaller increases in housing rents than (21a).

This forecast scenario, referred to as Alternative 4, is presented in Table 5a. Table 5b displays the differences in comparison to the baseline forecast, where everything is identical except that housing rents are determined by (21a). Figures 7 and 8 show the extent to which the forecasts for important endogenous variables of the model are affected by the change in the housing rent equation. Figure 7 compares the two scenarios with respect to CPI inflation and GDP growth. Figure 8 shows the deviations of Alternative 4 from the baseline path as level effects for interest rates, the output gap and the unemployment rate, and as differences in annualised quarterly growth rates for all other variables of the model.

Figure 7

Effects of linking housing rents to CPI

(baseline and Alternative 4)



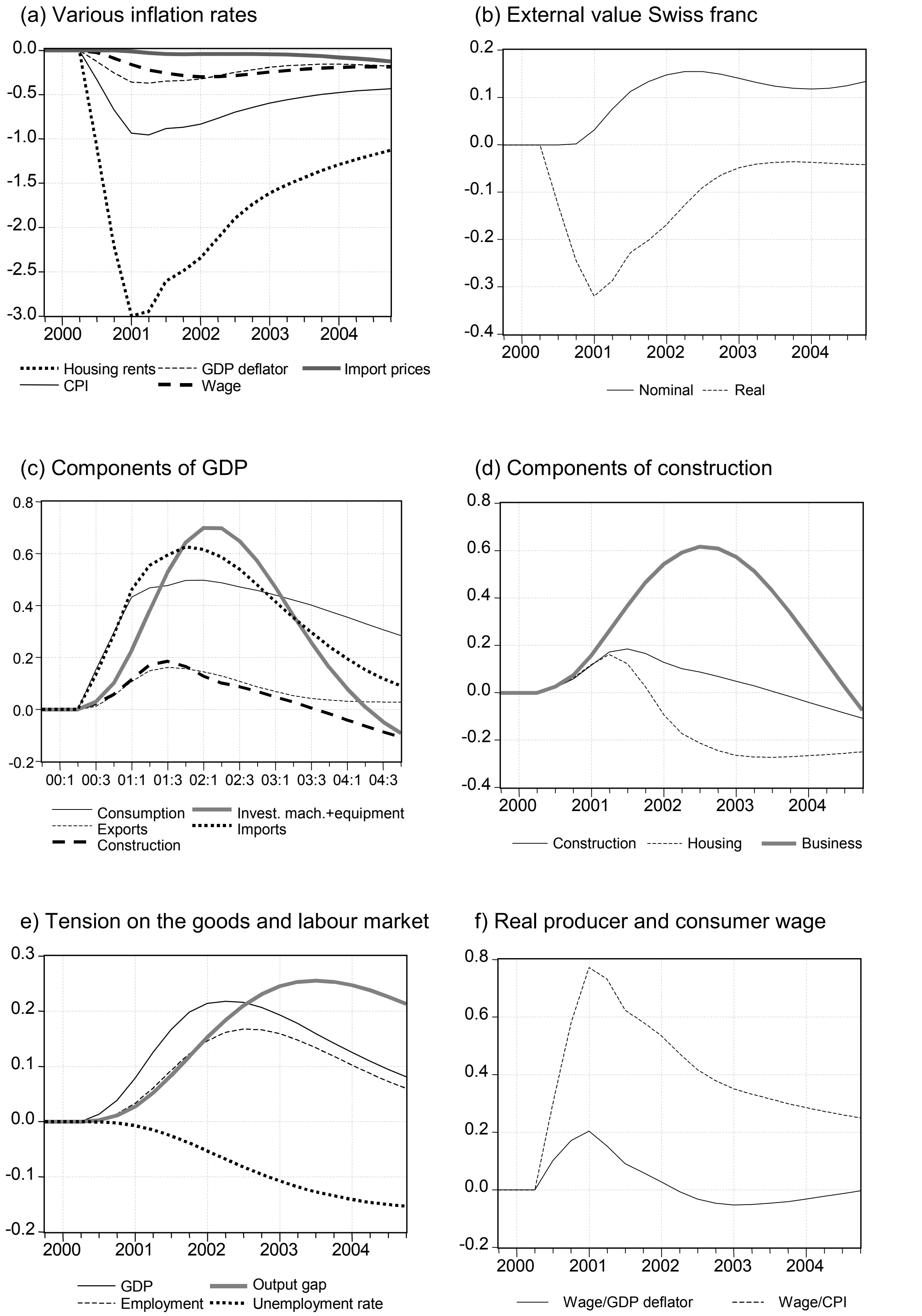
Suppressing the impact of interest rates on housing rents by linking them to the CPI has a considerable effect on the inflation forecast. Whereas CPI inflation is temporarily pushed as high as 2.5% in the baseline forecast, it hovers close to 1.7% throughout the forecast period in Alternative 4 (Figures 7a and c). At the same time, there is a small positive effect on GDP growth (Figure 7b). In terms of differences in annualised quarterly growth rates, housing rent inflation is reduced by a maximum of 3 percentage points in 2001 Q1 (Figure 8a). This is reflected in a reduction of overall CPI inflation of almost 1 percentage point. Due to second-round effects, the reaction of CPI inflation exceeds the direct impact of housing rents to some extent. Inflation measured by the GDP deflator is dampened by about 0.4 percentage points. Nominal wage growth is also reduced, but by less than CPI inflation, so that real wages, in particular real consumer wages, are positively affected by the CPI rule (Figure 8f).

The second-round effects on inflation have to be seen in the context of the wage equation of the model that links wages to a weighted average of the CPI and the GDP deflator, and the "wedge" driven between the CPI and the GDP deflator by increasing housing rents. This wedge, reflecting the income claims of house owners, is reduced in Alternative 4 as compared to the baseline forecast. Hence, the inflationary pressure resulting from conflicting income claims becomes smaller, and this lets the economy move towards a new equilibrium with lower unemployment, increased capacity utilisation and higher income shares of workers and firms. For a more detailed explanation of these mechanisms on the basis of a stylised version of the model's wage-price dynamics, see the Box on page 249.

Figure 8

Effects of linking housing rents to CPI

Alternative 2, deviations from baseline growth rates or levels (interest rates and unemployment rate)



Lower inflation raises real disposable household incomes, although non-wage incomes are depressed somewhat by the smaller increase in housing rents. As a result, the growth rate of private consumption shows a positive reaction (Figure 8c). Lower inflation also leads to a real depreciation of the Swiss franc (always in relation to the baseline forecast), which stimulates export growth. This effect is, however, mitigated in the course of the forecast period by a nominal appreciation (Figure 8b). The higher growth of consumption and exports sets in motion a multiplier-accelerator process by which employment, capacity utilisation, investment in machinery and equipment and construction investment are all positively affected (Figure 8c). The stronger growth of aggregate demand is, however, partly absorbed by higher imports, so that the GDP effect turns out to be rather small. Nevertheless, the output gap narrows (higher capacity utilisation) and unemployment decreases (Figure 8e). Towards the end of the forecast period, the growth rate of construction shows a negative reaction. This is due to the fact that the smaller increase of housing rents depresses the profitability of housing investment. Accordingly, as can be seen from Figure 8d, the growth rate of housing investment is negatively affected, whereas business construction shows a positive response, in close connection to the behaviour of investment in machinery and equipment.

Box: The role of housing rents in a stylised version of the wage-price block[1]

Wages *w* react to a weighted average of the GDP deflator *p* and consumer prices *pci* and in addition depend on labour market tension (π_L):

$w = w(p, pci, \pi_L)$ (This equation represents the income claims of workers.)

The GDP deflator (to be viewed as the aggregate price of domestic production) depends in a flexible mark-up equation on wages *w* and tension in the goods market (π_G):

$p = p(w, \pi_G)$ (This equation represents the income claims of firms.)

Consumer prices depend on the GDP deflator *p*, housing rents *phr* and import prices *pimp*:

$pci = pci(p, phr, pimp)$

Now, a rise in *phr* entails an increase of *pci* in relation to *p* and - since *w* partly depends on *pci* - also an increase of *w* in relation to *p* (for given labour market tension). Thus, a rise in *phr* produces a lower real consumer wage *w/pci* (since *w* is only partly adjusted to *pci*) but a higher real producer wage *w/p* (since *w* is partly adjusted to *pci*). However, the higher real producer wage *w/p* is in conflict with the *p*-equation, which - for given tension in the goods market - implies a fixed mark-up of *p* over *w*. In other words, for given market tension, the income claims of workers and firms become incompatible as a result of the higher income claims of house owners, exceeding what is actually available for distribution. This conflict sets in motion an inflationary process, which must continue to the point where reduced market tension re-establishes compatibility of the income claims. In the *w*-equation, a lower value of π_L (higher unemployment) dampens *w* in relation to *p*. In the *p*-equation, a lower value of π_G (lower capacity utilisation) reduces the mark-up of *p* over *w*.

A conceivable new equilibrium (taking the increase in *phr* as exogenous) has π_G and thus the mark-up of *p* over *w* back to the starting point, whereas π_L and *w/pci* are lower. So firms are eventually unaffected by the higher *phr*, while workers carry the full burden in the form of a reduced real consumer wage. This is brought about in the *w*-equation by lower π_L (higher unemployment), which completely counteracts the response of *w* to the higher *pci* (weaker bargaining position of workers). Of course, alternative equilibrium positions in which firms also carry part of the burden in the form of a lower π_G and thus a lower mark-up of *p* over *w* are conceivable as well. But what happens in the model is closer to the first solution for the following reason. Investment and thus production capacity react fairly quickly to reduced capacity utilisation so that π_G has a rather strong tendency to return to the initial equilibrium. In contrast, the supply side of the labour market is much more rigid. Accordingly, compatibility of the income claims is re-established primarily through higher unemployment and a lower real consumer wage *w/pci* - and not through reduced capacity utilisation and a higher real producer wage *w/p* (smaller mark-up of *p* over *w*).

Exactly the same “wedge” mechanism comes into play if import prices (*pimp*) increase. In both cases, the inflationary pressure and the increase in unemployment depend crucially on the weights of *p* and *pci* in the *w*-equation. If *w* depended only on *p*, then workers would “voluntarily” accept a lower real consumer wage *w/pci*. In this case, an increase in *phr* or *pimp* would not set in motion an inflationary spiral of wages and prices. The stronger the impact of *pci* in the *w*-equation, the more workers have to be forced to accept a lower real consumer wage *w/pci* by higher unemployment. Until this point is reached, the incompatibility of income claims gives rise to an inflationary process with wages pushing up prices and prices pushing up wages.

[1] The specification is in the spirit of Layard et al (1991); see also Section 2.1.

6.2 Implications for monetary policy

In the simulations of Section 5, it was shown that the inflation forecast depends quite strongly on alternative assumptions as to future productivity growth, even if these assumptions remain within the bounds of possibility. This was an illustration of one of the various types of uncertainty surrounding monetary policy (parameter uncertainty, model uncertainty, uncertainty with respect to the exogenous variables in the forecast period, future shocks). The simulation in this section with a changed equation for housing rents is different in character. The current legislation on rent control is known and a potential new rule would be introduced only after a lengthy political process. The simulation is therefore rather to be viewed as a counterfactual experiment, shedding light on the question of whether the current legislation should be changed.

Due to the constant term in the CPI rule (21b), the development of housing rents is the same on average as for the interest rate rule (21a) in a long-term simulation. In the concrete forecasting situation under consideration, however, using the CPI rule instead of the interest rate rule makes quite some difference because it prevents higher interest rates from being passed on to housing rents. Supposing again an inflation target of 1.7% for the year 2004, the forecast of Alternative 4 implies that monetary policy may remain unchanged (three-month Libor = 3.5%) since the inflation target is just met.[10] In contrast, the baseline forecast has inflation at 2.2% in 2004 and therefore signals that monetary conditions must be tightened, as in Alternative 1 (three-month Libor = 4.5%). In other words, it is the interest rate rule for housing rents that necessitates a move to a more restrictive stance of monetary policy - and at the same time hampers the effectiveness of monetary tightening in reducing inflation.

Considering the entire forecasting horizon and also taking GDP growth into account, the advantage of the CPI rule becomes even more evident (Figure 9). Alternative 1 (interest rate rule, three-month Libor = 4.5%) and Alternative 4 (CPI rule, three-month Libor = 3.5%) both produce an inflation rate of 1.7% in 2004. However, whereas the inflation dampening effect of tighter monetary policy is subject to a long lag, the replacement of the interest rate rule by the CPI rule reduces inflation to 1.7% right from the beginning of the forecast period. Moreover, there is a sizeable real side effect of monetary tightening that reduces GDP growth temporarily to 1.2%, while GDP growth remains at about 2% throughout the forecast period in the scenario with the CPI rule.

The beneficial impact of a switch to the CPI rule should, however, be interpreted with care. In particular, it must be recognised that it is not a general result but applies to the concrete forecasting situation with rising interest rates. To be sure, interest rates do not rise much *during* the forecast period, but they rise by 1.5 percentage points in the seven quarters *preceding* the forecast period. This increase, given the delay in the adjustment of housing rents to interest rates, is thus in the pipeline under the interest rate rule. The switch to the CPI rule then simply blocks up this pipeline at a time when it matters a great deal. Hence, the strong inflation dampening effect of the switch to the CPI rule is conditional on the concrete forecasting situation.

A way to assess the difference between the two rules for housing rents from a more general perspective is to analyse the monetary transmission mechanism under the two regimes. This requires a further simulation in which three-month Libor is raised to 4.5% under the CPI rule as well - as was done under the interest rate rule in Alternative 1. This forecast, referred to as Alternative 5, is documented in Table 6a and compared to Alternative 4 (three-month Libor = 3.5%) in Table 6b. Table 6b thus shows the effects of raising three-month Libor by 1 percentage point under the CPI rule. Table 2b, comparing Alternative 1 with the baseline forecast, does the same for the model with the interest rate rule. These effects are not conditional on the concrete forecasting situation since the past interest rate increases that are in the pipeline under the interest rate rule are cancelled out by the comparison of the scenarios. Thus, Tables 6b and 2b show only the effect of the *additional* increase in interest rates that takes place *within* the forecast period.

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[10] To be precise, one should mention that the constant term in (21b) has been set to a slightly larger value of 0.00247 in order to obtain this result. With the estimated value of 0.0023, inflation would even fall somewhat below 1.7% in 2004.

Figure 9

Housing rents linked to CPI (Alternative 4) versus tighter monetary policy under the “mortgage rate-housing rent” link (Alternative 1)

(a) CPI inflation (b) GDP growth

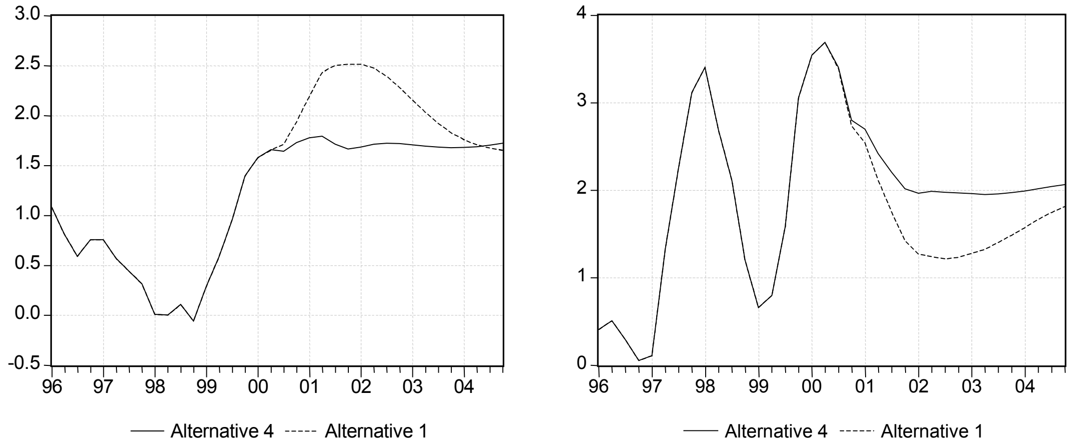
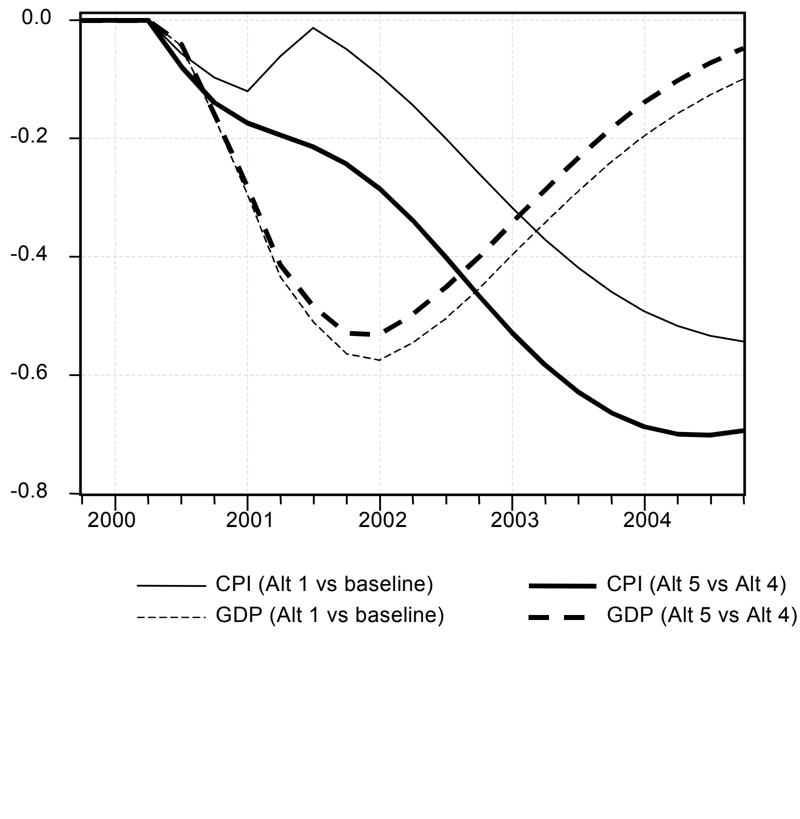


Figure 10 shows the effects of monetary tightening on inflation and GDP growth under the two regimes. The thin (bold) lines refer to the model with the interest rate rule (CPI rule). The solid (dashed) lines show the reaction of CPI inflation (GDP growth rates). The CPI rule makes the monetary transmission mechanism more efficient in two respects. First, while the interest rate rule pushes CPI inflation almost back to the baseline path by the fifth quarter of the simulation, monetary tightening under the CPI rule entails a smoother and overall stronger reduction in CPI inflation. At the end of the forecasting horizon, the reduction is 0.54 percentage points in case of the interest rate rule and 0.69 percentage points in case of the CPI rule. Second, the negative side effect of monetary tightening on GDP growth is somewhat less pronounced under the CPI rule.

Figure 10

Effects of tighter monetary policy (three-month Libor raised from 3.5% to 4.5%)

Housing rents linked to interest rates:	Alternative 1 vs baseline
Housing rents linked to CPI:	Alternative 5 vs alternative 4



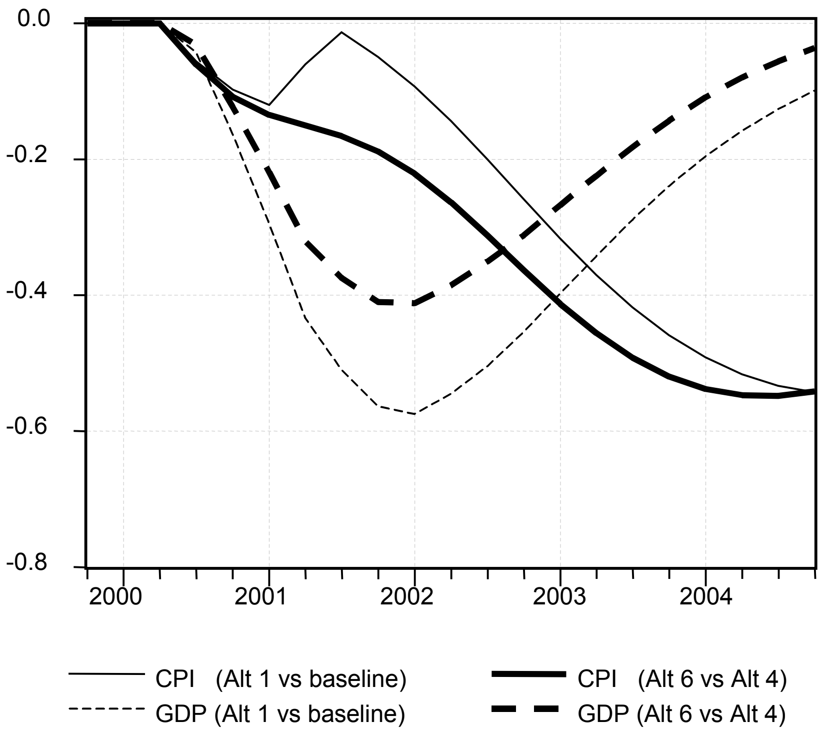
A more detailed account of the differences between the two regimes is given by a comparison of Table 6b with Table 2b. Monetary tightening reduces the growth rate of private consumption to a lesser extent under the CPI rule. The mirror image is a somewhat stronger negative effect on housing investment. The more favourable development of private consumption under the CPI rule is partly absorbed by higher import growth. Moreover, lower inflation initially results in a somewhat smaller real appreciation of the Swiss franc. This is, however, compensated later in the forecast period by a stronger nominal appreciation. The growth rate of exports thus differs only very little between the two regimes. Taken together, the reactions of the various demand components amount to a somewhat smaller reduction of overall GDP growth under the CPI rule.

Of course, one should not expect big differences in overall GDP growth between the two regimes in the first place. The only way for monetary policy to bring down inflation is through a depressing impact on the real economy. What differs to some extent between the two regimes is the distribution of the effects on the different sectors of the economy. However, the main difference between the two regimes pertains to inflation. Given a certain degree of monetary tightening (three-month Libor = 4.5% instead of 3.5%), the inflation dampening effect is more pronounced under the CPI rule. Of course, turning the argument around, one may also say that, for a certain reduction in the inflation rate, a less resolute monetary tightening is required under the CPI rule. This point can be made more concrete by solving the model for the three-month Libor that produces the same inflation dampening effect as the increase in the three-month Libor from 3.5% to 4.5% under the interest rate rule. It turns out that three-month Libor must be raised to 4.27% only, and this is associated with a smaller adverse GDP effect. As shown in Figure 11, the maximum loss in GDP growth is only about 0.4 percentage points instead of nearly 0.6 percentage points in case of the interest rate rule.

Figure 11

Effects of tighter monetary policy

Housing rents linked to interest rates: Alternative 1 (three-month Libor = 4.5%) vs baseline
Housing rents linked to CPI: Alternative 6 (three-month Libor = 4.27%) vs Alternative 4



Overall, the simulations of this section show that the link of housing rents to interest rates, as established by Swiss legislation on tenancy rights, hampers the efficacy of monetary policy in two dimensions. First, the inflation dampening effect of monetary tightening is reduced. Second, the adverse side effects on the real economy are larger. Under an alternative CPI rule, the same reduction in the inflation rate is attained with a less restrictive course of monetary policy and thus a smaller loss in real GDP. In other words, Swiss legislation on tenant protection forces monetary policy to become more restrictive if a certain reduction in the inflation rate is to be achieved, since the countereffect of increasing housing rents has to be compensated for.

7. Summary and conclusions

At the beginning of the year 2000, the Swiss National Bank (SNB) replaced its traditional monetary targeting approach by a concept that focuses on inflation forecasts. The key elements of this concept are: (i) an explicit definition of price stability (CPI inflation below 2%), (ii) regularly updated conditional inflation forecasts with a horizon of three years and (iii) the announcement of a target range for short-term interest rates (three-month Libor). For instance, an inflation forecast - obtained on the provisional assumption of an unchanged three-month Libor - exceeding 2% gives a signal for monetary tightening. The simulations presented in this paper have to be seen in the context of this adapted concept of monetary policy.

It is a commonplace to say that monetary policy, irrespective of the concrete concept, has always been a difficult area. One of the advantages of the modified concept is that it makes these difficulties more transparent and therefore offers a better chance to learn from past errors. From a methodological point of view, things are in fact quite simple: the appropriateness of monetary policy hinges directly on the reliability of the inflation forecast. If the stance of monetary policy in a certain period turns out to be inappropriate, the error can be traced back to an erroneous inflation forecast for that period, although the overlapping character of updated inflation forecasts and monetary reactions would complicate this task in practice.

Forecasting errors may arise for several reasons. First, the economy may be affected by shocks in the forecast period, as was the case in the past. However, while past shocks are captured by the stochastic error terms of the model, these error terms are set to zero in the forecast period since future shocks are - by definition - unpredictable. Second, the parameters of the model are estimated on the basis of a limited sample and are therefore subject to sampling error. Third, the forecast may be led astray by incorrect assumptions with respect to the exogenous variables of the model. It should be recognised that all these types of errors will occur even if the model gives an adequate description of the data generating process. However, assuming one can obtain such an ideal, correctly specified model is unwarranted, as documented by the simple fact that different researchers typically advocate different types of models. Hence, forecast errors of a fourth type must be expected in practice, arising from the uncertainty with respect to the adequate specification of the model.

Against this background, this paper presents two specific examples of structural/institutional changes that affect the inflation forecast and thus - if not taken into account properly in the forecasting model - would give wrong signals for monetary policy. The first simulation experiment deals with the impact of productivity growth on inflation. This experiment may be regarded as an example of model uncertainty. Can the historical estimate of technical progress be carried over to the forecast period, or is it more realistic to assume a faster rate of technical progress in the era of the "new economy", liberalised and globalised markets and tougher competition? If such considerations seem relevant, to what extent do they affect technical progress in the forecast period? The second simulation deals with a potential change in the Swiss legislation on tenancy rights, replacing the traditional link of housing rents to mortgage rates by an alternative link to the CPI. This simulation is somewhat different in character since it addresses the implications of an institutional change that, in principle, would be known to the monetary authorities some time in advance, although the practical working of the new rule might be less obvious.

These simulation experiments are carried out with a medium-size structural macromodel and are imbedded in a forecasting situation similar to the one faced by the SNB in August 2000. As in the actual monetary policy decision process, the first step is thus to compute a baseline forecast conditional on the assumption of an unchanged three-month Libor. The baseline forecast is intentionally made somewhat more inflationary than the actual SNB forecast of August 2000. The inflation rate increases from 1.7% in the current year to 2.5% in 2001-02 and falls back slightly to 2.3% and 2.2% in 2003-04. Hypothetically assuming an inflation target of 1.7%, the baseline forecast thus gives a signal for monetary tightening. According to the model, as shown in a second simulation

(Alternative 1), three-month Libor has to be raised from the current 3.5% to 4.5% in order to attain the inflation target.

In the model used so far, productivity growth proceeds on its historical trend. A further simulation (Alternative 2) then addresses the implications of higher productivity growth. The simulation is implemented by raising the technical progress parameter of the model by 50%, implying an annual rate of labour-augmenting technical progress of 1.8% instead of 1.2% as in the baseline forecast. Since the production function of the model is of a vintage type, faster technical progress falls exclusively on new equipment. The productivity gain on the whole production apparatus is endogenous, depending on the replacement of old equipment by new equipment (scrapping and investment). Although this process is sped up by a higher rate of technical progress on new equipment (old equipment loses its competitiveness more quickly), the share of new equipment in the production apparatus remains relatively small in the time horizon under consideration. Hence, overall productivity increases by less than productivity on new equipment. Nevertheless, the productivity gain in Alternative 2 is sufficient to bring inflation down to 1.7% in 2004. As this is just the assumed target value, no monetary tightening is indicated - in contrast to the baseline forecast, where the inflation target is missed by 0.5 percentage points.

Evidence for a sustained boost to productivity growth in Switzerland is, at least for the time being, far from being conclusive. Monetary policy can thus be misled in two directions. First, future productivity growth may be overestimated. In this case, monetary policy is based on an overly optimistic inflation forecast and thus turns out to be too lax. The cost of the forecast error shows up in the form of an inflation rate that exceeds the target value. Second, productivity growth may be underestimated. In this case, monetary policy is based on an overly pessimistic inflation forecast and thus turns out to be too restrictive: the inflation rate falls below the target value at the cost of an unnecessary depression of real GDP growth. This is an illustration of the many uncertainties surrounding monetary policy. Changes in parameter values, even if they remain within the bounds of possibility, can have sizeable effects on the inflation forecast and hence on monetary policy decisions.

As a second issue, the paper tries to assess the implications of a potential change in the formation of housing rents. The equation for housing rents reflects current legislation on tenant protection, which permits house owners to pass higher mortgage rates in certain proportions on to housing rents.[11] If monetary policy is tightened, mortgage rates and thus housing rents increase. Housing rents being an important component of the CPI, one may suspect that this mechanism hampers the efficiency of monetary policy. In order to see to what extent, the housing rent equation of the model is replaced by an alternative rule that links housing rents to the CPI. On the basis of this model, two further simulations are performed. The first refers to the concrete forecasting situation of August 2000. The second compares the monetary transmission mechanism between the two regimes from a more general perspective.

In the forecasting situation of August 2000, the alternative CPI rule lowers the inflation forecast significantly (Alternative 4). Supposing again an inflation target of 1.7%, the forecast implies that monetary policy may remain unchanged. In contrast, the baseline forecast has inflation at 2.2% in 2004 and therefore signals that monetary policy should be tightened. Moreover, while monetary tightening lowers inflation only slowly and in company with a substantial negative GDP effect under the interest rate rule, the switch to the CPI rule reduces inflation to 1.7% right from the beginning of the forecast period and has a small positive impact on GDP growth.

These beneficial effects may be traced back to the formation of wages, which depend on a weighted average of the CPI and the GDP deflator, and the “wedge” driven by increasing housing rents between the CPI and the GDP deflator. The existence of this wedge, reflecting the income claims of house owners, requires higher unemployment and lower capacity utilisation in order to confine the income claims of workers and firms. The switch to the CPI rule lowers the wedge, so that the economy moves towards a new equilibrium with lower inflation, higher employment and higher GDP.

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[11] The term *tenant protection* and the right of house owners to pass higher mortgage rates on to tenants may seem somewhat contradictory at first sight. However, one should recognise that rents of older apartments are often below potential market prices. Therefore, the principle of cost-determined housing rents “protects” tenants from market-determined rent increases. Moreover, the mechanism should also go in the other direction, ie lower mortgage rates should be passed to tenants as well. To what extent this actually happens in reality is, however, less clear.

It should be stressed, however, that these results are not general but apply to the specific forecasting situation, which was preceded by a considerable increase in interest rates. Due to adjustment lags, a strong increase in housing rents is therefore already in the pipeline under the interest rate rule. The switch to the CPI rule then cuts this pipeline at a time when it matters a great deal. Hence, the rather strong inflation dampening effect is conditional on the concrete forecasting situation.

In order to assess the differences in the monetary transmission mechanism between the two regimes from a more general perspective, a final simulation is carried out that tightens monetary policy under the CPI rule as well (although this is not necessary with regard to the inflation target). It turns out that the CPI rule makes the monetary transmission mechanism more efficient in two respects. First, the inflation dampening effect is quicker and stronger, since the adverse countereffect of rising housing rents is suppressed. Second, the negative side effects on GDP growth are less pronounced. Put differently, Swiss legislation on tenant protection forces monetary policy to become more restrictive if a certain reduction in the inflation rate is to be achieved, and this additional tightening is reflected in a higher loss of real GDP growth.

Appendix: Tables for the various scenarios

Table 1

Baseline forecast

		1998	1999	2000	2001	2002	2003	2004	
Exogenous:									
GDP EU 15	GDPEUR	2.64	2.34	3.32	3.37	3.03	2.98	3.05	(a)
GDP USA	GDPUSA	4.31	4.15	5.07	3.28	2.74	2.88	3.19	(a)
GDP Japan	GDPJAP	– 2.55	0.27	1.41	1.89	2.59	2.93	2.83	(a)
Consumer price Germany	PCONS_GE	0.93	0.59	1.53	1.83	2.00	1.66	1.49	(a)
Short-term interest rate euro	SRATE_GE	3.55	2.96	4.30	4.95	5.00	5.00	5.00	(b)
Short-term interest rate US dollar	SRATE-US	4.78	4.64	5.89	5.83	4.94	4.72	4.72	(b)
Long-term interest rate Germany	LRATE_GE	4.62	4.53	5.46	5.64	5.56	5.55	5.55	(b)
Price of oil in USD	POILUSD	12.7	17.8	28.2	30.0	30.0	30.0	30.0	(c)
Exchange rate USD/Euro	EDOEURO	1.11	1.07	0.93	0.89	0.91	0.93	0.94	(c)
Swiss monetary policy:									
Short-term interest rate	SRATE	1.55	1.40	3.10	3.50	3.50	3.50	3.50	(b)
Endogenous:									
Private consumption	CONSP	2.24	2.21	2.04	1.81	1.71	1.61	1.72	(a)
Real disp household income	YDISPBR	3.80	1.98	2.07	1.99	1.72	1.63	1.79	(a)
Construction investment	ICNSTR	0.92	– 6.24	2.28	– 0.58	1.51	2.45	2.48	(a)
Investm in mach and equipment	IME	8.89	8.82	2.42	3.66	2.77	2.98	3.90	(a)
Exports (incl services & tourism)	EXTOT	5.03	5.82	9.56	4.77	4.19	4.29	4.64	(a)
Imports (incl services & tourism)	IMTOT	9.60	5.50	7.37	2.41	3.29	4.22	4.96	(a)
Inventory investment	IINVWB	1.61	– 0.09	0.63	– 0.40	– 0.35	– 0.14	– 0.04	(d)
Gross domestic product	GDP	2.35	1.53	3.35	2.25	1.77	1.77	1.90	(a)
Employment (labour input in hours)	LVOLUS	1.32	0.34	1.53	0.94	0.36	0.23	0.29	(a)
Labour productivity	LPROD	1.01	1.18	1.80	1.30	1.40	1.54	1.61	(a)
Labour producitiviy, technical	LTPROD	1.05	0.94	1.32	1.42	1.45	1.48	1.52	(a)
Labour productivity, new equipment	LCPROD	1.55	1.67	2.16	2.25	1.84	2.05	2.10	(a)
Consumer price (CPI)	PCI	0.02	0.81	1.74	2.48	2.52	2.30	2.18	(a)
Construction price (NaAcc deflator)	PICNSTR	– 0.25	2.90	2.12	1.21	1.08	1.15	1.32	(a)
Housing rents	PHR	0.05	0.69	1.83	5.07	5.02	4.35	4.01	(a)
Price of IME (NaAcc deflator)	PIME	– 0.05	– 2.00	– 2.32	– 0.49	0.19	– 0.54	– 0.43	(a)
Export price (NaAcc deflator)	PEXTOT	– 0.94	1.17	2.00	1.98	1.74	1.38	1.47	(a)
Import price (NaAcc deflator)	PIMTOT	– 3.88	– 1.24	3.97	1.22	0.36	– 0.19	– 0.06	(a)
GDP deflator	PGDP	0.24	0.55	0.91	1.76	2.36	2.24	2.21	(a)
Nominal wage (BfS index)	WAGE	0.70	1.21	1.44	2.26	2.80	2.78	2.72	(a)
Nominal wage (NaAcc concept)	WINCI	1.12	1.69	2.63	3.39	3.71	3.69	3.66	(a)
Real consumer wage	WRINC	1.10	0.87	0.87	0.88	1.16	1.36	1.45	(a)
External value of CHF	EVN	1.71	– 0.49	– 1.80	0.55	0.33	0.49	0.26	(a)
Real external value of CHF	EVR	0.49	– 1.38	– 3.15	– 0.12	0.43	0.52	0.31	(a)
Exchange rate CHF/euro	EFREURO	1.61	1.60	1.56	1.55	1.55	1.54	1.54	(c)
Exchange rate CHF/USD	EFRDO	1.45	1.50	1.69	1.73	1.70	1.66	1.64	(c)
Long-term interest rate	LRATE	2.81	3.01	4.01	4.14	4.10	4.10	4.10	(b)
Output gap	GDPGAP	– 4.89	– 5.29	– 1.94	– 1.45	– 1.51	– 1.45	– 1.23	(b)
Unemployment rate (seco)	UROFF	3.86	2.72	1.99	1.82	1.80	1.77	1.71	(b)

(a) Rate of change in % (b) Level in % (c) Level (d) Contribution to GDP growth rate in percentage points

Table 2a

Alternative 1 (tighter monetary policy)

		1998	1999	2000	2001	2002	2003	2004	
Swiss monetary policy:									
Short-term interest rate	SRATE	1.55	1.40	3.60	4.50	4.50	4.50	4.50	(b)
Endogenous:									
Private consumption	CONSP	2.24	2.21	2.03	1.69	1.41	1.16	1.35	(a)
Real disp. household income	YDISPBR	3.80	1.98	2.06	1.83	1.17	0.98	1.36	(a)
Construction investment	ICNSTR	0.92	– 6.24	2.25	– 1.16	0.53	1.93	2.33	(a)
Investm in mach and equipment	IME	8.89	8.82	2.41	3.08	1.49	2.42	4.27	(a)
Exports (incl services & tourism)	EXTOT	5.03	5.82	9.49	4.03	3.58	4.12	4.62	(a)
Imports (incl Services & tourism)	IMTOT	9.60	5.50	7.33	1.94	2.65	3.85	4.95	(a)
Inventory investment	IINVWB	1.61	– 0.09	0.63	– 0.35	– 0.42	– 0.23	– 0.05	(d)
Gross domestic product	GDP	2.35	1.53	3.34	1.96	1.24	1.37	1.70	(a)
Employment (labour input in hours)	LVOLUS	1.32	0.34	1.52	0.77	– 0.04	– 0.15	0.08	(a)
Labour productivity	LPROD	1.01	1.18	1.79	1.18	1.28	1.53	1.62	(a)
Labour producitiviy, technical	LTPROD	1.05	0.94	1.32	1.42	1.45	1.47	1.52	(a)
Labour productivity, new equipment	LCPROD	1.55	1.67	2.18	2.45	2.08	2.31	2.32	(a)
Consumer price (CPI)	PCI	0.02	0.81	1.72	2.41	2.42	1.99	1.70	(a)
Construction price (NaAcc deflator)	PICNSTR	– 0.25	2.90	2.12	1.07	0.55	0.30	0.43	(a)
Housing rents	PHR	0.05	0.69	1.83	5.19	5.30	4.39	3.82	(a)
Price of IME (NaAcc deflator)	PIME	– 0.05	– 2.00	– 2.50	– 1.34	– 0.83	– 1.88	– 1.73	(a)
Export price (NaAcc deflator)	PEXTOT	– 0.94	1.17	1.89	1.44	1.19	0.80	0.95	(a)
Import price (NaAcc deflator)	PIMTOT	– 3.88	– 1.24	3.68	– 0.09	– 0.60	– 0.90	– 0.67	(a)
GDP deflator	PGDP	0.24	0.55	0.91	1.75	2.18	1.75	1.61	(a)
Nominal wage (BfS index)	WAGE	0.70	1.21	1.44	2.22	2.61	2.34	2.13	(a)
Nominal wage (NaAcc concept)	WINCI	1.12	1.69	2.63	3.33	3.45	3.15	2.97	(a)
Real consumer wage	WRINC	1.10	0.87	0.89	0.89	1.01	1.14	1.25	(a)
External value of CHF	EVN	1.71	– 0.49	– 1.40	2.03	1.00	1.00	0.84	(a)
Real external value of CHF	EVR	0.49	– 1.38	– 2.76	1.34	0.93	0.55	0.30	(a)
Exchange rate CHF/euro	EFREURO	1.61	1.60	1.56	1.52	1.51	1.50	1.49	(c)
Exchange rate CHF/USD	EFRDO	1.45	1.50	1.68	1.70	1.65	1.61	1.58	(c)
Long-term interest rate	LRATE	2.81	3.01	4.10	4.34	4.30	4.30	4.30	(b)
Output gap	GDPGAP	– 4.89	– 5.29	– 1.95	– 1.65	– 1.99	– 1.99	– 1.64	(b)
Unemployment rate (seco)	UROFF	3.86	2.72	2.00	1.91	2.03	2.11	2.09	(b)

(a) Rate of change in % (b) Level in % (c) Level (d) Contribution to GDP growth rate in percentage points

Table 2b

Effects of tighter monetary policy

(Alternative 1 versus baseline: differences in growth rates or levels)

		2000	2001	2002	2003	2004	
Private consumption	CONSP	– 0.01	– 0.12	– 0.29	– 0.45	– 0.37	(a)
Construction investment	ICNSTR	– 0.03	– 0.58	– 0.98	– 0.52	– 0.16	(a)
Investm in mach and equipment	IME	– 0.01	– 0.59	– 1.28	– 0.56	0.36	(a)
Exports (incl services & tourism)	EXTOT	– 0.07	– 0.74	– 0.61	– 0.17	– 0.02	(a)
Imports (incl Services & tourism)	IMTOT	– 0.04	– 0.47	– 0.63	– 0.37	0.00	(a)
Gross domestic product	GDP	– 0.02	– 0.29	– 0.53	– 0.40	– 0.20	(a)
Employment (labour input in hours)	LVOLUS	– 0.01	– 0.16	– 0.41	– 0.38	– 0.21	(a)
Labour productivity	LPROD	– 0.01	– 0.13	– 0.12	– 0.01	0.01	(a)
Labour producitiviy, technical	LTPROD	0.00	0.00	0.00	0.00	0.01	(a)
Labour productivity, new equipment	LCPROD	0.02	0.19	0.24	0.25	0.22	(a)
Consumer price (CPI)	PCI	– 0.01	– 0.07	– 0.11	– 0.31	– 0.48	(a)
Construction price (NaAcc deflator)	PICNSTR	0.00	– 0.13	– 0.52	– 0.84	– 0.89	(a)
Housing rents	PHR	0.00	0.12	0.27	0.04	– 0.19	(a)
Price of IME (NaAcc deflator)	PIME	– 0.18	– 0.85	– 1.03	– 1.34	– 1.30	(a)
Export price (NaAcc deflator)	PEXTOT	– 0.11	– 0.54	– 0.55	– 0.57	– 0.52	(a)
Import price (NaAcc deflator)	PIMTOT	– 0.29	– 1.30	– 0.96	– 0.71	– 0.61	(a)
GDP deflator	PGDP	0.00	– 0.01	– 0.18	– 0.49	– 0.60	(a)
Nominal wage (NaAcc concept)	WINCI	0.00	– 0.06	– 0.26	– 0.54	– 0.69	(a)
Real consumer wage	WRINC	0.01	0.02	– 0.15	– 0.22	– 0.20	(a)
External value of CHF	EVN	0.40	1.48	0.68	0.51	0.59	(a)
Real external value of CHF	EVR	0.39	1.46	0.50	0.03	– 0.01	(a)
Long-term interest rate	LRATE	0.10	0.20	0.20	0.20	0.20	(b)
Unemployment rate (seco)	UROFF	0.00	0.08	0.23	0.34	0.38	(b)

(a) Rate of change in % (b) Level

Table 3a

Alternative 2 (higher productivity growth)

		1998	1999	2000	2001	2002	2003	2004	
Swiss monetary policy:									
Short-term interest rate	SRATE	1.55	1.40	3.10	3.50	3.50	3.50	3.50	(b)
Endogenous:									
Private consumption	CONSP	2.24	2.21	2.04	1.76	1.59	1.49	1.61	(a)
Real disp household income	YDISPBR	3.80	1.98	2.07	1.93	1.59	1.51	1.68	(a)
Construction investment	ICNSTR	0.92	– 6.24	2.28	– 0.61	1.48	2.45	2.52	(a)
Investm in mach and equipment	IME	8.89	8.82	2.39	3.54	2.91	3.40	4.46	(a)
Exports (incl services & tourism)	EXTOT	5.03	5.82	9.56	4.81	4.30	4.41	4.73	(a)
Imports (incl services & tourism)	IMTOT	9.60	5.50	7.37	2.34	3.21	4.20	4.99	(a)
Inventory investment	IINVWB	1.61	– 0.09	0.63	– 0.40	– 0.36	– 0.15	– 0.03	(d)
Gross domestic product	GDP	2.35	1.53	3.35	2.26	1.80	1.82	1.97	(a)
Employment (labour input in hours)	LVOLUS	1.32	0.34	1.53	0.92	0.33	0.18	0.22	(a)
Labour productivity	LPROD	1.01	1.18	1.80	1.33	1.47	1.64	1.74	(a)
Labour producitiviy, technical	LTPROD	1.05	0.94	1.32	1.44	1.52	1.59	1.67	(a)
Labour productivity, new equipment	LCPROD	1.55	1.67	2.24	2.71	2.45	2.74	2.82	(a)
Consumer price (CPI)	PCI	0.02	0.81	1.74	2.43	2.32	1.95	1.70	(a)
Construction price (NaAcc deflator)	PICNSTR	– 0.25	2.90	2.12	1.16	0.89	0.82	0.87	(a)
Housing rents	PHR	0.05	0.69	1.83	5.07	5.02	4.31	3.91	(a)
Price of IME (NaAcc deflator)	PIME	– 0.05	– 2.00	– 2.33	– 0.85	– 0.65	– 1.67	– 1.79	(a)
Export price (NaAcc deflator)	PEXTOT	– 0.94	1.17	1.99	1.84	1.44	0.97	0.95	(a)
Import price (NaAcc deflator)	PIMTOT	– 3.88	– 1.24	3.97	1.20	0.22	– 0.48	– 0.50	(a)
GDP deflator	PGDP	0.24	0.55	0.91	1.61	1.97	1.68	1.53	(a)
Nominal wage (BfS index)	WAGE	0.70	1.21	1.44	2.20	2.58	2.40	2.20	(a)
Nominal wage (NaAcc concept)	WINCI	1.12	1.69	2.63	3.35	3.57	3.42	3.27	(a)
Real consumer wage	WRINC	1.10	0.87	0.88	0.90	1.22	1.45	1.54	(a)
External value of CHF	EVN	1.71	– 0.49	– 1.80	0.58	0.53	0.89	0.82	(a)
Real external value of CHF	EVR	0.49	– 1.38	– 3.15	– 0.24	0.24	0.37	0.19	(a)
Exchange rate CHF/euro	EFREURO	1.61	1.60	1.56	1.55	1.54	1.53	1.52	(c)
Exchange rate CHF/USD	EFRDO	1.45	1.50	1.69	1.73	1.69	1.65	1.62	(c)
Long-term interest rate	LRATE	2.81	3.01	4.01	4.14	4.10	4.10	4.10	(b)
Output gap	GDPGAP	– 4.89	– 5.29	– 1.94	– 1.45	– 1.45	– 1.32	– 1.04	(b)
Unemployment rate (seco)	UROFF	3.86	2.72	2.00	1.83	1.82	1.81	1.77	(b)

(a) Rate of change in % (b) Level in % (c) Level (d) Contribution to GDP growth rate in percentage points

Table 3b

Effects of higher productivity growth

(Alternative 2 versus baseline: differences in growth rates or levels)

		2000	2001	2002	2003	2004	
Private consumption	CONSP	0.00	– 0.05	– 0.12	– 0.13	– 0.11	(a)
Construction investment	ICNSTR	0.00	– 0.02	– 0.03	0.00	0.04	(a)
Investm in mach and equipment	IME	– 0.03	– 0.13	0.14	0.41	0.55	(a)
Exports (incl services & tourism)	EXTOT	0.00	0.04	0.11	0.11	0.09	(a)
Imports (incl services & tourism)	IMTOT	– 0.01	– 0.08	– 0.08	– 0.02	0.03	(a)
Gross domestic product	GDP	0.00	0.01	0.03	0.05	0.06	(a)
Employment (labour input in hours)	LVOLUS	0.00	– 0.02	– 0.04	– 0.05	– 0.07	(a)
Labour productivity	LPROD	0.00	0.02	0.07	0.10	0.13	(a)
Labour producitiviy, technical	LTPROD	0.00	0.03	0.07	0.11	0.15	(a)
Labour productivity, new equipment	LCPROD	0.08	0.46	0.61	0.69	0.72	(a)
Consumer price (CPI)	PCI	0.00	– 0.06	– 0.20	– 0.35	– 0.48	(a)
Construction price (NaAcc deflator)	PICNSTR	0.00	– 0.05	– 0.18	– 0.32	– 0.46	(a)
Housing rents	PHR	0.00	0.00	– 0.01	– 0.04	– 0.10	(a)
Price of IME (NaAcc deflator)	PIME	– 0.01	– 0.36	– 0.84	– 1.13	– 1.36	(a)
Export price (NaAcc deflator)	PEXTOT	– 0.01	– 0.14	– 0.29	– 0.41	– 0.51	(a)
Import price (NaAcc deflator)	PIMTOT	0.00	– 0.02	– 0.14	– 0.30	– 0.44	(a)
GDP deflator	PGDP	– 0.01	– 0.15	– 0.39	– 0.56	– 0.69	(a)
Nominal wage (NaAcc concept)	WINCI	0.00	– 0.04	– 0.14	– 0.27	– 0.40	(a)
Real consumer wage	WRINC	0.00	0.02	0.06	0.08	0.09	(a)
External value of CHF	EVN	0.00	0.03	0.20	0.40	0.56	(a)
Real external value of CHF	EVR	0.00	– 0.12	– 0.19	– 0.15	– 0.12	(a)
Long-term interest rate	LRATE	0.00	0.00	0.00	0.00	0.00	(b)
Unemployment rate (seco)	UROFF	0.00	0.01	0.02	0.04	0.06	(b)

(a) Rate of change in % (b) Level

Table 4

Alternative 3 (higher productivity growth and tighter monetary policy)

		1998	1999	2000	2001	2002	2003	2004	
Swiss monetary policy:									
Short-term interest rate	SRATE	1.55	1.40	3.60	4.50	4.50	4.50	4.50	(b)
Endogenous:									
Private consumption	CONSP	2.24	2.21	2.03	1.64	1.29	1.03	1.24	(a)
Real disp household income	YDISPBR	3.80	1.98	2.06	1.77	1.05	0.86	1.25	(a)
Construction investment	ICNSTR	0.92	– 6.24	2.25	– 1.18	0.50	1.92	2.36	(a)
Investm in mach and equipment	IME	8.89	8.82	2.38	2.95	1.61	2.80	4.83	(a)
Exports (incl services & tourism)	EXTOT	5.03	5.82	9.49	4.07	3.68	4.23	4.71	(a)
Imports (incl services & tourism)	IMTOT	9.60	5.50	7.32	1.86	2.57	3.82	4.98	(a)
Inventory investment	IINVWB	1.61	– 0.09	0.64	– 0.35	– 0.43	– 0.23	– 0.05	(d)
Gross domestic product	GDP	2.35	1.53	3.34	1.96	1.27	1.42	1.76	(a)
Employment (labour input in hours)	LVOLUS	1.32	0.34	1.52	0.76	– 0.08	– 0.20	0.01	(a)
Labour productivity	LPROD	1.01	1.18	1.79	1.20	1.35	1.63	1.75	(a)
Labour producitiviy, technical	LTPROD	1.05	0.94	1.32	1.44	1.51	1.58	1.67	(a)
Labour productivity, new equipment	LCPROD	1.55	1.67	2.26	2.90	2.69	3.00	3.06	(a)
Consumer price (CPI)	PCI	0.02	0.81	1.72	2.35	2.21	1.63	1.22	(a)
Construction price (NaAcc deflator)	PICNSTR	– 0.25	2.90	2.11	1.02	0.37	– 0.02	– 0.03	(a)
Housing rents	PHR	0.05	0.69	1.83	5.19	5.29	4.34	3.72	(a)
Price of IME (NaAcc deflator)	PIME	– 0.05	– 2.00	– 2.51	– 1.70	– 1.67	– 3.02	– 3.11	(a)
Export price (NaAcc deflator)	PEXTOT	– 0.94	1.17	1.88	1.30	0.89	0.38	0.43	(a)
Import price (NaAcc deflator)	PIMTOT	– 3.88	– 1.24	3.68	– 0.11	– 0.74	– 1.20	– 1.12	(a)
GDP deflator	PGDP	0.24	0.55	0.91	1.60	1.79	1.19	0.92	(a)
Nominal wage (BfS index)	WAGE	0.70	1.21	1.44	2.16	2.39	1.96	1.62	(a)
Nominal wage (NaAcc concept)	WINCI	1.12	1.69	2.62	3.29	3.31	2.88	2.58	(a)
Real consumer wage	WRINC	1.10	0.87	0.89	0.92	1.07	1.23	1.34	(a)
External value of CHF	EVN	1.71	– 0.49	– 1.40	2.07	1.20	1.40	1.42	(a)
Real external value of CHF	EVR	0.49	– 1.38	– 2.76	1.22	0.74	0.40	0.18	(a)
Exchange rate CHF/euro	EFREURO	1.61	1.60	1.56	1.52	1.50	1.49	1.47	(c)
Exchange rate CHF/USD	EFRDO	1.45	1.50	1.68	1.70	1.65	1.60	1.56	(c)
Long-term interest rate	LRATE	2.81	3.01	4.10	4.34	4.30	4.30	4.30	(b)
Output gap	GDPGAP	– 4.89	– 5.29	– 1.95	– 1.64	– 1.94	– 1.86	– 1.43	(b)
Unemployment rate (seco)	UROFF	3.86	2.72	2.00	1.91	2.05	2.15	2.16	(b)

(a) Rate of change in % (b) Level in % (c) Level (d) Contribution to GDP growth rate in percentage points

Table 5a

Alternative 4 (housing rents linked to CPI)

		1998	1999	2000	2001	2002	2003	2004	
Swiss monetary policy:									
Short-term interest rate	SRATE	1.55	1.40	3.10	3.50	3.50	3.50	3.50	(b)
Endogenous:									
Private consumption	CONSP	2.24	2.21	2.08	2.17	2.19	2.05	2.07	(a)
Real disp household income	YDISPBR	3.80	1.98	2.15	2.56	2.35	2.19	2.23	(a)
Construction investment	ICNSTR	0.92	– 6.24	2.29	– 0.48	1.64	2.50	2.44	(a)
Investm in mach and equipment	IME	8.89	8.82	2.43	3.92	3.40	3.44	4.00	(a)
Exports (incl services & tourism)	EXTOT	5.03	5.82	9.57	4.86	4.33	4.36	4.67	(a)
Imports (incl services & tourism)	IMTOT	9.60	5.50	7.41	2.82	3.88	4.63	5.16	(a)
Inventory investment	IINVWB	1.61	– 0.09	0.62	– 0.42	– 0.31	– 0.10	– 0.02	(d)
Gross domestic product	GDP	2.35	1.53	3.36	2.33	1.97	1.96	2.03	(a)
Employment (labour input in hours)	LVOLUS	1.32	0.34	1.53	0.98	0.50	0.38	0.39	(a)
Labour productivity	LPROD	1.01	1.18	1.80	1.34	1.47	1.57	1.63	(a)
Labour producitiviy, technical	LTPROD	1.05	0.94	1.32	1.42	1.46	1.49	1.52	(a)
Labour productivity, new equipment	LCPROD	1.55	1.67	2.16	2.24	1.79	1.98	2.04	(a)
Consumer price (CPI)	PCI	0.02	0.81	1.65	1.74	1.71	1.69	1.70	(a)
Construction price (NaAcc deflator)	PICNSTR	– 0.25	2.90	2.12	1.23	1.19	1.36	1.53	(a)
Housing rents	PHR	0.05	0.69	1.56	2.73	2.72	2.70	2.71	(a)
Price of IME (NaAcc deflator)	PIME	– 0.05	– 2.00	– 2.32	– 0.55	0.11	– 0.54	– 0.48	(a)
Export price (NaAcc deflator)	PEXTOT	– 0.94	1.17	2.00	1.95	1.71	1.37	1.43	(a)
Import price (NaAcc deflator)	PIMTOT	– 3.88	– 1.24	3.97	1.20	0.32	– 0.23	– 0.14	(a)
GDP deflator	PGDP	0.24	0.55	0.88	1.48	2.05	2.04	2.05	(a)
Nominal wage (BfS index)	WAGE	0.70	1.21	1.43	2.00	2.36	2.42	2.44	(a)
Nominal wage (NaAcc concept)	WINCI	1.12	1.69	2.62	3.23	3.43	3.45	3.47	(a)
Real consumer wage	WRINC	1.10	0.87	0.95	1.47	1.69	1.73	1.74	(a)
External value of CHF	EVN	1.71	– 0.49	– 1.80	0.60	0.47	0.63	0.38	(a)
Real external value of CHF	EVR	0.49	– 1.38	– 3.18	– 0.36	0.27	0.47	0.27	(a)
Exchange rate CHF/euro	EFREURO	1.61	1.60	1.56	1.55	1.54	1.54	1.53	(c)
Exchange rate CHF/USD	EFRDO	1.45	1.50	1.69	1.73	1.69	1.65	1.63	(c)
Long-term interest rate	LRATE	2.81	3.01	4.01	4.14	4.10	4.10	4.10	(b)
Output gap	GDPGAP	4.89	– 5.29	– 1.94	– 1.38	– 1.32	– 1.20	– 1.00	(b)
Unemployment rate (seco)	UROFF	3.86	2.72	1.99	1.80	1.73	1.65	1.56	(b)

(a) Rate of change in % (b) Level in % (c) Level (d) Contribution to GDP growth rate in percentage points

Table 5b

Effects of linking housing rents to CPI

(Alternative 4 versus baseline: differences in growth rates or levels)

		2000	2001	2002	2003	2004	
Private consumption	CONSP	0.04	0.36	0.49	0.44	0.35	(a)
Construction investment	ICNSTR	0.01	0.11	0.13	0.05	– 0.04	(a)
Investm in mach and equipment	IME	0.01	0.26	0.63	0.46	0.10	(a)
Exports (incl services & tourism)	EXTOT	0.01	0.10	0.14	0.07	0.03	(a)
Imports (incl Services & tourism)	IMTOT	0.04	0.40	0.59	0.42	0.20	(a)
Gross domestic product	GDP	0.00	0.09	0.20	0.19	0.13	(a)
Employment (labour input in hours)	LVOLUS	0.00	0.04	0.14	0.15	0.10	(a)
Labour productivity	LPROD	0.00	0.04	0.06	0.03	0.02	(a)
Labour producitiviy, technical	LTPROD	0.00	0.00	0.01	0.01	0.01	(a)
Labour productivity, new equipment	LCPROD	0.00	– 0.01	– 0.04	– 0.07	– 0.06	(a)
Consumer price (CPI)	PCI	– 0.08	– 0.75	– 0.81	– 0.61	– 0.48	(a)
Construction price (NaAcc deflator)	PICNSTR	0.00	0.03	0.12	0.21	0.21	(a)
Housing rents	PHR	– 0.27	– 2.34	– 2.30	– 1.65	– 1.30	(a)
Price of IME (NaAcc deflator)	PIME	0.00	– 0.06	– 0.09	0.00	– 0.05	(a)
Export price (NaAcc deflator)	PEXTOT	0.00	– 0.03	– 0.03	– 0.01	– 0.04	(a)
Import price (NaAcc deflator)	PIMTOT	0.00	– 0.02	– 0.04	– 0.05	– 0.08	(a)
GDP deflator	PGDP	– 0.03	– 0.29	– 0.31	– 0.20	– 0.16	(a)
Nominal wage (NaAcc concept)	WINCI	– 0.01	– 0.15	– 0.28	– 0.25	– 0.20	(a)
Real consumer wage	WRINC	0.07	0.59	0.53	0.36	0.29	(a)
External value of CHF	EVN	0.00	0.04	0.14	0.14	0.12	(a)
Real external value of CHF	EVR	– 0.03	– 0.24	– 0.17	– 0.06	– 0.04	(a)
Long-term interest rate	LRATE	0.00	0.00	0.00	0.00	0.00	(b)
Unemployment rate (seco)	UROFF	0.00	– 0.02	– 0.07	– 0.12	– 0.15	(b)

(a) Rate of change in % (b) Level

Table 6a

Alternative 5 (housing rents linked to CPI, tighter monetary policy)

		1998	1999	2000	2001	2002	2003	2004	
Swiss monetary policy:									
Short-term interest rate	SRATE	1.55	1.40	3.60	4.50	4.50	4.50	4.50	(b)
Endogenous:									
Private consumption	CONSP	2.24	2.21	2.07	2.11	2.02	1.78	1.88	(a)
Real disp. household income	YDISPBR	3.80	1.98	2.14	2.47	1.96	1.71	1.96	(a)
Construction investment	ICNSTR	0.92	– 6.24	2.26	– 1.04	0.69	1.99	2.30	(a)
Investm. in mach. and equipment	IME	8.89	8.82	2.42	3.36	2.19	3.03	4.57	(a)
Exports (incl services & tourism)	EXTOT	5.03	5.82	9.49	4.14	3.74	4.22	4.69	(a)
Imports (incl services & tourism)	IMTOT	9.60	5.50	7.37	2.40	3.36	4.45	5.35	(a)
Inventory investment	IINVWB	1.61	– 0.09	0.63	– 0.38	– 0.39	– 0.18	– 0.03	(d)
Gross domestic product	GDP	2.35	1.53	3.34	2.06	1.48	1.62	1.88	(a)
Employment (labour input in hours)	LVOLUS	1.32	0.34	1.52	0.82	0.13	0.06	0.24	(a)
Labour productivity	LPROD	1.01	1.18	1.79	1.22	1.35	1.56	1.64	(a)
Labour producitiviy, technical	LTPROD	1.05	0.94	1.32	1.42	1.45	1.48	1.54	(a)
Labour productivity, new equipment	LCPROD	1.55	1.67	2.18	2.43	2.03	2.23	2.25	(a)
Consumer price (CPI)	PCI	0.02	0.81	1.63	1.58	1.41	1.17	1.03	(a)
Construction price (NaAcc deflator)	PICNSTR	– 0.25	2.90	2.12	1.10	0.70	0.56	0.71	(a)
Housing rents	PHR	0.05	0.69	1.54	2.57	2.42	2.18	2.03	(a)
Price of IME (NaAcc deflator)	PIME	– 0.05	– 2.00	– 2.50	– 1.41	– 0.95	– 1.93	– 1.81	(a)
Export price (NaAcc deflator)	PEXTOT	– 0.94	1.17	1.89	1.41	1.14	0.77	0.90	(a)
Import price (NaAcc deflator)	PIMTOT	– 3.88	– 1.24	3.68	– 0.10	– 0.66	– 0.97	– 0.76	(a)
GDP deflator	PGDP	0.24	0.55	0.88	1.43	1.80	1.46	1.36	(a)
Nominal wage (BfS index)	WAGE	0.70	1.21	1.43	1.94	2.09	1.86	1.73	(a)
Nominal wage (NaAcc concept)	WINCI	1.12	1.69	2.62	3.16	3.12	2.83	2.69	(a)
Real consumer wage	WRINC	1.10	0.87	0.96	1.56	1.68	1.64	1.65	(a)
External value of CHF	EVN	1.71	– 0.49	– 1.41	2.08	1.17	1.18	1.01	(a)
Real external value of CHF	EVR	0.49	– 1.38	– 2.80	1.07	0.72	0.44	0.22	(a)
Exchange rate CHF/Euro	EFREURO	1.61	1.60	1.56	1.52	1.50	1.49	1.48	(c)
Exchange rate CHF/USD	EFRDO	1.45	1.50	1.68	1.70	1.65	1.60	1.57	(c)
Long-term interest rate	LRATE	2.81	3.01	4.10	4.34	4.30	4.30	4.30	(b)
Output gap	GDPGAP	– 4.89	– 5.29	– 1.95	– 1.57	– 1.76	– 1.66	– 1.30	(b)
Unemployment rate (seco)	UROFF	3.86	2.72	2.00	1.88	1.94	1.95	1.90	(b)

(a) Rate of change in % (b) Level in % (c) Level (d) Contribution to GDP growth rate in percentage points

Table 6b

Effects of tighter monetary policy - housing rents linked to CPI

(Alternative 5 versus Alternative 4: differences in growth rates or levels)

		2000	2001	2002	2003	2004	
Private consumption	CONSP	– 0.01	– 0.06	– 0.17	– 0.27	– 0.19	(a)
Construction investment	ICNSTR	– 0.03	– 0.56	– 0.95	– 0.51	– 0.14	(a)
Investm in mach. and equipment	IME	– 0.01	– 0.56	– 1.21	– 0.42	0.57	(a)
Exports (incl services & tourism)	EXTOT	– 0.07	– 0.72	– 0.59	– 0.14	0.02	(a)
Imports (incl services & tourism)	IMTOT	– 0.04	– 0.42	– 0.51	– 0.18	0.19	(a)
Gross domestic product	GDP	– 0.02	– 0.28	– 0.49	– 0.34	– 0.15	(a)
Employment (labour input in hours)	LVOLUS	– 0.01	– 0.15	– 0.38	– 0.33	– 0.15	(a)
Labour productivity	LPROD	– 0.01	– 0.12	– 0.11	– 0.01	0.01	(a)
Labour producitiviy, technical	LTPROD	0.00	0.00	0.00	0.00	0.01	(a)
Labour productivity, new equipment	LCPROD	0.02	0.19	0.24	0.25	0.21	(a)
Consumer price (CPI)	PCI	– 0.02	– 0.16	– 0.30	– 0.52	– 0.67	(a)
Construction price (NaAcc deflator)	PICNSTR	0.00	– 0.13	– 0.50	– 0.79	– 0.82	(a)
Housing rents	PHR	– 0.02	– 0.16	– 0.30	– 0.53	– 0.68	(a)
Price of IME (NaAcc deflator)	PIME	– 0.18	– 0.86	– 1.06	– 1.40	– 1.33	(a)
Export price (NaAcc deflator)	PEXTOT	– 0.11	– 0.54	– 0.56	– 0.60	– 0.53	(a)
Import price (NaAcc deflator)	PIMTOT	– 0.29	– 1.30	– 0.98	– 0.74	– 0.62	(a)
GDP deflator	PGDP	0.00	– 0.05	– 0.26	– 0.58	– 0.69	(a)
Nominal wage (NaAcc concept)	WINCI	0.00	– 0.07	– 0.31	– 0.62	– 0.78	(a)
Real consumer wage	WRINC	0.02	0.09	– 0.01	– 0.09	– 0.09	(a)
External value of CHF	EVN	0.39	1.49	0.71	0.55	0.63	(a)
Real external value of CHF	EVR	0.38	1.43	0.45	– 0.02	– 0.06	(a)
Long-term interest rate	LRATE	0.10	0.20	0.20	0.20	0.20	(b)
Unemployment rate (seco)	UROFF	0.00	0.08	0.21	0.30	0.33	(b)

(a) Rate of change in % (b) Level

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Understanding the recent behaviour of inflation: an empirical study of wage and price developments in eight countries[1]

Palle S Andersen and William L Wascher

Abstract

An important and surprising characteristic of the economies in industrialised countries in the 1990s was the extent to which prices decelerated in an environment of generally rising economic activity and tightening labour markets. The coexistence of a healthy economic environment and low inflation can appropriately be described as good news. However, economists tended to overstate underlying inflation pressures in many of these countries during most of the decade, and these prediction errors demonstrate our lack of understanding of the inflation process and raise questions about the appropriate stance of monetary policy in such an uncertain environment.

In this paper, we investigate the magnitudes and potential sources of inflation forecast errors during the 1990s in a sample of eight industrialised countries. Our analysis consists of two separate approaches. First, we examine the errors in official OECD forecasts, which we take to be representative of the mainstream of macroeconomic analysis during that time. Second, we document and analyse prediction errors in our own set of econometric specifications, which are loosely based on the Phillips curve model of the inflation process.

Our analysis of OECD forecast errors is indicative of persistent overpredictions of price inflation for most of the countries in our sample. In contrast, little bias is evident in the OECD forecasts of wage inflation. The combination of the forecast errors for wages and prices thus implies that *real* wage growth has been unexpectedly strong during the 1990s and that the major *sources* of the forecast errors are likely to be located in that part of the Phillips curve framework which models firms' prices as a mark-up on costs. More precisely, the unexpectedly slow rise in prices relative to wages could indicate that firms have benefited from favourable supply shocks or that they lost pricing power during the 1990s in that they were not able to fully pass on wage cost increases into their prices.

Our own models for consumer prices also consistently overpredict inflation in nearly every country. Nonetheless, there is little statistical evidence of parameter instability. The one exception is a decline in the intercept term in the 1990s, a finding indicative of structural change but, unfortunately, not particularly helpful in identifying the source of the change. In contrast, the parameters in our wage models appear to have changed in about half of the countries. However, no single coefficient stands out as particularly sensitive to the addition of the more recent data.

1. Introduction

An important and, to many observers, surprising characteristic of the economies in industrialised countries in the 1990s was the extent to which prices decelerated in an environment of generally rising economic activity and tightening labour markets. Measured by the private consumption deflator, the average inflation rate among OECD member countries fell from 4.6% in 1990 to just 1.2% in 1999, while the average unemployment rate for 2000 was the lowest in 10 years. Moreover, for the first time

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since 1990 actual output for the whole OECD area exceeded potential output last year. To further illustrate the degree of disinflation during the 1990s, only four industrial countries (Greece, Iceland, Ireland and Spain) had an inflation rate *higher* than 2½% in 1999, while in 1990 only three countries (Ireland, Luxembourg and the Netherlands) had an inflation rate *lower* than 2½%. Moreover, as we shall discuss in this paper, economists evidently overstated underlying inflation pressures in many of these countries during most of the decade, at least as indicated by the persistent overpredictions of price changes evident across a wide range of forecasts. While the coexistence of a healthy economic environment and low inflation can appropriately be described as good news, these prediction errors also demonstrate our lack of understanding of the inflation process and raise questions about the appropriate stance of monetary policy in such an uncertain environment.

Given that disinflation has occurred in so many countries, it might be expected that the primary reason for this favourable development would be clearly evident and pertain to a large number of - if not all - industrialised nations. Indeed, there is a general consensus as to the most likely sources of disinflation, including monetary policies aimed at price stability, declines in relative import prices, a fall in the natural rate of unemployment, increased globalisation and firms' loss of pricing power. However, estimates of the contribution of these various sources and the degree to which they apply across countries are not very precise, and thus there is less agreement as to the causes of the persistent overpredictions of inflation over this period. For example, in some countries, most notably the United States and Australia, an unanticipated increase in structural productivity growth is often cited as a key cause. However, an increase in trend productivity is an unlikely candidate for consideration in many continental European countries simply because no such improvement is evident in the statistics. Similarly, while there are signs of higher productivity growth late in the 1990s in Canada, such improvements came too late for productivity developments to be a credible source of forecast errors. In several of these countries, as well as in the United Kingdom, labour market reforms (in many cases aimed at increasing the labour intensity of output growth), inflation targeting and other structural changes are typically highlighted instead.

In this paper, we investigate the magnitudes and possible sources of inflation forecast errors during the 1990s in a sample of eight industrialised countries.[2] Our analysis consists of two separate approaches. First, we examine the errors in official OECD forecasts, which we take to be representative of the mainstream of macroeconomic analysis during that time.[3] Such an exercise helps us document the direction and magnitude of forecast errors and allows us to look at possible correlations between the surprises in wage and price inflation and surprises in other variables that are typically included in forecasters' models of the inflation process. We then turn to our own set of econometric specifications, which are loosely based on the Phillips curve model of the inflation process. We again document the size of prediction errors made by these models, but we also use them to test for possible structural change, either in the NAIRU (non-accelerating inflation rate of unemployment) or in the responsiveness of wage and price inflation to changes in the various determinants of inflation included in the models.

To preview the results, our analysis of OECD forecast errors is indicative of persistent overpredictions of price inflation for many - although not all - of the countries included in our sample; especially large forecast biases are evident for the United States, Canada and Australia. In contrast to the results for prices, little bias is evident in the OECD forecasts of wage inflation, with the notable exception of Japan. For most countries, the combination of the forecast errors for wages and prices implies that *real* wage growth was unexpectedly strong during the 1990s and that the major *sources* of the forecast errors are likely to be located in that part of the Phillips curve framework which models firms' prices as a mark-up on costs. Thus, the unexpectedly slow rise in prices relative to wages could indicate that firms have benefited from favourable supply shocks or that they lost pricing power during the 1990s in that they were not able to fully pass on wage cost increases into their prices. In contrast, the part of the Phillips curve framework that models wages as a function of labour market slack and the expected rate of inflation seems to contain fewer systematic errors.

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[2] The countries included in our analysis were selected because of the participation of their central banks in the workshop.

[3] See Batchelor (2000), who analyses the accuracy of forecasts for the Group of Seven countries made by the OECD, the IMF and the consensus of private sector economists published by Consensus Economics. While the private sector forecasts appear to be more accurate than those made by the OECD and the IMF, all three groups have tended to overpredict inflation in the 1990s.

We also compared the forecast errors for wage and price inflation with the levels and forecast errors for some of the standard determinants of inflation. In particular, we first analysed the correlation matrix of these forecast errors, but found no dominant explanation for the OECD's overly pessimistic view of inflation pressures in the 1990s. Larger than expected declines in relative import prices seem to be a relevant explanation for some countries. However, a number of countries for which the bias in the OECD inflation forecasts was small also benefited from lower import prices. For other countries, an acceleration in productivity appears to be an important factor, while in still others, errors in forecasts of the GDP gap and/or the unemployment rate appear to play a role. We also regressed the forecast errors directly on the exogenous determinants of inflation to test for structural changes. Again, the results varied across countries. Although there was evidence of some structural change in most cases, the specific nature of the parameter changes differed considerably, ranging from a step-down in the average rate of inflation to changes in the responsiveness of wages or prices to supply shocks or cyclical influences.

Turning to our own specifications, the estimated models for consumer prices consistently overpredict inflation in nearly every country. Nonetheless, there is little statistical evidence of parameter instability in these models. The one exception is a decline in the intercept term in the 1990s, a finding indicative of structural change but, unfortunately, not particularly helpful in identifying the source of the change. In contrast to the price models, the cumulative forecast errors from our models of wage inflation are negative in some countries but positive in others. Moreover, the parameters in about half of the countries appear to have changed during the 1990s, although no single coefficient stands out as particularly sensitive to the addition of the more recent data.

2. Alternative explanations of inflation developments in the 1990s

Recent characterisations of macroeconomic conditions have been influenced to a significant degree by developments in the United States, where inflation and unemployment fell simultaneously over much of the 1990s. Accordingly, many of the hypotheses advanced to explain this favourable economic performance emphasise the US experience and underweight important developments elsewhere in the industrialised world. That said, the following brief review also focuses mainly on explanations put forward with regard to the US economy, although we attempt to include, where appropriate, other hypotheses that seem more relevant elsewhere.

In general, the recent literature on this issue can be loosely classified into three broad categories.[4] The first includes arguments that the inflation process has irrevocably changed; on this view, the models that economists have traditionally used to forecast inflation are no longer applicable. At the other end of the spectrum are claims that recent inflation developments are easily explained in the context of standard inflation models as long as various one-time supply shocks are accounted for. The third category comprises those in the middle who argue that the underlying model of inflation still holds, but that some of the key parameters may have changed. Because this group is very large, it is useful to divide it into several subcategories, depending on the parameters of interest and the nature of the changes. For instance, some parameter shifts may at first glance seem permanent, but are in fact the manifestation of very long adjustment lags to either transitory or permanent changes in other variables.

Returning to the first category and the argument that the inflation process has irrevocably changed, such views often appear in the popular press with little explanation. But more serious proposals along these lines seem to have their roots in the way that information technology has altered traditional relationships between economic agents. For example, some proponents of this view cite DeLong and Froomkin (1999), who argue that recent technological advances in electronic commerce and data communications technology are leading to changes in how competitive markets function that may have important implications for firms' price setting behaviour.

[4] Although most of the players and the arguments are different, this debate in many respects resembles that of the late 1970s. At that time it was also postulated that because of structural changes (notably with respect to the modelling of expectations) the inflation process had fundamentally changed and the Phillips curve had broken down. Others, however, argued that as long as one-time supply shocks were taken into account, the Phillips curve was still alive and well.

Regarding claims that recent inflation developments are easily explained in the context of the standard models of inflation, Rich and Rissmiller (2000) argue that a traditional Phillips curve model tracks US inflation quite well during the 1990s and that a significant decline in import prices in that period is the main source of the deceleration in prices. However, according to others, the decline in relative import prices does not fully explain the decline in US inflation. For instance, Brayton et al (1999) find that an equation including changes in relative import prices still tends to overpredict inflation, and the same is true for our own estimates presented in Section 4.[5] Similarly, Gordon (1998) suggests that, in addition to import prices, a substantial portion of the deceleration in prices is due to a combination of unusually sharp declines in computer prices, extremely modest growth in the cost of medical care, and a reduction in measured inflation relative to true inflation. Gordon further notes that the decline in US inflation is not surprising given changes in capacity utilisation over the period. Leaving aside ambiguities about the precise size of the shocks, one implication of these explanations is that the shocks generating the favourable inflation outcomes may well be transitory and subject to reversal. This contrasts sharply with the polar "new economy" view that low inflation represents a more fundamental change in wage and price setting behaviour.

It is helpful to organise a review of the alternative explanations of inflation developments in the third category around the standard reduced-form equations for price and wage inflation:

$$\Delta w_t = \mu + \chi \sum_i (U - U^*)_{t-i} + \sum \delta_j \Delta w_{t-j} + \phi z_t + \eta \qquad (1)$$

$$\Delta pc_t = \alpha + \beta \sum_i Gap_{t-i} + \sum_j \varphi_j \Delta pc_{t-j} + \gamma z'_t + \varepsilon_t \qquad (2)$$

where Δpc and Δw denote price and wage inflation respectively, Gap denotes the output gap, U-U* is the unemployment gap (with U* a measure of the NAIRU), *z* and *z*' are supply side disturbances, and *i* and *j* are lags in years.

At its simplest level, the third category would include the argument that the NAIRU has declined in recent years.[6] Such a decline is variously attributed to a number of sources, including the impact of technological change on productivity growth. While the consensus view is that higher productivity growth has helped to keep inflation low and thus prolonged the expansion in several countries, it is debatable whether its impact on the NAIRU is permanent or just the result of very long adjustment lags. As pointed out by Blanchard and Katz (1997), productivity growth is neutral with respect to the NAIRU in the long run if wage aspirations and reservation wages adjust to the change in productivity growth. However, experience suggests that this adjustment is rather slow, so that if prices are set as a mark-up on unit labour costs, price inflation will be lower during a period of adjustment, with the slowdown most likely to be reflected in a lower intercept term (α).[7] Alternatively, since the output level associated with stable inflation temporarily increases, the effect of higher productivity growth may be seen as a decline in the sensitivity of price inflation to the output gap (β).

Another popular explanation for the recent good inflation performance involves increased globalisation and an associated rise in competition in both national and international markets. To the extent that these changes are permanent, they might affect most of the parameters in the above equations. For

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5 When using the impact coefficients from our own equations to estimate the contributions of import shocks (incorporating the effects of lower foreign prices as well as movements in exchange rates) to domestic inflation, we find particularly large effects for the United States and the United Kingdom, most notably during the latter half of the 1990s. For the other six countries, the decline in price inflation during the late 1990s mainly appears to reflect domestic factors.

6 Although we have placed Gordon (1998) in the previous category, he also finds some decline in the NAIRU even after making adjustments for the five supply shocks he considers. Changes in labour markets, such as the increased use of temporary workers and a higher rate of incarceration of previously unemployed individuals (Katz and Krueger, 1999) have also been mentioned as sources of changes in the NAIRU in the United States, as has hysteresis (Ball, 1999).

7 The adjustment lag can perhaps be partly attributed to the difficulty of identifying the nature and size of changes in productivity growth. For instance, efficiency gains obtained through job cuts or the elimination of non-profitable firms and activities will not have the same effect on real wage claims as technological progress. In addition, since a change in aggregate productivity gains often results from staggered shifts in the level of output per hour in individual firms or sectors, an alternative way of capturing the adjustment process would be to augment the wage equation with an error correction term written as $\theta \log((W/P)/Q)_{t-1}$, where Q denotes the level of productivity and θ is negative. Price and wage equations with error correction terms are discussed at greater length later in this section as well as in Section 4.

instance, the sensitivity of domestic prices and wages to changes in relative import prices (γ and ϕ) would be likely to increase. Moreover, a tendency for increased competition to curb firms' and wage earners' real income aspirations might be reflected in a reduction of the intercept terms α and μ or, perhaps, in lower sensitivities to domestic market conditions (β and χ).

Structural policies and an associated greater influence of market forces comprise another set of explanations for the disinflation of the 1990s. In theory, such policies can improve the growth-inflation trade-off through several interdependent channels (Dicks, 2000), but in practice, this explanation is probably more relevant to the European countries in our sample than to the United States (Siebert, 1997).[8] As labour markets are freed up, one would expect a greater influence of market forces to lower the NAIRU and possibly increase the sensitivity to labour market slack (χ). Similarly, in less regulated product markets the output level associated with stable inflation would probably increase. Moreover, the demand curves facing each firm are likely to be more elastic, encouraging or forcing firms to lower their mark-ups. In practice, however, the effects of structural policies overlap with many of the hypotheses considered above and they are also difficult to quantify. In addition, since the short-run effects of deregulation and other structural measures on the real economy are frequently negative, the time horizon over which the policies and their effects are analysed is of particular importance.

As highlighted in several other contributions, the coefficients in the typical forecasting equations may, in part, depend on the level of inflation, though the sign of this influence is ambiguous. According to Ball et al (1988), Lucas (1972) and Hutchison and Walsh (1998), nominal rigidities tend to increase when inflation declines. However, more recent proponents of this view have argued that, in a low-inflation regime, the sum of the coefficients on the lagged inflation terms ($\Sigma\varphi_j$ and $\Sigma\delta_j$) tends to be less than unity. This would imply that forecasts should be based on the "old-fashioned" downward-sloping Phillips curve rather than on an equation with a long-run vertical slope. For example, Taylor (2000) argues that the erosion in firms' pricing power during the late 1990s mainly resulted from a decline in the persistence of inflation in a low-inflation regime. This lower persistence is likely to have raised the elasticity of the demand curve facing firms and forced or encouraged them to reduce mark-ups. Moreover, in a less persistent inflation environment, firms may reduce the pass-through of costs into their own prices, which would be reflected in a smaller coefficient on past inflation.[9] In a low-inflation economy, agents may also view exchange rate changes as mainly transitory, with the result that domestic prices become less sensitive to exchange rate shocks. Indeed, several event studies (the United Kingdom and Sweden following the ERM crisis in 1992, Australia in the aftermath of the Asian crisis and Brazil in early 1999) suggest that the pass-through of exchange rate changes may have fallen in the 1990s.

Others have focused on the process determining expectations of inflation or on the way in which agents react to such expectations. For instance, Roberts (1997) finds that the expectation formation process is not entirely rational. Akerlof et al (2000) go one step further by arguing that workers and firms do not fully utilise information about inflation in determining wages and prices during periods of persistently low inflation. Their hypothesis is supported by empirical estimates and results in dynamics that are very similar to those highlighted by Taylor and thus deviate importantly from the traditional accelerationist models of the inflation process.[10] The regime dependence of the coefficients is also evident in Brainard and Perry (1999), who specify a model of US inflation that allows for time variation

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8 In the United States, many regulations were removed during the 1970s and 1980s, while UK product and labour markets underwent major deregulation during the 1980s. In contrast, markets in most continental European countries were still subject to various regulatory constraints and rigidities through much of the 1990s. However, there are signs that some of these constraints are being removed or have lost their effectiveness. For instance, several countries have eased working hour regulations, and companies are increasingly taking advantage of these measures to introduce more flexible labour contracts. Thus, the proportion of both temporary and part-time jobs in the EU countries increased sharply during the 1990s, with temporary job contracts particularly prominent in Spain and part-time jobs in the Netherlands. Moreover, the output growth required to keep the rate of unemployment stable in the euro area seems to have declined significantly during the 1990s, though the precise source of this change is unclear and probably differs across member countries (Schnabel, 2000).

9 In Taylor's model, a profit-maximising firm sets its optimal price as $x_t = .125\ \Sigma(Et\ c_{t+i} + E_t\ p_{t+i} + E_t\ \varepsilon_{t+i})$, with c denoting marginal costs, p prices of other firms, ε a random error, E expectations and i = 0…3. If c*t* (or p_t) follows a simple first-order regression ($c_t = \rho c_{t-1} + \mu_t$), the pass-through or mark-up coefficient would be $.125\ (1 + \rho + \rho^2 + \rho^3 + \rho^4 + \ldots)$. Consequently, less persistence (ie a lower ρ) will lead to a lower pass-through. See Taylor, op cit, pp 10-11.

10 The model has the further implication that the unemployment rate associated with the optimal level of inflation is lower than typical measures of the NAIRU.

in several of the key parameters and find that the estimated coefficient on lagged inflation declines substantially in the 1990s.[11]

Finally, Brayton et al (1999) focus on changes in the price mark-up in explaining US inflation during the 1990s. By augmenting a traditional Phillips curve with an error correction term, measured as the inverse of real unit labour costs, they find evidence of an unusually high price mark-up during the 1990s, and argue that this factor, rather than a falling NAIRU, explains much of the disinflation over the last decade. Similarly, Gali et al (2000) rely on a mark-up model in analysing inflation in the euro area. While their model successfully explains price inflation, it does so by making prices conditional on labour costs rather than on economic activity, whereas in the model by Brayton et al both determinants are present. As noted by Roberts (1999), however, this splitting of the Phillips curve into a price and a wage component entails a risk that the former is well explained while developments in the latter (and potential sources of prediction errors) may not be given sufficient attention.

All in all, the range of potential explanations reviewed in this section highlights the uncertainty faced by policymakers in assessing current inflation risks and provides the motivation for the remainder of this paper. However, it should be stressed that while trying to distinguish between various explanations is intuitively appealing, such distinctions are often difficult to verify empirically. This is particularly true when considering the different implications of transitory influences and permanent changes and it is especially relevant to the 1990s, when a number of favourable supply shocks occurred more or less simultaneously with other, more permanent changes. While a model would ideally allow for the influence of both structural shifts and transitory supply shocks, this is rarely possible in practice and is particularly difficult when the sample period is very short. Nonetheless, we will attempt to highlight patterns that seem to us relevant to the question of whether the behaviour of inflation changed in the 1990s in the eight countries under consideration and, when it did, of the extent to which such a change was the result of structural developments as opposed to temporary and potentially reversible supply shocks.

3. Forecast errors in the 1990s

a. The OECD forecasts

In this section, we analyse the size and sign of inflation forecast errors, using forecasts of wage and price developments made by the OECD. These forecasts are prepared twice each year and presented in the semiannual *Economic Outlook*. For the purposes of this study, we take the forecasts for the following year as of June of the current year and compare them to the actual outcome as currently published.[12] Throughout this section, we measure forecast errors as *forecast* less *outcome* so that a positive error indicates that inflation has been overpredicted.

We should emphasise that we have not chosen this source with the intention of criticising the OECD forecasting procedures and record. On the contrary, the OECD forecasts offer several advantages over possible alternatives. For example:

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[11] When they apply a Kalman filter procedure that uses all observations in the sample period (1965-98), both the intercepts and the coefficients with respect to the unemployment gap are remarkably stable. In contrast, the sum of coefficients on lagged inflation varies significantly over the sample period, in the case of wage inflation rising from about 0.35 in the mid-1960s to around 0.55 in 1980 and then dropping to just above 0.30 in the late 1990s. For price inflation the change is equally pronounced, with the influence of lagged inflation increasing from just below 0.60 in the 1960s to 0.80 in 1980 and then dropping to just above 0.40 by the end of the sample period.

[12] To be more precise, the forecasts for year t refer to those made by the OECD in June of year t-1, while the outcomes for year t are those reported in the Economic Outlook as of June 2000. This differs from other evaluations of forecasts, which typically measure outcomes as of the data reported at time t. Given that we are interested in the sources of the forecast errors rather than the quality of the forecasts, we view our definition - which takes the revised data as the best measure of the true outcome - as the most relevant comparator to the forecast values. However, the results in this section were qualitatively similar when the forecast errors were defined using the outcomes as of year t.

- They provide a consistent set of time series with few breaks and virtually no changes in the dates of the forecasts;
- They include forecasts of a number of additional variables that may be relevant when searching for possible sources of errors;
- Forecast errors made by the OECD are generally of the same magnitude as those made by other international institutions, for instance the IMF and the European Commission;
- Given the semiannual meetings of forecasters held at the OECD, the forecasts presented in the *Economic Outlook* are fairly representative of official forecasts for individual countries.[13]

b. Properties of the inflation forecast errors

Tables 2 and 3 present the forecast errors for the period 1991-99 for changes in the consumption deflator (Δpc) and compensation per employee in the business sector (Δw) respectively. The tables are organised to show four standard measures used in forecast evaluation: accuracy, bias, efficiency and serial correlation. However, as we are primarily interested in the extent to which conventional forecasts overpredicted inflation during the 1990s, we shall focus on the bias and efficiency statistics.

Turning first to the results for price inflation (Table 2), the mean errors indicate that consumer price inflation was overpredicted in all of the eight countries we analyse except for Spain and the United Kingdom. Especially large and statistically significant mean errors are evident for Australia, the United States and Canada. In each of these countries, the U^M statistic indicates that 50% or more of the total mean squared error is due to the bias in the forecast. Moreover, as indicated by the % > 0 line, the forecasts were too high for at least eight of the nine years considered. In spite of smaller average prediction errors, the forecasts for several other countries also exhibit a tendency to overpredict inflation. In particular, the forecasts for Japan, Sweden and Switzerland were too high more than 75% of the time, possibly indicating that systematic errors in the forecasting procedure were also present for these countries.

The existence of bias in the inflation forecasts for some countries also raises doubts about the efficiency of these forecasts. In particular, an optimal forecasting procedure would yield forecast errors with specific, well defined properties that can be derived through an optimisation problem. This can be illustrated by assuming a linear relationship between the forecasts (y^f) and the outcomes (y):

$$y_t = \alpha + \beta y_t^f + \varepsilon \quad (3)$$

and rearranging this with the forecast error as the left-hand variable:

$$y_t^f - y_t = -\alpha + (1-\beta) y_t^f + \varepsilon \quad (4)$$

From this characterisation, the optimality conditions are seen to be consistent with the usual statistical criterion for minimising the sum of squared errors and can thus be stated as:

$\alpha : E(y_t^f - y_t) = 0$ and

$1-\beta : E((y_t^f - y_t) y_t^f) = 0$

where *E* denotes expected values. The first condition requires the average forecast errors to be zero; in other words optimal forecasts should be unbiased. According to the second condition, the forecasts should also take account of all existing information. A necessary condition for this to be satisfied is that (1-β) = 0. In addition, current forecast errors should not repeat past errors, so a further requirement for

[13] As an illustration, Table 1 shows forecasts and outcomes for the US Federal Open Market Committee (FOMC) and the OECD respectively. While the average forecast error for the OECD (0.8) is almost twice as high as that of the FOMC (0.45) both institutions tended to overpredict inflation in the 1990s.

efficiency is that the forecast errors are not serially correlated; we test for this using the Ljung-Box Q-statistic.[14]

Given that unbiasedness is a necessary condition for efficiency, it is not surprising that the forecasts for the three countries for which the mean error is positive and statistically significant are also not efficient. However, despite the small average errors, it also appears that the OECD forecasts for Switzerland are inefficient. In contrast, there is no evidence of either inefficiency or serial correlation in the OECD forecasts of inflation for the other four countries.

Some additional insights can be gleaned from the pattern of forecast errors shown in Chart 1. For example, while the average forecast errors for Sweden and Switzerland are rather small, each of these countries shows sizeable negative errors early in the 1990s, followed by a string of positive errors over the remainder of the decade. Similarly, for Japan, positive errors for much of the decade are largely offset by a large negative error in 1997, presumably because the introduction of a sales tax pushed up inflation by more than predicted by the OECD. Even for Spain, the underprediction of price inflation is mostly confined to the early part of the decade; in more recent years, the OECD has tended to overpredict inflation, although the errors are relatively small. With regard to the United States and Australia, the OECD forecasts show no obvious tendency to improve or worsen, while the errors for Canada, albeit still generally positive, have mainly fallen over time.

Turning to the OECD forecasts of wage inflation (Table 3), the largest average errors are observed for Japan and Australia, which are also the only countries for which the mean is statistically different from zero. Indeed, according to the measures we report, there is little evidence of a significant bias in the wage forecasts in any of the other six countries. Nonetheless, although the average forecast errors for the United States and Spain are relatively small, the pattern of errors in both countries fails the efficiency test. Among the other countries, forecast errors for Canada are predominantly positive, albeit small, while the forecasts for the United Kingdom, Sweden, and Switzerland satisfy all of the standard optimality conditions.

As shown in Chart 2, the forecast errors for compensation growth exhibit some interesting patterns. In the United States and Switzerland, for example, the OECD tended to overpredict compensation growth during the first half of the 1990s, but more recent forecasts have shown no upward bias despite the persistent positive errors in price forecasts. A similar pattern of positive errors in the first half of the 1990s is evident for Canada and the United Kingdom, although in the latter case the OECD has consistently underpredicted wage growth in recent years. Among the other countries, the forecasts for both Japan and Australia are consistently too high throughout the decade, while a tendency to underpredict wage growth in Spain in the early part of the 1990s gave way to persistent overpredictions beginning in 1994.

For the majority of countries in our sample, there seems to have been a greater tendency by the OECD to overpredict price inflation than wage inflation, a pattern that is especially apparent when the early 1990s are excluded from the time period we consider. Taken alone, and assuming that the OECD forecasts are representative of mainstream expectations, our analysis of the OECD forecast errors supports some explanations for the favourable performance of inflation in the 1990s more than others. In particular, in the absence of clear evidence of persistent positive errors in the wage forecasts, it is difficult to argue that there have been NAIRU declines associated with labour market changes that were larger than those expected by the OECD forecasters. In contrast, the upward biases in the forecasts for price inflation in many countries arguably point to a role for unanticipated supply shocks of the type emphasised by Gordon (1998) and Rich and Rissmiller (2000) or for globalisation and associated pressures on the mark-up, as suggested by Brayton et al (1999) and Taylor (2000). Of course, the absence of a consistent pattern of forecast errors across countries raises some questions about these interpretations, although the primary exceptions (Japan and Spain) appear to have been unduly influenced by atypical domestic developments.

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[14] This concept of efficiency is a relatively weak one in that it excludes a test of whether the information contained in other variables has been used. In addition, as the regression estimates of α and $(1-\beta)$ are likely to be correlated, a joint test of their significance is required. Interested readers are referred to Wallis (1989) and Barrionuevo (1992) for additional information.

c. A decomposition of the forecast errors

To investigate whether unexpected, but now identifiable, supply shocks were an important contributor to the surprisingly low inflation rates of the 1990s or whether the forecast errors tend to be more closely associated with changes in the parameters of the underlying structural model, we decomposed the OECD forecast errors into two separate components. In particular, letting the subscripts *f* and *a* denote the forecast and actual values respectively, we assume that the process used by the OECD to generate the forecast value of inflation (*y*) can be represented as:

$$y_f = \alpha_f + X_f \beta_f \tag{5}$$

where *X* represents the vector of exogenous variables used in the forecasting procedure. Similarly, the process generating the outcomes is assumed to be represented as:

$$y_a = \alpha_a + X_a \beta_a \tag{6}$$

The forecast error is the difference between these two equations:

$$y_f - y_a = (\alpha_f - \alpha_a) + X_f \beta_f - X_a \beta_a \tag{7}$$

which can be rewritten as:

$$y_f - y_a = (\alpha_f - \alpha_a) + X_a(\beta_f - \beta_a) + (X_f - X_a)\beta_f \tag{8}$$

The first two terms on the right-hand side of this equation provide an estimate of how the parameters generating the outcomes differ from those generating the OECD forecasts and can be thought of as an approximation to structural changes that have led to errors in the inflation forecasts. The last term provides an estimate of the extent to which errors in OECD forecasts of the exogenous variables contributed to the forecast errors.[15]

Can forecast errors in other variables explain the overprediction of inflation?

Because we have only nine observations with which to work, we examine the two major pieces of this decomposition separately. We consider first the potential effects of errors made by the OECD in its forecasts of variables that could be considered inputs into standard models of wage and price inflation. For instance, if import price inflation is overpredicted and import prices enter the price equation with a positive coefficient, this might explain an overprediction of consumer prices as well. Similarly, on the assumption that prices are set as a mark-up on unit labour costs, an underprediction of labour productivity growth would contribute to an overprediction of price inflation. In contrast, underpredicting labour productivity growth might be expected to cause an underprediction of wage inflation if workers alter their wage aspirations in response to rising productivity. Forecast errors for the degree of slack could also influence inflation forecasts. For instance, if the rate of unemployment were overpredicted, either wage or price inflation might be expected to be underpredicted, giving rise to a *negative* partial correlation between the prediction errors. Conversely, if the output gap turns out to be larger (ie more negative) than predicted, the forecast error on inflation would also be positive, generating a *positive* partial correlation between the errors.

In Table 4 we present the average values and forecast errors over the 1991-99 period for the four exogenous variables considered. The strongest evidence for the supply shock hypothesis comes from the fact that the OECD, on average, overpredicted import price inflation in every country during the 1990s. Similarly, average productivity growth was underpredicted (negative forecast errors) for the United States, Australia and Sweden; in contrast, there are large positive and significant forecast errors for productivity growth in Japan and Switzerland. Finally, in all countries, the OECD

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15 This procedure obviously makes strong assumptions about the relationship between the OECD forecasting procedures and the data-generating process. In particular, we are implicitly assuming that the forecasts and outcomes are both generated by the same set of variables so that there are no omitted variables. In addition, characterising differences in the parameter values as structural changes implies that the OECD estimates of the parameters at the time the forecasts are prepared represent the true values for the period prior to the forecast. Moreover, as Andersen (1997) notes, it is generally not possible to definitively identify the sources of forecast errors in the framework we are using. For these reasons, the results in this and the following subsection are intended to be suggestive rather than explicit tests of particular hypotheses.

underpredicted the unemployment rate (negative forecast errors), although only five of these countries show a commensurate positive forecast error in the degree of output slack.

As a more formal method of assessing the importance of these factors, Table 5 presents bivariate regressions of the forecast errors in price and wage inflation on the forecast errors for the four exogenous variables, along with regressions of the errors in the price forecasts on the errors in the wage forecasts and vice versa. Interestingly, there are only two cases (Canada and Australia) where forecast errors for price and wage inflation are significantly and positively correlated. In contrast, a positive correlation between forecast errors for import prices and consumer prices is evident for most countries. Indeed, given the size of the change in import prices and the associated forecast errors shown in Table 4, the surprising weakness in import prices appears to have been an important source of the overpredictions of price inflation.

The results also support the hypothesis that unexpectedly strong productivity growth contributed to the overprediction of inflation in some countries. In particular, in both the United States and Australia, the OECD underpredicted productivity growth in the 1990s, and in both countries, this underprediction appears to be associated with the positive forecast errors for price inflation. The correlation between the forecast errors for productivity and price inflation is also negative and statistically significant in Japan, although in this case, an overprediction of productivity is systematically related to an underprediction of price inflation.

Turning to the regressions of forecast errors of wage and price inflation on forecast errors of unemployment, we find three countries (the United States, Japan and Australia) with the expected negative correlations but also two cases (the United Kingdom and Spain) with a positive correlation. For the gap measure, positive and significant coefficients were found for the United States and Japan, which are consistent with the results for unemployment. However, we again find coefficients of opposite sign for the United Kingdom and Spain. In addition, the results for the United States are consistent with the traditional view that wages are more sensitive to utilisation rates than prices.

To what extent do these correlations of forecast errors "explain" the overpredictions of inflation during the 1990s? Focusing on those countries for which Tables 2 and 3 suggested a systematic overprediction, we would summarise the results in Tables 4 and 5 as follows:

- For the *United States*, a faster rate of decline in import prices than expected by the OECD and a faster rate of productivity growth both appear to have been important sources of the overprediction of price inflation. However, there are two caveats we would add to this interpretation. First, much of the rapid decline in import prices over the period occurred in imported investment goods and thus is only indirectly linked to consumer price inflation. This suggests that some of the correlation between falling import prices and consumer price disinflation may be coincidental. Second, the results indicate that the underprediction of productivity growth contributed both to the overprediction of price inflation and the underprediction of wage inflation in the 1990s. In other words, while external shocks are important to the US inflation story, it appears to be productivity shocks rather than import prices that have been the driving force.
- For *Australia*, a very similar picture emerges, as productivity growth in the 1990s seems to have been significantly underpredicted and this was transmitted into an overprediction of consumer prices. It also appears that the interaction between price and wage inflation is an important part of the disinflation process and of the inaccuracy of the forecasts, as the bivariate correlation of the forecast errors for wages and prices is sizeable and statistically significant.
- For *Japan*, higher than expected import price inflation contributes the most to the overprediction of price inflation. The forecast errors for productivity growth are significant but, in contrast to the two countries discussed above, productivity growth has been overpredicted. This helped to reduce the overprediction of price inflation in that country, but also contributed to the overprediction of wage inflation. In addition, the OECD tended to underpredict the unemployment rate during the 1990s, which also added to the positive forecast errors for wages.
- For the *United Kingdom*, the results are difficult to relate to specific hypotheses discussed in Section 2. In particular, price inflation was underpredicted slightly despite a tendency by the OECD to overpredict the degree of slack during the 1990s. Some overprediction of productivity, however, may be one source of the negative forecast errors for inflation.

- For *Canada*, a more negative than expected output gap and a positive correlation between price and wage inflation appear to be the primary sources of the forecast error for price inflation.
- For *Spain*, we find a significant positive correlation between forecast errors for productivity growth and wage inflation. This could potentially explain the overprediction of the latter, even though the average forecast error for productivity growth is very small. On the other hand, the underprediction of slack in both labour and product markets, coupled with the correlations shown in Table 5, implies a tendency to underpredict inflation.
- For *Sweden*, part of the overprediction of price inflation can be explained by an overprediction of import prices. At the same time, while productivity growth appears to be significantly underpredicted in Table 4, the corresponding bivariate regression coefficients are small and insignificant. Similarly, the rise in the estimated degree of slack (as measured by the output gap) and the associated forecast error do not seem to have contributed to the forecast errors for inflation.
- For *Switzerland*, a steeper fall in import prices than predicted by the OECD contributed to an overprediction of price inflation, as did the overprediction of wage inflation combined with relatively strong price-wage interaction effects. With regard to wage inflation, part of the positive bias appears to be related to an underprediction of the unemployment rate.

Evidence of structural change

As indicated above, an alternative potential source of forecast error are structural changes that alter the coefficients in the implicit model used by the OECD to forecast inflation. In particular, even if the OECD correctly forecast the exogenous variables, forecast errors might arise if there are changes in the responsiveness of inflation to these factors.

To test for this possibility, we regressed the forecast errors on the observed values of import prices, productivity growth, unemployment and the output gap. As suggested by the decomposition shown above, the parameters in these regressions are intended to represent estimates of the extent to which the actual parameters prevailing over the 1990s differ from those implicitly used by the OECD in making their inflation forecasts. As before, due to the paucity of observations, we used a set of bivariate regressions to assess the possibility of structural change rather than a single multivariate regression. Thus, these results, which are presented in Table 6, are again meant primarily to be illustrative.

Similar to the absence of a "smoking gun" in the correlations between forecast errors of inflation and forecast errors of the explanatory variable, there is no dominant parameter change evident in these results. However, in most countries, there are some coefficients that are suggestive of structural changes in the inflation process. In Australia, for example, the significant intercept coefficients provide some evidence of a shift in the average rate of both price and wage inflation over the 1990s, which could be interpreted as being associated with a decline in the NAIRU. The intercept term is also statistically significant for the price inflation errors in the United States, but given the absence of a significant effect on average wages and the evidence pointing to an increase in the response of wage growth to productivity growth, these results are more suggestive of a structural change involving the mark-up rather than of a fall in the NAIRU.

For other countries, the results are more difficult to interpret. For the United Kingdom, for example, there is no evidence of structural change in the parameters influencing price inflation, but substantial evidence of structural change in how wages are determined, although no single parameter dominates the results. In Japan, prices appear to have become more sensitive to the output gap and to import prices, while for wages, the intercept term points to a downward shift in the underlying pace of wage growth. For Spain, the estimates suggest that wage growth has become more responsive to productivity growth, which in turn has had a larger effect on price inflation. Finally, the results for Sweden point to a greater cyclical response in wages and a greater sensitivity of price inflation to import price shocks, while for Switzerland, there is evidence of a lower response of price inflation to changes in productivity as well as an increased sensitivity to changes in unemployment.

4. Structural changes, supply shocks and forecast errors

a. Some salient features of developments in the 1990s

As a preliminary to developing our own model-based tests of structural change, we first attempted to get a "feel" for such changes by looking at actual developments in indicators of activity and inflation (Table 7). In particular, we looked for evidence that the observed changes in price or wage inflation did not correspond to predictions based on standard Phillips curve relationships and for instances of changes in relative demand pressures in product and labour markets.

As indicators of resource utilisation, we use the log difference between actual and potential GDP (Gap)[16] as calculated by the OECD and the deviation of actual unemployment from our own estimates of the NAIRU (U*-U),[17] both measured as five-year averages for the three subperiods shown in the table. As indicators of inflation, we used the private consumption deflator and compensation per employee in the business sector; for both indicators, Table 7 includes two measures: the average rate of inflation for each five-year period (Δpc and Δw) and the change in the rate of inflation during each subperiod ($\Delta(\Delta pc)$ and $\Delta(\Delta w)$). The last two columns of the table give a sense of how the actual movements in the data correspond to the simple bivariate correlations implicit in simple Phillips curve relationships. In particular, a positive (negative) output gap might be expected to be associated with a rising (falling) rate of price inflation. Thus, a positive sign in the penultimate column ($\Delta(\Delta pc)$/Gap) of the table would indicate that the change in inflation is consistent with the hypothesised relationship, while a negative sign signals either that inflation has increased in a period when the output gap was negative or that inflation has fallen despite a positive gap. To identify possible asymmetries, the ratios are written in italics for periods of negative output gaps. The last column of the table contains a corresponding measure of the relationship between changes in the rate of wage inflation and labour market slack ($\Delta(\Delta w)$/(U* - U)). As with the product market measure, the ratio is constructed so that a negative sign is indicative of an unusual development, such as wage inflation falling (rising) when actual unemployment is below (above) the estimated NAIRUs.

For all countries, the early 1990s is the principal period of disinflation. Although declining rates of inflation are not surprising given that six of the eight countries recorded negative output gaps during this period, the degree of disinflation of both wage and price inflation is unusually large. This is particularly noticeable for the United Kingdom, Australia and Switzerland, but the decline in wage inflation in Spain and Sweden is also worth noting. Apart from the size of disinflation in these countries, the only "surprises" during the early 1990s were that both wage and price inflation declined in Japan and Spain, despite excess demand in both product and labour markets. For Japan, however, the OECD's estimate of the output gap is subject to a high degree of uncertainty, while in the case of Spain, the high rate of measured unemployment makes it difficult to derive a reliable measure of labour market slack, particularly for the 1990s, when measures deregulating the labour market were introduced.

While the early 1990s stand out as a period of disinflation with relatively few surprises, the second half of the 1990s contain several surprises but a relatively low degree of disinflation.[18] In terms of country-specific developments, the decline in price inflation in a period of excess demand in the product market is a main area of surprise for the United States, whereas wage developments are largely in line with predictions of a Phillips curve style relationship.[19] For Japan, the movements during 1995-99

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[16] It would have been preferable to use rates of capacity utilisation as a complementary or alternative indicator, but comparable utilisation measures are only available for some of the countries.

[17] Estimates of a time-varying U* were derived by applying a Kalman filter to an Okun's law relationship using the OECD's estimates of potential GDP. Thus for U<U* or excess demand in the labour market, the deviation will be positive and comparable to the Gap measure of conditions in the output market.

[18] For several countries (notably Japan and Switzerland), the low degree of disinflation is a "non-surprise" given that the rate of price inflation had already fallen to very low levels by the end of the 1990-94 period. In other countries (the United Kingdom, Canada and Australia), the decline in wage inflation may have slowed as actual rates of unemployment came closer to, or fell below, the estimated NAIRUs.

[19] Gordon (1998) makes a similar point.

largely correspond to the predictions of the Phillips curve: price inflation declined in the presence of a large and widening output gap while wages decelerated in response to rising unemployment. Nonetheless, the fact that the rate of disinflation did not increase as the output gap widened is surprising and might indicate a change in firms' price setting behaviour.

In the case of the United Kingdom, the principal period of disinflation was obviously the first half of the 1990s: price inflation declined by 5.5 percentage points despite a relatively small output gap, while wage inflation declined by almost 7 percentage points, even though the actual rate of unemployment was only slightly above the estimated NAIRU. Developments during the second period are similar to those observed for the United States. The main surprise is that price inflation declined further despite a positive output gap. In contrast, the acceleration of wages is in line with unemployment falling below the NAIRU.

For Canada, the changes observed in inflation and activity measures are in line with predictions from the Phillips curve for both the first and the second half of the 1990s, though the smaller degree of deceleration during the second half is worth noting.[20] As in the United Kingdom, the early 1990s were the principal period of disinflation in Australia. However, even though there were signs of excess demand in both product and labour markets during 1995-99, prices and wages continued to decelerate. The fact that wages also continued to decelerate in Spain, Sweden and Switzerland is less surprising, as actual rates of unemployment exceeded the NAIRU. Similarly, the continued decline in price inflation is in line with predictions from the Phillips curve as all three countries recorded relatively large output gaps.

b. Price and wage model forecast errors

We next turn to an evaluation of forecast errors from our own price and wage equations. Our procedure is as follows:[21]

- First, we estimated wage and price equations for the period 1960-90 using an error correction model allowing for wage-price feedbacks in both levels and first differences;[22]
- Second, when the error correction term was insignificant, we reestimated the equations and tested the homogeneity constraint implied by the assumption that wage and price inflation are I(1) processes;
- Third, when the price-wage feedback term in first differences was also insignificant, we estimated reduced-form price equations with and without the homogeneity constraint;
- Finally, the most satisfactory versions were used to make forecasts for the period 1991-99 and reestimated over the full sample period (1960-99) in an attempt to identify parameter changes as possible sources of forecast errors.

Price equations

The price equations estimated under the first step mentioned above were specified as:[23]

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[20] The behaviour of price inflation in Canada in part depends on the measure used. While the change in the private consumption deflator was largely constant during 1995-99, inflation measured by the GDP deflator declined by 0.6 percentage points. In contrast, during 1990-94 the GDP deflator decelerated by only 2 percentage points, compared with more than 3 percentage points for the consumption deflator.

[21] Before adopting this procedure, we tested the dynamic properties of the relevant variables, using an augmented Dickey-Fuller test. With the exception of Switzerland, the tests suggested that price inflation is an I(1) process, while wage inflation is found to be I(1) in all countries save Australia. As might be expected, the output gap is I(0) while actual unemployment tends to be I(1). However, when measured as a deviation from the NAIRU, unemployment also becomes I(0).

[22] For some countries, we had to derive our own estimates for the output gap in the 1960s, using a quadratic trend and the rate of unemployment, and then combine them with the output gaps published by the OECD.

[23] It is debatable whether the GDP deflator or the consumption deflator should be used in measuring real compensation. Since the price equation refers to consumer price inflation, we used the consumption deflator. We also estimated an alternative set of regressions, using changes in unit labour costs instead of compensation per employee. Significant coefficients of the expected positive sign were only found for Canada and Sweden, but only when the sample period was extended to include

$$\Delta pc = \alpha + \beta Gap_{-1} + \gamma \Delta pc_{-1} + \eta \Delta pc_{-2} + \varsigma \Delta w_{-1} + \lambda((w - pc) - q)_{-1} + \phi(\Delta pm - \Delta pc_{-1}) + \varepsilon \quad (9)$$

Where *pc* denotes the (log) private consumption deflator, *w* (log) compensation per employee, *q* (log) output per employed person, Gap the output gap, and *pm* (log) import prices. Subscripts refer to lags in years and Δ is the first-difference operator.

In equation (9), the coefficient on the error correction term (λ) is expected to be positive if a decline in real wages relative to productivity puts downward pressure on prices.[24] However, when λ was negative or insignificant, the price equation was specified as:

$$\Delta pc = \alpha + \beta Gap_{-1} + \gamma \Delta pc_{-1} + \eta \Delta pc_{-2} + \varsigma \Delta w_{-1} + \phi(\Delta pm - \Delta pc_{-1}) + \varepsilon \quad (10)$$

As the unit root tests frequently indicated that price inflation was I(1), we also estimated a variant of (10) constraining the coefficients on lagged rates of price and wage inflation to sum to unity (ie with $\gamma+\eta+\zeta=1$ imposed). Finally, in those cases where we were unable to identify any significant wage-price feedbacks, we dropped the lagged wage term for both the unconstrained and constrained versions of the model.

Before discussing the results from our preferred specifications, it is worth pointing out that estimates of (9) provided little support for the hypothesis that firms increase prices in response to a rise in real unit labour costs (or a fall in the mark-up). For five countries we obtained the "wrong" sign and in two cases the coefficient on real unit labour costs was insignificant, albeit positive. Only Sweden exhibited a positive and significant coefficient, although this result was limited to the longer sample period.

The estimates obtained from equation (10) also provided little evidence of wage-price feedbacks. In particular, statistically significant coefficients on the lagged wage terms were evident only for Japan, Switzerland and Spain.[25] In the case of Japan, the addition of lagged wage changes was a significant improvement compared with the results obtained from the price equations excluding this feedback. The diagnostic statistics were better and, above all, the tendency to overpredict was much lower. For Switzerland and Spain, we also obtained significant coefficients for the lagged change in wages, and the forecasts derived from this specification were fairly accurate. Overall, however, the results were less satisfactory than those based on the reduced-form price equations. Particularly for Spain, this finding is somewhat surprising as the deceleration of wages has been more pronounced than in most other countries; yet, lagged wage changes seem to have had only a marginal impact on the path of consumer prices.

As a result, with the exception of Japan, Table 8a only presents estimates for the reduced-form price equations. However, because there are major differences in their ability to forecast, we report results for both the unconstrained and the constrained versions of the model.

Turning first to the estimates for the unconstrained equations, the coefficients on the output gap range from 0.2 to 0.6 and are statistically significant for six of the eight countries. Except for Japan, where lagged changes in wages dominate lagged price changes, all the coefficients on the one-year lagged inflation term have significant t-values. In contrast, most of the coefficients on the two-year lagged inflation term are insignificant, though none of the t-values is less than unity. Changes in relative import prices, which were included as a proxy for supply shocks, are significant for all countries, and in several cases the coefficients are close to the import share of GDP. The autocorrelation statistics are not indicative of specification errors and the R^2s range from 0.7 to 0.95.

For the constrained version, the coefficient on the output gap is higher for five of the countries, but is somewhat lower for Switzerland and, especially, Australia. Most of the coefficients on the lagged inflation terms are negative and imply a slightly greater influence of one-year lagged inflation as compared with the unconstrained version; in the case of Japan, the influence of lagged changes in

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the 1990s. Finally, we experimented with longer lags on the determining variables in (9) but, with the exceptions of Australia (two-year lag on the output gap) and the United Kingdom (both current and one-year lagged changes in import prices significant), the lag specification shown in equation (9) worked best.

24 More particularly, since wages decelerated faster than consumer prices during the 1990s, leaving out the feedback from wages to prices might be a source of overpredicting price inflation. Moreover, as found by Brayton et al (1999) and Gali et al (2000), firms' pricing decisions seem to have been affected by deviations of real unit labour costs from their long-run trend.

25 Replacing compensation per employee with a measure of unit labour costs did not change this result.

real wages has the right sign but is not significant. The influence of relative import prices is relatively stable, the largest change being observed for Switzerland.

According to the F-statistics shown in the penultimate row of the table, the homogeneity constraint is rejected for five of the countries, most convincingly for those (Switzerland, the United States and Australia) where Δpc is (or is close to being) an I(0) variable. Nonetheless, except for the United Kingdom, the constrained version produces smaller forecast errors than the unconstrained version despite the fact that the constrained version assigns larger weights to past rates of inflation and that inflation decelerated during the 1990s.[26] This finding stands in contrast to the results reported by Stock and Watson (1999) who find that the unconstrained version of their model generates better forecasts for US inflation in the more recent years when inflation was low and close to being an I(0) variable.

Looking more specifically at the size of the forecast errors, Australia, Spain, and Canada show the largest cumulative errors for simulations based on the unconstrained equation, while those for Switzerland, the United States and the United Kingdom are quite small.[27] Together with Japan, these are also the only countries for which inflation is actually underpredicted for the 1990s once the homogeneity constraint is imposed.[28]

The parameters obtained when extending the sample period to 1999 are presented in Table 8b. For neither the unconstrained nor the constrained version of the price equation can the hypothesis of parameter stability be rejected for any country when the test is applied to all the parameters jointly.[29] Nonetheless, there are notable changes in the point estimates of the coefficients which may help to explain the forecast errors discussed above:

- For most countries, the intercept term declines when the sample is extended to include the 1990s. The decline is most pronounced for Australia and Spain; ie the two countries with the largest prediction errors in Table 8a;
- For both Japan and Australia, the influence of product market conditions declines significantly when the 1990s are included. In the case of Japan, this implies that the rise in the output gap since 1997 has had a smaller disinflationary (or deflationary) impact than suggested by historical patterns. For Australia, the rise in actual relative to potential GDP during the second half of the 1990s had a smaller impact on the rate of inflation than the historical estimates would have implied. Spain also experienced a decline, albeit small, in the gap coefficient while Canada shows a slight increase. For the other four countries, there were virtually no changes in the parameter on the output gap;
- As discussed earlier, there is some ambiguity with respect to the influence of lagged inflation in a low-inflation regime. The results obtained by extending the sample period to include the 1990s "straddle the fence" between the opposing views, as the sum of the coefficients on the lagged inflation terms change only marginally. The main exceptions are Australia and Switzerland, for which inflation persistence increases somewhat;

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[26] A marked drop in the intercept terms in the constrained equations accounts for a substantial part (largest for Switzerland and Australia and lowest for Canada and Spain) of the smaller overprediction for the 1990s. However, since we know little about the causes of this change, its contribution should be regarded as a quantification of our surprise rather than as an explanation.

[27] We also calculated forecast errors based on dynamic simulations. While this method increased the size of the errors, the ranking of the countries did not change.

[28] Using the unconstrained equation, it appears that the forecast errors for the United States and Australia were evenly distributed between the two halves of the 1990s, while for Japan, the United Kingdom, Canada and Spain the overpredictions were most pronounced during the first half, when the speed of disinflation was also most pronounced. The equation for Switzerland underpredicted inflation during the first half but overpredicted during the second half, while the errors for Sweden are dominated by an especially large miss in 1991. We also tested whether the tendency to overpredict increased as the rate of inflation declined by regressing the forecast errors on the actual rates of inflation. The hypothesis is confirmed for the whole sample period. However, when the regression is confined to the out-of-sample prediction errors, we only obtain significant and negative coefficients for Sweden and Switzerland.

[29] On the assumption that structural changes have taken place but that the source of the changes is not known, we also estimated the price equations allowing the intercept term to differ after 1990. For the unconstrained model, the coefficients on the dummy variable were always negative but statistically significant only for Australia, though the coefficients for Japan and Canada also obtained relatively high t-values. The coefficients for the constrained model were also mostly negative but never came close to being significant.

- The hypothesis that the parameters of the price equation may be regime-dependent is also not supported by the coefficients obtained for changes in relative import prices in the extended sample. Except for Sweden, for which the pass-through actually increases,[30] the coefficients remain remarkably constant, suggesting that the influence of changes in relative import prices in the 1990s was little different from that of earlier decades.

To sum up, when extending the sample period to 1999, the cumulative within-sample forecast errors for both the unconstrained and the constrained equations decline to only marginal levels and, except for Sweden, the principal parameter change contributing to this improvement is the decline in the intercept term. For the two countries with the largest forecast errors when using the shorter sample (Australia and Spain), the lower intercept terms would imply a cumulative reduction in the inflation forecasts of 4-8 percentage points. However, while these results are indicative of structural change, there is little information as to what might have caused this decline.

Wage equations

Similar to the procedure used for estimating price equations, we initially attempted to explain wage changes using a specification with an error correction term:

$$\Delta w = \alpha + \beta(U - U^*)_{-i} + \delta\Delta(U - U^*)_{-i} + \lambda((w - pc) - q)_{-1} + \sum_i \phi_i \Delta w_{-1} + \sum_j \varphi_j \Delta pc_{-j} + \varepsilon \quad (11)$$

with w denoting log compensation per employee, U-U* the deviation between actual unemployment and the NAIRU, pc the log private consumption deflator, q log productivity, Δ the first-difference operator, i = 1, 2 and j = 0, 1. On the assumption that employees will push for higher wages when their income share declines, the coefficient on the error correction term (λ) is expected to be negative. However, when λ was either positive or insignificant, (11) was reestimated without the error correction term:

$$\Delta w = \alpha + \beta(U - U^*)_{-1} + \delta\Delta(U - U^*)_{-1} + \sum_i \phi_i \Delta w_{-i} + \sum_j \varphi_j \Delta pc_{-j} + \varepsilon \quad (12)$$

Moreover, since the gap between actual unemployment and the NAIRUs is an I(0) variable and wage inflation in most countries is I(1), we also estimated an equation with consistent dynamic structures by forcing the coefficients on the lagged wage and price changes to sum to unity (ie with $\Sigma\phi_i+\Sigma\varphi_j=1$).[31] As with the constrained price equation, the dynamics of the inflation process are reflected in the lagged dependent variable while the lagged change in real wages captures potential feedbacks between price and wage inflation. However, in contrast to the price equations, for which we were able to use fairly similar specifications for all countries, it turned out to be far more difficult to find comparable wage equations. In several cases it was necessary to extend the lag structure on price changes in order to obtain specifications that did not suffer from autocorrelation. Moreover, for three countries, actual unemployment rather than the unemployment gap seemed to be the best indicator of labour market conditions.

The results obtained from applying the same four-step procedure as for price inflation are displayed in Tables 9a (shorter sample period) and 9b (extended sample period). In general, the cumulative forecast errors tend to be of the same size as for prices, though three differences compared with the price equations are worth noting. First, for about half the countries, the constrained equation does not generate lower forecast errors, even though the constraint is never rejected. Second, wage inflation for the 1990s is underpredicted in half the cases, while for price inflation, positive forecast errors were recorded for nearly all countries. Third, when the sample period is extended to include the 1990s,

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[30] This seems to be the principal reason for the lower forecast error for Sweden. However, the autocorrelation coefficients suggest that the equation is misspecified when the data sample includes the 1990s.

[31] On the assumption that wage demands may be influenced by expected developments in labour productivity, we also estimated equations including changes in output per person employed, smoothed by an HP filter. In all cases, the productivity term entered with a positive coefficient and for about half the countries it was also significant. However, in most cases, the overall fit was inferior to those of (11) and (12) and coefficients that were significant in (11) and (12) were less precisely estimated. The only exceptions were Japan and Switzerland, for which the addition of changes in productivity substantially improved the fit. However, as discussed below, even better results for these two countries were obtained when the influence of productivity developments was captured through the error correction term.

parameter stability is rejected (or is close to being rejected) for about half the countries; in contrast, the coefficients of price inflation were mostly stable.

Turning to the results for individual countries, the wage equation for the *United States* slightly underpredicts wage inflation in the 1990s. The homogeneity constraint is not rejected and the coefficients not only confirm the long lag structure found in other analyses of US wage inflation but also suggest that current wage inflation tends to rise in response to past declines in real wages (see also Gordon (1998)). When the equations are extended to include the 1990s, there are signs of parameter instability. In particular, the lag structure appears to have become shorter while the response of current wages to past changes in real wages increases somewhat. The intercept term also increases, perhaps indicative of stronger productivity growth and associated real wage gains, while the sensitivity to the unemployment gap is unchanged.

The unconstrained wage equation for the *United Kingdom* has the highest prediction errors in our sample, though the errors are concentrated in the first half of the 1990s, when the deceleration of wages was most pronounced. The imposition of the homogeneity constraint leads to a marked decline in the intercept term and a stronger reaction to changes in labour market conditions, significantly improving the accuracy of the predictions. Unlike the equations for the United States, the coefficients appear to be stable when the sample period is extended to 1999, although the tendency to overpredict remains. Another feature of the UK equation, and a possible source of the overpredictions, might be that the coefficient on the one-year lagged inflation rate exceeds unity. In a period of rapidly decelerating prices, this tends to keep wages growing faster than they otherwise would have done.

For both *Canada* and *Australia*, the actual rate of unemployment (lagged one year) produced better results than the unemployment gap. Nevertheless, a specification with U rather than U-U* raises several questions. First, such a specification implicitly assumes that U* has been constant over the period, in contrast to the pattern suggested by the NAIRUs calculated from the OECD output gaps. Second, there are issues about the correct modelling of the dynamic structures. If wage inflation is an I(1) variable, the unconstrained version of equation (12) would be the correct specification, assuming that Δw and U are cointegrated. Conversely, if wage inflation is I(0), an error correction term should be included (as in equation (11)) to ensure dynamic consistency.

For *Canada*, the empirical evidence favours the first hypothesis. Even though wage inflation is close to being I(0), the error correction term was insignificant and had the wrong sign.[32] In addition, equation (12) yields smaller cumulative forecast errors than for any other country. Moreover, there is no sign of parameter instability when the sample is extended to include the 1990s, possibly suggesting that the equation is capturing a cointegrating relationship between wage inflation and the rate of unemployment that is suppressed in the constrained version.

The estimates for *Australia* are considerably more problematic.[33] First, the dynamic response of wages to prices is highly erratic, with a large positive coefficient on the first lag of inflation and a large negative coefficient on the second lag. This pattern produces large prediction errors for individual years, with both the constrained and unconstrained versions of the model underpredicting wage inflation in the 1990s by a cumulative 19 percentage points.[34] Second, including an error correction term, as in (11), helped only little. The volatile dynamic structure remained and the coefficient on the error correction term was insignificant, though of the right sign. Third, while parameter stability cannot be rejected when the sample is extended to include the 1990s, the coefficient on the unemployment rate *does* decline substantially, and this change alone reduces the predicted wage changes in the 1990s by a cumulative 15½ percentage points. However, while the parameter shift is significant, it raises the question as to why, in a period of deregulation and a more flexible labour market, wage earners in Australia should have become less sensitive to changing market conditions. Indeed, the

[32] When the error correction terms were included together with (U-U*), we obtained a highly significant coefficient of the correct (negative) sign. However, U-U* still provided no explanatory power.

[33] We attempted to compare our estimates with those presented in Gruen et al (1999). However, their results are based on four-quarter changes of consumer prices and unit labour costs and the time profile of their estimates of the NAIRU is quite different from ours, making such comparisons difficult.

[34] We experimented with various lag structures for both wage and price inflation, but those shown in the tables produced the best diagnostic statistics as well as the smallest overall prediction errors.

downgrading of the Arbitration system and the greater role of bargaining at the firm level would seem to point to a *greater* sensitivity of wages to labour market developments.

Sweden is another country for which wage inflation in the 1990s is underpredicted and, again, the main source of the prediction errors appears to be parameter instability, with the largest shifts observed for the intercept term and the coefficients on the level of and changes in the unemployment gap. For the constrained version, these parameter changes alone "explain" 75% of the cumulative underpredictions. There is also some decline in the influence of current price inflation and lagged wages, but this changes the predictions only marginally.

The wage equation for Spain contains a relatively large autoregressive component which, combined with the sharp deceleration of wages in the 1990s, appears to be the main source of the overpredictions. The feedback from prices to wages is relatively moderate and, except for the intercept term, the parameters remain rather stable for the longer sample period. Although the homogeneity constraint cannot be rejected, the constrained version of (12) predicts less well and produces less satisfactory diagnostic statistics.

We next turn to the two countries for which the specification including an error correction term (equation (11)) produced the best results. In the case of Switzerland, adding the error correction term leads to a substantial improvement compared with the properties of equation (12), including a marked decline in autocorrelation and a dynamic structure that looks more plausible. Moreover, the unemployment gap is highly significant, the R^2 rises to 0.87, the cumulative prediction error is only 0.7 percentage points, and the parameter estimates change little when the sample is extended to include the 1990s.

At first glance, the wage equation for Japan also looks plausible when allowing for price-wage feedbacks. The error correction term is highly significant and the diagnostic statistics are satisfactory. Moreover, because real unit labour costs increased by almost 5% during the first half of the 1990s, significantly depressing wage demands later in the decade, wage inflation is underpredicted by a cumulative 7½ percentage points, compared with an overprediction of 14½ percentage points when using equation (12).[35] Yet, the addition of real unit labour costs is not entirely satisfactory. Even though the hypothesis of parameter stability cannot be rejected when the sample period is extended to include the 1990s and the within-sample forecast error is reduced to less than 3 percentage points, there are clear signs of parameter instability, as both the intercept term and the coefficient on unemployment become insignificant. Moreover, the coefficient on the error correction term increases (in absolute terms) to 24.7, almost twice the value obtained for the shorter sample.

5. Conclusions

An important and welcome feature of economic developments in the 1990s was the extent to which inflation fell in an environment of high or rising economic activity and tightening labour markets. At the same time, the fact that most forecasters underestimated the degree of disinflationary pressure during the decade raises questions about the appropriate stance of monetary policy. If the forecast errors mainly reflect the effects of favourable supply shocks but policymakers attribute them to permanent structural changes, there is a risk that monetary policy will be too expansionary and that the disinflationary gains will be lost. Conversely, if the unexpected declines in inflation are due to irrevocable changes in the inflation process but policymakers interpret them as only transitory, policies might be kept too tight, with a risk that potential gains in output and employment will not be realised.

In this paper, we first document the extent to which inflation was overpredicted in the 1990s, using a sample of eight industrialised countries and forecasts produced by the OECD as well as by our own models. According to both sources, the overprediction of inflationary pressures has been most pronounced for prices, whereas wage gains have been more in line with predictions based on traditional Phillips curves. This is an important finding as it suggests that the source of the forecast

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[35] The change in the sign of the prediction errors might be related to the fact that when including real unit labour costs as a determinant, the measured rate of unemployment (rather than its deviation from the NAIRU) appears to be the appropriate measure of labour market slack.

errors is mainly to be found in firms' price setting behaviour. At the same time, it leaves open the question of whether the implied reduction in firms' mark-ups reflect favourable supply shocks, such as lower relative import prices and one-time productivity gains, or a more permanent erosion of firms' pricing power due to other factors, such as globalisation and deregulation of product markets.

Consequently, the paper attempts to identify the sources of the apparent change in firms' price setting behaviour, relying again on forecasts made by the OECD and our own price and wage equations, and using a wide range of econometric and non-econometric tests. While we do find some evidence of structural shifts in the inflation process, in only a few cases are we able to identify the source of these shifts. Moreover, the significant changes that we find differ widely across the eight countries in their nature as well as their size. For instance, for the United States and Australia it appears that higher productivity gains are a main source of the tendency to overpredict price inflation. In contrast, the overpredictions of inflation in Japan and Switzerland seem to reflect movements in real unit labour costs (or mark-ups), which traditional Phillips curves tend to ignore. In the case of Sweden, favourable import price shocks appear to be the main source of overpredicting consumer price inflation while for the three remaining countries (the United Kingdom, Canada and Spain) we were unable to find any dominant cause.

In some ways, it is not surprising that we are unable to find a unique explanation of these forecast errors. While disinflation and monetary policies aimed at price stability were common to all countries during the 1990s, the accompanying cyclical developments progressively diverged. In the four English-speaking countries, economic activity tended to exceed earlier estimates of potential output levels, while continental Europe experienced a slow and moderate recovery from the recession in the early 1990s and Japan moved deeper into recession. The processes of deregulation also differed. In the United States, few regulations were left by the start of the 1990s, and the other English-speaking countries either took major steps to deregulate labour and product markets during the 1990s or had already done so during the late 1980s. In continental Europe, by contrast, progress has been much slower, and even though many rigidities have been removed, these changes have probably not yet affected the inflation process in a significant way. Finally, in Japan, major reforms have been announced but the implementation of reform measures has barely started. As a result, the influence of globalisation and developments associated with the new economy on firms' price setting behaviour is likely to have differed widely, being most pronounced in those countries that have gone furthest in liberalising their markets.

In addition to our inability to clearly identify and explain the sources of the changes we find, the paper leaves a number of other questions unresolved, some of which are also relevant to policies. One puzzling result is that the homogeneity constraints on the price equations are often rejected, and yet the constrained versions produce more accurate forecasts. Related to this, and of potential importance to forecasting procedures, we were unable to find any evidence of the regime-dependent changes in the parameters of the inflation process highlighted in recent empirical work. In particular, neither the OECD forecasts nor our own estimates suggest that economic agents tend to ignore inflation when it is very low or that the pass-through of import prices and other costs is smaller in a low-inflation environment. Another puzzle is that even though our estimated price equations tend to overpredict inflation in the 1990s, the parameters appear to be stable. In contrast, several of our wage equations show signs of parameter instability but produce forecasts that are less biased. Whatever the source of this inconsistency and despite the evidence pointing to changes in firms' price setting behaviour as the likely source of the forecast errors, it implies that in order to better understand the inflation process in the 1990s, it is important to look at both the price and the wage components of the Phillips curve framework.

Against this background, it is also not surprising that the empirical evidence we present does not clearly favour any of the alternative theoretical explanations of recent inflation performance discussed in Section 2, either for the eight countries as a group or for any individual country. In particular, even though parameter shifts and specific sources of forecast errors have been identified in a number of cases, we are unable to distinguish between one-time shock effects and permanent changes in the inflation process. This is unfortunate and disappointing from a policy point of view; however, it should not be regarded as a major surprise, considering that most of our evidence is based on only nine years of observations while the debate about shocks versus permanent changes is at least 25 years old.

Table 1

Forecast errors for US inflation

Year	OECD (PCE deflator)			FOMC (CPI)		
	Forecast	Outcome	Difference	Forecast[1]	Outcome	Difference
1991	4.6	3.8	0.8	4.1	3.0	1.1
1992	3.9	3.1	0.8	3.5	3.1	0.4
1993	3.2	2.4	0.8	3.0	2.7	0.3
1994	2.8	2.0	0.8	2.7	2.6	0.1
1995	3.1	2.3	0.8	3.1	2.7	0.4
1996	3.4	2.1	1.3	3.1	3.1	0.0
1997	2.3	2.0	0.3	2.9	1.9	1.0
1998	2.4	0.9	1.5	2.7	1.5	1.2
1999	1.7	1.6	0.1	2.2	2.6	– 0.4

[1] Based on the midpoint of the central tendency.

Table 2

Forecast errors for price inflation in the 1990s

Selected countries, 1991-99, annual data

	United States	Japan	United Kingdom	Canada	Australia	Spain	Sweden	Switzerland
Summary statistics								
MAE	0.80	0.53	0.58	0.67	1.36	0.57	1.23	1.00
RMSE	0.89	0.63	1.03	0.85	1.45	0.70	1.42	1.19
Bias measures								
Mean	0.80[2]	0.26	– 0.12	0.58[1]	1.36[2]	– 0.32	0.33	0.32
U^M	0.81	0.17	0.01	0.46	0.88	0.22	0.06	0.07
% > 0	1.00	0.78	0.33	0.89	1.00	0.33	0.78	0.78
Efficiency								
α	0.29	0.25	1.69	0.19	0.50	– 0.04	1.06	2.54[2]
$1 - \beta$	0.17	0.00	– 0.53	0.17	0.26[1]	– 0.07	– 0.20	– 0.95[2]
Joint F-test	17.30[2]	0.70	1.19	3.69[1]	46.16[2]	1.08	0.60	5.64[2]
Serial correlation								
Q(1)	6.55[2]	0.01	0.17	0.46	2.54	0.43	1.70	2.00
Q(2)	9.46[2]	3.78	0.36	0.65	2.68	0.65	3.84	2.19

Definitions*:* Price inflation is measured as the percentage change in the personal consumption deflator. Forecast errors are measured as forecast less outcome; ie a positive (negative) error indicates that inflation has been over-(under-)predicted. Notation: MAE = mean average forecast error; RMSE = root mean squared errors; mean = average forecast error; U^M = the proportion of the mean squared error due to the mean error; % > 0 = the proportion of years in which the OECD overpredicted inflation; α and $1 - \beta$ = coefficients obtained when regressing forecast errors for year t on an intercept term and the predicted inflation rate for year t; joint F-test tests the hypothesis $\alpha = 0$ and $\beta = 1$; Q(1) and Q(2) = Ljung-Box Q-statistics for 1 and 2 lags respectively.

[1] and [2] denote 90 and 95% levels of significance.

Table 3

Forecast errors for wage inflation in the 1990s

Selected countries, 1991-99, annual data

	United States	Japan	United Kingdom	Canada	Australia	Spain	Sweden	Switzerland
Summary statistics								
MAE	1.13	1.65	1.56	1.14	1.47	2.16	1.43	0.85
RMSE	1.24	1.87	1.85	1.56	1.71	2.49	1.64	1.08
Bias measures								
Mean	0.48	1.65[1]	0.39	0.34	1.21[1]	– 0.04	0.19	0.32
U^M	0.15	0.78	0.04	0.05	0.50	0.00	0.01	0.09
% > 0	0.55	1.00	0.56	0.89	0.89	0.67	0.44	0.56
Efficiency								
α	– 0.94	1.36	– 1.28	– 1.14	– 2.42	6.61[1]	– 2.69	0.69
$1 - \beta$	0.35	0.11	0.32	0.45	0.82	– 1.36[1]	0.64	– 0.12
Joint F-test	0.78	12.73[1]	0.41	0.45	7.15[1]	10.85[1]	1.19	0.51
Serial correlation								
Q(1)	0.00	1.18	3.10	0.24	0.57	2.34	0.24	0.19
Q(2)	0.00	2.59	3.12	0.32	0.97	2.51	0.13	0.28

Definitions: Wage inflation is measured as the percentage change in compensation per employee. Forecast errors are measured as forecast less outcome; ie a positive (negative) error indicates that inflation has been over-(under-)predicted. Notation: MAE = mean average forecast error; RMSE = root mean squared errors; mean = average forecast error; U^M = the proportion of the mean squared error due to the mean error; % > 0 = the proportion of years in which the OECD overpredicted inflation; α and $1 - \beta$ = coefficients obtained when regressing forecast errors for year t on an intercept term and the predicted inflation rate for year t; joint F-test tests the hypothesis α=0 and β=1; Q(1) and Q(2) = Ljung-Box Q-statistics for 1 and 2 lags respectively.

[1] Denotes a 95% level of significance.

Table 4

Exogenous variables: means (μ) and average forecast errors (ε)

1991-99, based on data as of June 2000

Country	Import prices (%Δ)		Productivity (%Δ)		Unemployment (per cent)		Output gap (per cent)	
	μ	ε	μ	ε	μ	ε	μ	ε
United States	– 0.9	1.6	1.8	– 0.6[2]	5.8	– 0.1	– 0.2	0.8
Japan	– 2.6	3.9	0.9	1.1[2]	3.1	– 0.3[3]	– 0.6	0.0
United Kingdom	0.3	2.0	1.9	0.3	8.2	– 0.1	– 0.6	– 1.2[3]
Canada	1.7	0.0	1.2	0.4	9.7	– 0.3	– 2.3	0.9
Australia	0.5	0.7	2.4	– 1.0[3]	9.0	– 0.2	– 0.4	– 0.7
Spain	2.5	0.1	1.5	0.1	20.0	– 0.1	– 0.5	0.4
Sweden	2.3	0.3	2.5	– 1.1[3]	6.7	– 0.7[2]	– 2.4	1.4[2]
Switzerland	– 0.8	3.0[3]	0.4	0.9[2]	3.7	– 0.5	– 2.3[1]	– 0.8[1]
Average	*0.4*	*1.5*	*1.6*	*0.0*	*8.3*	*– 0.3*	*– 1.2*	*0.1*

[1] Output gap forecasts for Switzerland are only available from 1996 to 1999. [2] and [3] denote 90% and 95% levels of significance.

Table 5

Bivariate regressions of forecast errors[1]

1991-99, based on data as of June 2000

Country	Import prices		Productivity		Unemployment		Output gap		Δpc or Δw	
	Δpc	Δw	Δpc	Δw	Δpc	Δw	Δpc	Δw	Δpc	Δw
United States	0.20[4]	0.05	– 0.50[3]	0.44	– 0.08	0.44	– 0.08	0.60	0.31	0.61
Japan	0.05[4]	0.09	– 0.68[3]	0.57[3]	0.12	0.57[3]	0.12	0.12	0.15	1.34
United Kingdom	– 0.05	– 0.24[3]	– 0.76	– 0.23	0.87[3]	– 0.23	0.87[3]	– 0.23	0.11	0.35
Canada	– 0.07	– 0.16	0.31	0.31	– 0.19	0.31	– 0.19	0.32	0.32[3]	1.06[3]
Australia	0.12	– 0.04	– 0.63[3]	– 0.39	– 0.46	– 0.39	– 0.46	– 0.02	0.60[4]	0.84[4]
Spain	0.12	– 0.08	0.18	1.19	0.08	1.19	0.08	– 0.67	0.04	0.46
Sweden	0.18[4]	0.05	– 0.07	– 0.08	0.38	– 0.08	0.38	0.14	0.24	0.32
Switzerland	0.08	0.13	– 0.31	0.06	0.21	0.06	0.21	0.30[2]	0.50	0.41

[1] Coefficients are those obtained by regressing (with no intercept term) forecast errors for Δpc and Δw on forecast errors for the exogenous variables listed at the top, with the figures in the last column showing the coefficients from bivariate regressions between forecast errors for Δpc and Δw. [2] Based on only four observations. [3] and [4] denote 90% and 95% levels of significance.

Table 6

Bivariate regressions of forecast errors on outcomes[1]

1991-99, based on data as of June 2000

Country	Intercept[2]		Import prices		Productivity		Unemployment		Output gap		Δpc or Δw	
	Δpc	Δw	Δpc	Δw	Δpc	Δw	Δpc	Δw	Δpc	Δw	Δpc	Δw
United States	0.78[5]	0.37	– 0.06	0.22	0.05	– 1.23[5]	0.05	0.21	– 0.07	– 0.45	0.18	– 0.18
Japan	0.15	1.66[5]	– 0.06[4]	– 0.01	– 0.10	– 0.17	0.13	– 0.15	– 0.17[5]	0.01	0.26	0.56
United Kingdom	– 0.12	– 0.36	0.04	0.31[5]	0.69	1.39[4]	0. 10	1.07[5]	0.01	– 1.26[5]	– 0.03	0.70[4]
Canada	0.18	– 0.39	0.06	0.18	0.20	0.34	0.20	0.38	– 0.17	– 0.32	0.42[5]	0.23
Australia	1.32[5]	1.08[5]	– 0.07[4]	0.07	0.00	– 0.23	0.05	0.09	– 0.10	– 0.36	0.24	0.15
Spain	– 0.33	– 0.37	– 0.12	– 0.02	– 0.18	– 1.33[5]	– 0.04	0.12	– 0.01	– 0.68	– 0.20	– 1.17[5]
Sweden	1.19	1.19	– 0.21[5]	– 0.09	– 0.15	– 0.34	– 0.01	– 0.56[4]	0.36	0.42	0.15	0.14
Switzerland	1.85	– 3.34	– 0.15	– 0.15	0.66[5]	0.06	0.68[5]	0.46	0.35[3]	– 1.55[3]	– 0.26[5]	0.13

[1] Coefficients obtained by regressing forecast errors for Δpc and Δw on an intercept term and the exogenous variables listed at the top. [2] Coefficients are taken from a regression of the forecast errors on an intercept term and the output gap. [3] Regressions including the output gap are based on only four observations. [4] and [5] denote 90% and 95% levels of significance.

Table 7

Activity indicators and inflation in the 1990s

Country	Period	Gap	Δpc	Δ(Δpc)	U*– U	Δw	Δ(Δw)	Δ(Δpc)/Gap	Δ(Δw)/(U*– U)
United States	1985-89	0.7	3.6	0.9	0.3	4.1	– 0.8	1.3	– 2.7
	1990-94	– 0.7	3.2	– 2.6	– 0.4	3.9	– 2.6	*3.7*	*6.5*
	1995-99	0.6	1.8	– 0.7	0.3	3.5	2.5	– 1.2	8.3
Japan	1985-89	– 1.2	1.2	– 0.2	– 0.2	3.0	0.3	*0.2*	– *1.5*
	1990-94	0.8	1.8	– 1.8	0.2	2.6	– 3.1	– 2.1	– 15.5
	1995-99	– 1.5	0.2	0.0	– 0.4	0.2	– 1.2	*0.0*	*3.0*
United Kingdom	1985-89	2.8	4.9	1.0	1.1	8.2	1.2	0.3	1.1
	1990-94	– 0.8	5.2	– 5.5	– 0.2	5.7	– 6.7	*6.9*	*33.5*
	1995-99	0.3	2.7	– 0.5	0.2	5.0	2.1	– 1.7	10.5
Canada	1985-89	2.0	4.0	0.5	0.9	5.5	– 0.6	0.2	– 0.7
	1990-94	– 2.7	2.7	– 3.2	– 1.3	3.2	– 4.5	*1.2*	*3.5*
	1995-99	– 1.3	1.3	0.0	– 0.7	3.1	– 0.2	*0.0*	*0.3*
Australia	1985-89	1.0	7.2	– 1.4	0.3	6.1	2.4	– 1.4	8.0
	1990-94	– 1.4	3.2	– 5.3	– 0.7	4.0	– 6.4	*3.8*	*9.1*
	1995-99	0.8	1.5	– 0.7	0.3	3.5	– 0.9	– 0.9	– 3.0
Spain	1985-89	1.7	6.8	– 0.5	0.6	5.7	– 2.0	– 0.3	– 3.3
	1990-94	1.4	5.9	– 1.6	1.7	8.7	– 6.7	– 1.1	– 3.9
	1995-99	– 1.3	3.1	– 1.9	– 1.2	2.1	– 2.8	*1.4*	*2.3*

Table 7 (cont)

Country	Period	Gap	Δpc	Δ(Δpc)	U*– U	Δw	Δ(Δw)	Δ(Δpc)/Gap	Δ(Δw)/(U*– U)
Sweden	1985-89	1.7	6.2	0.0	0.5	8.9	3.8	0.0	7.6
	1990-94	– 1.9	6.2	– 7.2	– 0.5	6.0	– 4.4	*3.8*	*8.8*
	1995-99	– 1.7	1.6	– 2.2	– 0.6	3.7	– 0.9	*1.3*	*1.5*
Switzerland	1985-90	0.8	1.6	– 0.4	0.0	3.9	0.6	– 0.5	.
	1990-94	– 0.3	4.0	– 4.1	0.0	4.3	– 3.7	*13.5*	.
	1995-99	– 2.4	0.7	– 1.3	– 0.2	1.6	– 0.9	*0.5*	*4.5*

Notation: Gap = average output gap; Δpc = average rate of inflation (private consumption deflator); Δ(Δpc) = change in the rate of inflation during period; U* – U = deviation of actual unemployment from the NAIRU estimates discussed in Note 17; Δw = average rate of wage inflation (compensation per employee, business sector); Δ(Δw) = change in the rate of wage inflation during period; Δ(Δpc)/Gap = change in rate of inflation relative to output gap; and Δ(Δw)/(U* – U) = change in the rate of wage inflation relative to deviation of actual unemployment from estimated NAIRU.

Table 8a

Price equations, 1960-90

Variables	United States		Japan		United Kingdom		Canada	
	Unconstrained	Constrained	Unconstrained	Constrained	Unconstrained	Constrained	Unconstrained	Constrained
Intercept	0.83 (3.0)	– 0.05 (0.4)	0.63 (0.8)	– 0.53 (0.6)	1.37 (2.0)	0.25 (0.7)	1.33 (3.4)	0.38 (1.8)
Gap_{-1}	0.20 (2.7)	0.28 (3.2)	0.47 (1.0)	0.81 (1.4)	0.54 (3.4)	0.63 (3.9)	0.20 (2.2)	0.17 (1.7)
Δpc_{-1}	0.68 (7.6)	0.72^c	0.06 (0.3)	0.42^c	0.55 (3.8)	0.63^c	1.05 (7.7)	1.16^c
Δpc_{-2}	0.14 (1.5)	– 0.28 (2.5)	0.14 (1.0)	0.35 (2.0)	0.34 (5.8)	0.37 (2.5)	– 0.22 (1.7)	– 0.16 (1.1)
$\Delta pm - \Delta pc_{-1}$	0.13 (8.7)	0.13 (6.9)	0.09 (2.4)	0.08 (1.7)	0.30 (3.0)	0.34 (5.5)	0.17 (4.3)	0.19 (4.3)
Δw_{-1}	.	.	0.44 (2.6)	0.23 (1.1)	.	.	.	.
R^2	0.94	0.79	0.85	0.57	0.88	0.68	0.90	0.55
Durbin's h	0.14	0.85	– 0.04	2.21	0.41	0.88	1.58	2.50
Standard error	0.61	0.76	1.91	2.47	1.81	1.91	0.90	1.02
F-test, constraint[1]	.	13.0	.	11.96	.	3.64	.	7.39
ΣErrors[2]	2.2	– 1.3	4.4	– 2.3	1.0	– 4.0	6.4	1.7

Notation: See equations (9)-(10) in the text. [1] The 0.05 (0.01) probability value for not rejecting the constraint is for most countries 4.15 (7.50). [2] Cumulative forecast errors (1991-99), static simulation. [c] Constrained estimate.

Table 8a (cont)

Variables	Australia		Spain		Sweden		Switzerland	
	Unconstrained	Constrained	Unconstrained	Constrained	Unconstrained	Constrained	Unconstrained	Constrained
Intercept	2.19 (3.7)	0.26 (0.8)	1.04 (0.8)	0.26 (0.5)	1.03 (1.1)	– 0.01 (0.0)	2.52 (5.4)	0.11 (0.3)
Gap_{-1}	0.23 (1.4)	– 0.03 (0.2)	0.54 (2.5)	0.59 (2.9)	0.30 (2.1)	0.36 (2.6)	0.36 (5.1)	0.10 (1.2)
Δpc_{-1}	1.12 (8.2)	1.30[c]	0.68 (3.6)	0.69[c]	0.67 (3.7)	0.73[c]	0.47 (3.0)	0.97[c]
Δpc_{-2}	– 0.38 (2.9)	– 0.30 (1.9)	0.25 (1.2)	0.31 (1.7)	0.20 (1.1)	0.27 (1.6)	– 0.18 (1.5)	– 0.03 (0.2)
$\Delta pm - \Delta pc_{-1}$	0.18 (4.5)	0.17 (3.5)	0.13 (2.9)	0.13 (2.9)	0.09 (2.0)	0.09 (1.9)	0.12 (3.7)	0.17 (3.6)
Δw_{-1}	.	.	.	.	.	.	.	.
R^2	0.88	0.33	0.80	0.38	0.69	0.30	0.81	0.30
Durbin's h	0.16	2.34	– 0.31	– 0.23	– 1.35	– 0.86	0.91	2.39
Standard error	1.34	1.65	2.46	2.42	1.76	1.77	0.99	1.51
F-test, constraint[1]	.	12.7	.	0.44	.	0.99	.	31.2
ΣErrors[2]	14.0	2.7	8.9	5.1	7.2	1.7	2.2	– 0.1

Notation: See equations (9)-(10) in the text. [1] The 0.05 (0.01) probability value for not rejecting the constraint is for most countries 4.15 (7.50). [2] Cumulative forecast errors (1991-99), static simulation. [c] Constrained estimate.

Table 8b

Price equations, 1960-99

Variables	United States		Japan		United Kingdom		Canada	
	Unconstrained	Constrained	Unconstrained	Constrained	Unconstrained	Constrained	Unconstrained	Constrained
Intercept	0.70 (3.6)	– 0.02 (0.2)	0.37 (0.8)	– 0.40 (0.8)	1.25 (2.5)	0.32 (1.1)	1.11 (3.2)	0.38 (1.9)
Gap_{-1}	0.19 (3.1)	0.27 (3.8)	0.29 (1.4)	0.44 (1.7)	0.59 (4.7)	0.67 (5.1)	0.33 (4.0)	0.28 (3.3)
Δpc_{-1}	0.70 (9.1)	0.73[c]	0.10 (0.5)	0.53[c]	0.58 (4.7)	0.64[c]	0.90 (6.6)	0.99[c]
Δpc_{-2}	0.13 (1.6)	– 0.27 (2.9)	0.13 (1.1)	0.30 (2.3)	0.29 (2.3)	0.36 (2.8)	– 0.04 (0.3)	0.01 (0.0)
$\Delta pm - \Delta pc_{-1}$	0.13 (10.7)	0.13 (8.3)	0.10 (4.5)	0.11 (3.7)	0.31 (6.9)	0.31 (6.4)	0.15 (3.8)	0.17 (4.1)
Δw_{-1}	.	.	0.44 (3.4)	0.17 (1.2)	.	.	.	.
R^2	0.95	0.79	0.88	0.63	0.90	0.68	0.90	0.45
Durbin's h	0.37	0.85	– 0.14	2.00	0.42	1.12	0.27	0.95
Standard error	0.54	0.76	1.59	2.06	1.59	1.69	1.01	1.09
F-test, constraint[1]	.	17.3	.	18.00	.	5.07	.	6.06
F-test, stability[2]	0.27	0.21	2.25	1.56	0.23	0.23	1.90	1.51
ΣErrors[3]	1.3	– 0.9	1.8	– 2.6	0.9	– 2.4	2.9	0.2

Notation: see equations (9)-(10). [1] The 0.05 (0.01) probability value for not rejecting the constraint is for most countries 4.15 (7.50). [2] The 0.05 (0.01) probability value for not rejecting parameter stability is for most countries 2.70 (4.05). [3] Cumulative forecast errors (1991-99), static simulations. [C] Constrained estimate.

Table 8b (cont)

Variables	Australia		Spain		Sweden		Switzerland	
	Unconstrained	**Constrained**	**Unconstrained**	**Constrained**	**Unconstrained**	**Constrained**	**Unconstrained**	**Constrained**
Intercept	1.26 (2.8)	0.16 (0.7)	0.55 (0.7)	0.10 (0.2)	0.97 (1.4)	– 0.05 (0.1)	2.13 (5.5)	0.12 (0.5)
Gap_{-1}	0.08 (0.6)	– 0.07 (0.5)	0.45 (2.9)	0.48 (3.2)	0.33 (2.9)	0.32 (2.8)	0.36 (5.6)	0.10 (1.5)
Δpc_{-1}	1.22 (9.6)	1.32[c]	0.73 (4.6)	0.74[c]	0.65 (4.4)	0.73[c]	0.51 (3.7)	1.00[c]
Δpc_{-2}	– 0.39 (3.1)	– 0.32 (2.4)	0.22 (1.3)	0.26 (1.7)	0.19 (1.3)	0.27 (1.9)	– 0.14 (1.3)	0.00 (0.0)
$\Delta pm - \Delta pc_{-1}$	0.18 (4.7)	0.17 (4.1)	0.13 (3.5)	0.13 (3.5)	0.14 (3.0)	0.14 (3.0)	0.12 (4.0)	0.17 (4.1)
Δw_{-1}	.	.	.	.	.	.	.	.
R^2	0.89	0.35	0.86	0.36	0.73	0.37	0.84	0.31
Durbin's h	0.83	2.00	0.07	0.13	– 1.92	– 1.79	1.63	1.69
Standard error	1.35	1.49	2.11	2.09	1.88	1.92	0.97	1.38
F-test, constraint[1]	.	8.14	.	0.43	.	2.51	.	34.9
F-test stability[2]	1.05	0.32	0.22	0.21	1.51	1.67	0.84	0.38
ΣErrors[3]	7.4	2.4	5.2	3.3	4.8	1.9	1.1	– 0.6

Notation: see equation (9)-(10). [1] The 0.05 (0.01) probability value for not rejecting the constraint is for most countries 4.15 (7.50). [2] The 0.05 (0.01) probability value for not rejecting parameter stability is for most countries 2.70 (4.05). [3] Cumulative forecast errors (1991-99), static simulations. [C] Constrained estimate.

Table 9a

Wage equations, 1960-90

Variables	United States		Japan	United Kingdom		Canada	
	Unconstrained	Constrained	Unconstrained	Unconstrained	Constrained	Unconstrained	Constrained
Intercept	0.17 (0.2)	0.24 (1.0)	7.77 (1.5)	2.77 (4.0)	5.12 (4.3)	4.44 (3.9)	4.44 (3.9)
U	.	.	– 3.1 (1.8)	.	.	– 0.36 (2.3)	– 0.41 (2.6)
U – U*	– 0.81 (4.1)	– 0.80 (4.7)	.	.	.	.	.
Δ(U – U*)	.	.	.	– 2.43 (2.6)	– 3.14 (4.0)	.	.
Δpc	.	.	0.73 (4.9)	.	.	1.05 (4.2)	1.13[c]
Δpc_{-1}	0.29 (2.0)	0.30 (2.0)	.	1.15 (5.5)	1.24[c]	– 0.23 (0.9)	– 0.13 (0.5)
Δpc_{-2}	.	.	.	– 0.37 (1.7)	– 0.24 (1.2)	.	.
Δw_{-1}	0.30 (1.5)	0.29[c]	0.22 (1.9)	.	.	.	.
Δw_{-2}	0.42 (2.1)	0.41 (2.5)	.	.	.	.	.
$\text{Log}\ ((^{W}/_{PC})/Q)_{-1}$	.	.	–13.4 (1.3)	.	.	.	.
R^2	0.77	0.47	0.93	0.60	0.40	0.68	0.22
Durbin's h (DW)	0.38	1.21	2.33	(1.92)	(1.84)	(1.71)	(1.53)
Standard error	0.91	0.89	1.67	3.45	3.52	1.72	1.77
F-test, constraint[1]	.	0.01	.	.	2.03	.	2.40
ΣErrors[2]	– 2.2	– 1.9	– 7.5	20.2	9.9	0.8	– 6.6

Notation: See equations (11)-(12) in the text. [1] The 0.05 (0.01) probability values for not rejecting the constraint is for most countries 4.24 (7.77). [2] Cumulative prediction errors (1991-99), static simulations. [c] Constrained estimate.

Table 9a (cont)

Variables	Australia		Spain		Sweden		Switzerland
	Unconstrained	Constrained	Unconstrained	Constrained	Unconstrained	Constrained	Unconstrained
Intercept	4.06 (3.5)	4.03 (4.1)	0.72 (0.4)	1.03 (1.1)	0.02 (0.80)	0.58 (1.0)	0.11 (0.1)
U	– 0.48 (2.4)	– 0.48 (2.6)	.	.	.	.	.
U – U*	.	.	– 0.56 (1.8)	– 0.55 (1.8)	– 1.30 (1.9)	– 1.29 (2.0)	– 4.74 (3.9)
Δ(U – U*)	.	.	.	.	– 2.56 (1.5)	– 2.27 (2.1)	.
Δpc	1.82 (7.0)	1.83 (7.3)	0.35 (1.4)	0.32 (1.6)	0.83 (3.4)	0.81 (3.7)	.
Δpc_{-1}	– 0.83 (3.1)	– 0.83[c]	.	.	– 0.26 (1.0)	– 0.27 (1.0)	.
Δpc_{-2}	.	.	.	.	.	.	– 0.30 (2.5)
Δw_{-1}	.	.	0.67 (3.3)	0.68[c]	0.49 (2.4)	0.46[c]	0.53 (4.0)
Δw_{-2}	.	.	.	.	.	.	.
$\text{Log}\ ((^{W}/_{PC})/Q)_{-1}$	.	.	.	.	.	.	– 16.0 (3.5)
R^2	0.76	0.75	0.79	0.20	0.49	0.56	0.87
Durbin's h (DW)	(2.55)	(2.55)	1.72	(1.76)	– 0.59	(2.08)	0.25
Standard error	2.53	2.46	3.12	3.04	2.24	2.19	1.12
F-test, constraint[1]	.	0.00	.	0.05	.	0.06	.
ΣErrors[2]	– 19.1	– 19.4	11.7	13.5	– 13.1	– 9.9	0.69

Notation: See equations (11)-(12) in the text. [1] The 0.05 (0.01) probability values for not rejecting the constraint is for most countries 4.24 (7.77). [2] Cumulative prediction errors (1991-99), static simulations. [C] Constrained estimate.

Table 9b

Wage equations, 1960-99

Variables	United States		Japan	United Kingdom		Canada	
	Unconstrained	**Constrained**	**Unconstrained**	**Unconstrained**	**Constrained**	**Unconstrained**	**Constrained**
Intercept	0.64 (1.2)	0.37 (1.7)	0.57 (0.2)	3.37 (3.2)	2.50 (4.7)	5.23 (4.7)	4.13 (4.1)
U	.	.	– 0.78 (0.2)	.	.	– 0.37 (3.1)	– 0.34 (2.7)
U – U*	– 0.80 (4.7)	– 0.83 (4.9)	.	.	.	.	.
Δ(U – U*)	.	.	.	– 2.69 (4.1)	– 2.97 (5.0)	.	.
Δpc	.	.	0.80 (6.0)	.	.	0.98 (4.7)	1.08[c]
Δpc_{-1}	0.37 (2.7)	0.36 (2.8)	.	1.20 (6.5)	1.24[c]	– 0.15 (0.7)	– 0.08 (0.4)
Δpc_{-2}	.	.	.	– 0.32 (1.6)	– 0.24 (1.4)	.	.
Δw_{-1}	0.30 (1.8)	0.32[c]	0.32 (3.2)	.	.	.	.
Δw_{-2}	0.29 (1.9)	0.32 (2.3)	.		.		.
$\text{Log}\ ((^{W}/_{PC})/Q)_{-1}$	.	.	–24.7 (4.3)		.		.
R^2	0.79	0.43	0.94	0.68	0.45	0.77	0.19
Durbin's h (DW)	0.73	1.24	2.31	(1.77)	(1.77)	(1.80)	1.59
Standard error	0.95	0.94	1.65	3.17	3.17	1.62	1.69
F-test, constraint[1]	.	0.32	.	.	0.92	.	4.02
F-test, stability[2]	5.00	5.78	0.98	1.60	1.05	1.89	2.10
ΣErrors[3]	– 0.4	– 1.3	– 2.9	11.7	7.9	0.4	– 3.7

Notation: See Table 9a. [1] The 0.05 (0.01) probability values for not rejecting the constraint is for most countries 4.15 (7.50). [2] The 0.05 (0.01) probability values for not rejecting parameter stability is for most countries 2.28 (3.21). [3] Cumulative prediction errors (1991-99), static simulations. [c] Constrained estimate.

Table 9b (cont)

Variables	Australia		Spain		Sweden		Switzerland
	Unconstrained	Constrained	Unconstrained	Constrained	Constrained	Unconstrained	Unconstrained
Intercept	4.13 (3.9)	3.32 (4.0)	0.21 (0.2)	0.55 (0.8)	2.55 (2.1)	1.00 (2.0)	0.02 (0.0)
U	– 0.29 (2.2)	0.27 (2.0)	.	.	.	.	.
U – U*	.	.	– 0.61 (2.5)	– 0.59 (2.4)	– 1.16 (2.2)	– 0.92 (1.8)	– 5.36 (4.2)
Δ(U – U*)	.	.	.	.	– 1.02 (1.0)	– 1.71 (2.0)	.
Δpc	1.80 (7.9)	1.87 (8.3)	0.44 (2.1)	0.30 (1.9)	0.64 (3.6)	0.71 (4.0)	.
Δpc_{-1}	– 0.92 (4.1)	– 0.87[c]	.	.	– 0.15 (0.8)	– 0.11 (0.6)	.
Δpc_{-2}	.	.	.	.	.	.	– 0.23 (1.9)
Δw_{-1}	.	.	0.65 (4.0)	0.70[c]	0.31 (1.9)	0.40[c]	0.51 (4.0)
Δw_{-2}	.	.	.	.	.	.	.
Log $((^{W}/_{PC})/Q)_{-1}$	.	.	.	.	.	.	– 15.3 (3.4)
R^2	0.80	0.72	0.86	0.21	0.62	0.44	0.87
Durbin's h (DW)	(2.34)	(2.25)	1.75	(1.72)	– 0.74	(2.13)	– 0.29
Standard error	2.32	2.34	2.90	2.80	2.31	2.35	1.25
F-test, constraint[1]	.	1.55	.	1.00	.	2.05	.
F-test, stability[2]	1.28	1.75	1.87	2.25	1.28	1.59	2.13
ΣErrors[3]	– 4.8	– 8.3	5.5	9.4	2.6	– 2.6	0.04

Notation: See Table 9a. [1] The 0.05 (0.01) probability values for not rejecting the constraint is for most countries 4.15 (7.50). [2] The 0.05 (0.01) probability values for not rejecting parameter stability is for most countries 2.28 (3.21). [3] Cumulative prediction errors (1991-99), static simulations. [c] Constrained estimate.

Chart 1

Errors: consumer prices

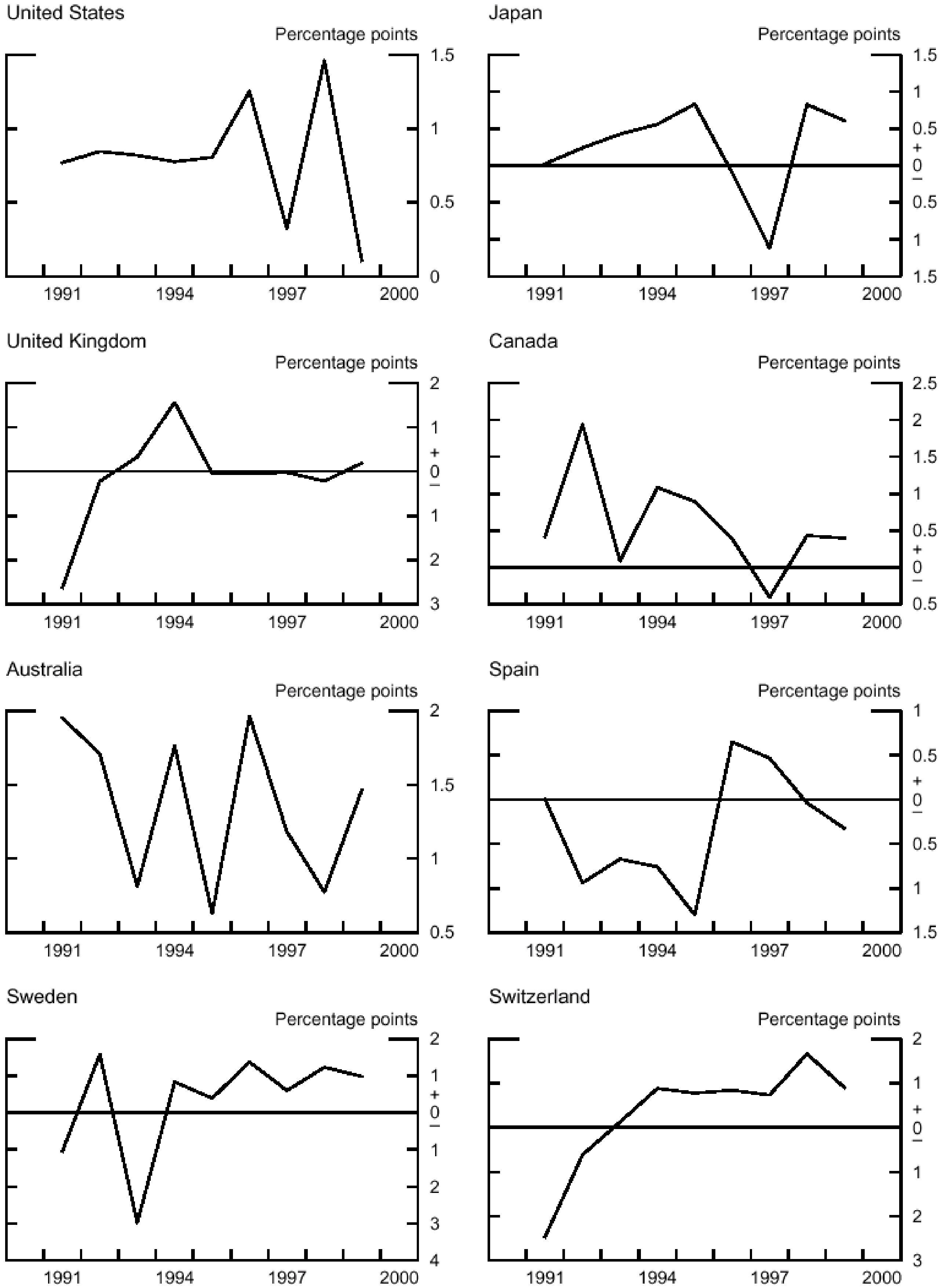
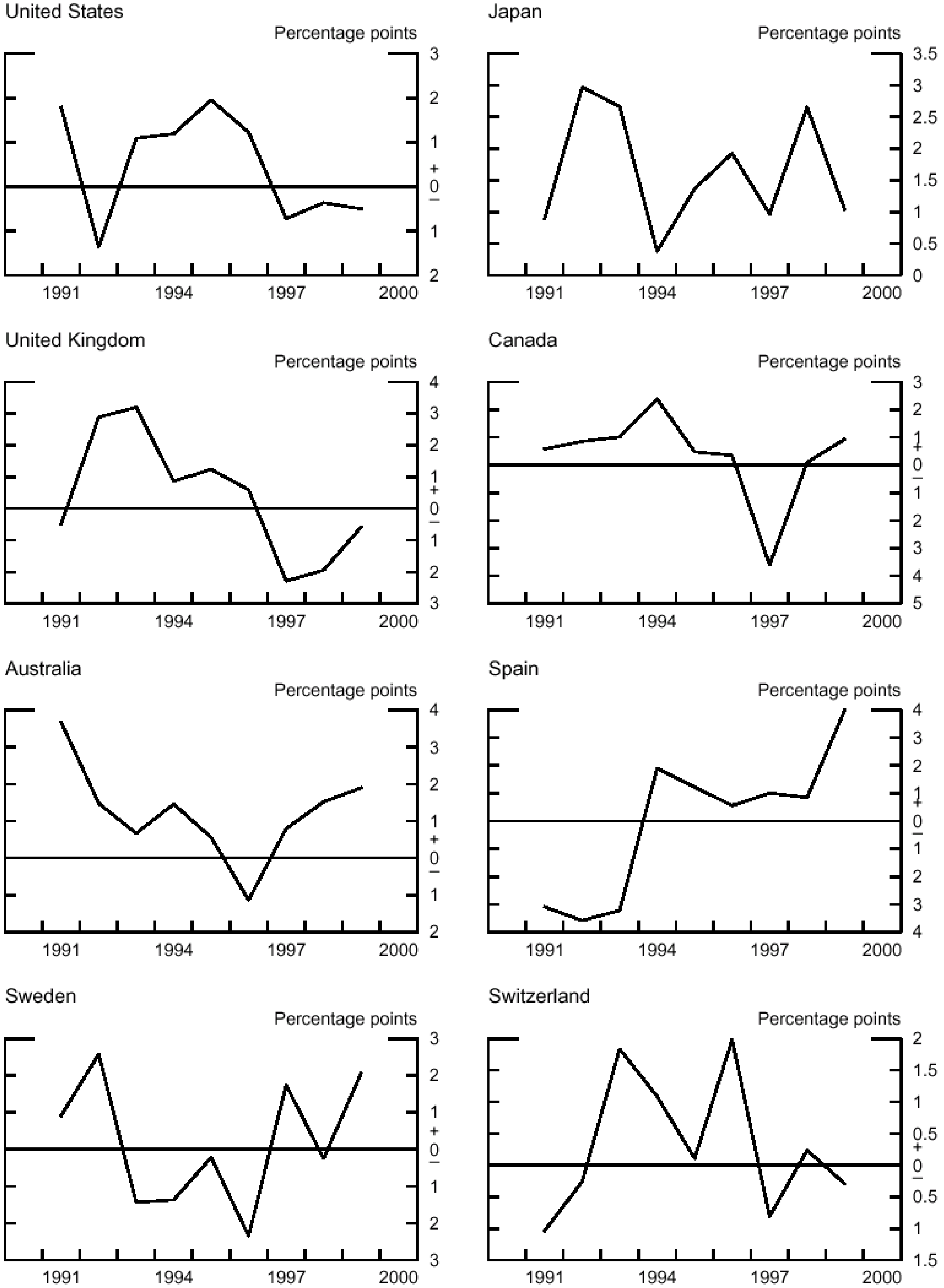


Chart 2

Errors: compensation



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