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:

$$\pi_t = \beta E_t \{\pi_{t+1}\} + \lambda \widehat{mc}_t \qquad (2)$$

where $\widehat{mc}_t$ 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]

$$\widehat{mc}_t = \delta\ (y_t - y_t^*) \qquad (3)$$

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]

$$\pi_t = \beta E_t \{\pi_{t+1}\} + \kappa \left(y_t - y_t^*\right) \qquad (4)$$

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:

$$\pi_t = \kappa \sum_{k=0}^{\infty} \beta^k E_t\left\{\left(y_{t+k} - y_{t+k}^*\right)\right\} \qquad (5)$$

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 $\mu \equiv \log \frac{\in}{\in -1}$ 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

$$MC_t \equiv \frac{(W_t / P_t)}{(1-\alpha)(Y_t / N)_t} \tag{8}$$

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:

$$\hat{mc}_{t,t+\kappa} = \hat{mc}_{t+\kappa} - \frac{\in \alpha}{1-\alpha}\left(p_t^* - p_{t+\kappa}\right) \tag{9}$$

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),

$$\pi_t = \beta \ E_t\{\pi_{t+1}\} + \lambda \hat{mc}_t \tag{10}$$

with

$$\lambda \equiv \frac{(1-\theta)(1-\beta\theta)(1-\alpha)}{\theta[1+\alpha(\in -1)]} \tag{11}$$

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,

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:

$$\pi_t = \gamma_b \pi_{t-1} + \gamma_f E_t\{\pi_{t+1}\} + \lambda \hat{mc}_t \quad (12)$$

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:

$$Y_t = A_t K_t^{\alpha} N_t^{1-\alpha} \quad (13)$$

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:

$$\hat{mc}_t = \hat{s}_t \quad (14)$$

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:

$$Y_t = F(K,N) = \left[\alpha_k K_t^{1-\frac{1}{\sigma}} + \alpha_N (Z_t N_t)^{1-\frac{1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

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 $\hat{\gamma}_t = -\delta \hat{n}_t, \hat{gN}_t \equiv \log(N_t / N_{t-1})$ 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:

$$\frac{N_t}{M_t} = \left(P_{\frac{M,t}{W_t}} \right)^{\sigma} \tag{20}$$

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:

[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:

$$(\hat{\omega}_t - \hat{p}_t) = \hat{mrs}_t + \hat{\mu}_t^w \tag{23}$$

[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:

$$\hat{mc}_t = \hat{\mu}_t^{w} + \left[\left(\hat{a}_t + \varphi \hat{n}_t\right) - \left(\hat{y}_t - \hat{n}_t\right)\right] \tag{26}$$

with the wage markup defined as follows:

$$\hat{u}_t^{w} = \left(\hat{w}_t - \hat{p}_t\right) - \left(\hat{a}_t + \varphi \hat{n}_t\right)$$

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.

[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:

$$\hat{mc}_t = \hat{s}_t - \hat{\gamma}_t \tag{27}$$

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 $\left(YK_t \equiv Y_t / K_t\right)$: $\gamma_t = 1 - \kappa \left(YK_t\right)^{\frac{1}{\sigma}-1}$. 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:

$$\hat{mc}_t = \hat{s}_t + \eta\ \hat{yk}_t \tag{28}$$

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:

$$\hat{mc}_t = \hat{s}_t + \delta\ \hat{n}_t \tag{29}$$

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:

$$\hat{mc}_t = \hat{s}_t - \hat{\gamma}_t + \xi\left\{\hat{g}_{Nt} - \zeta E_t\left[\hat{g}_{Nt+1}\right]\right\} \tag{30}$$

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

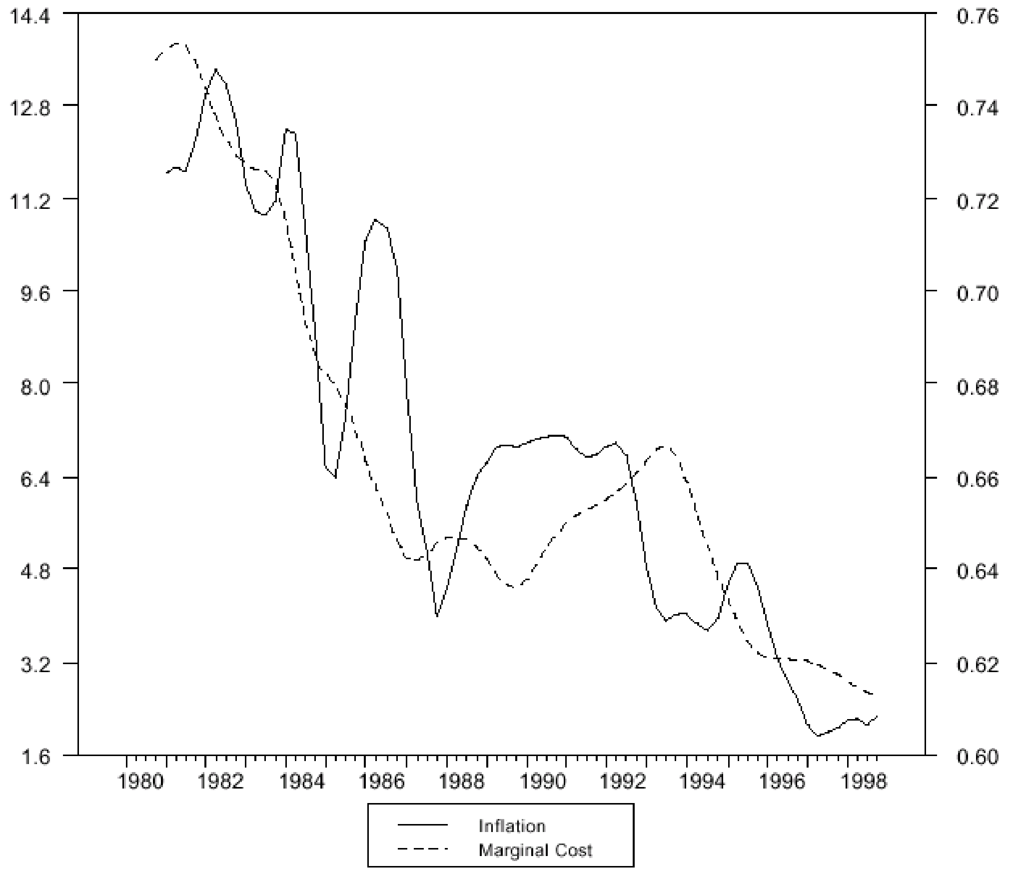

Figure 3
Comparing alternative marginal costs

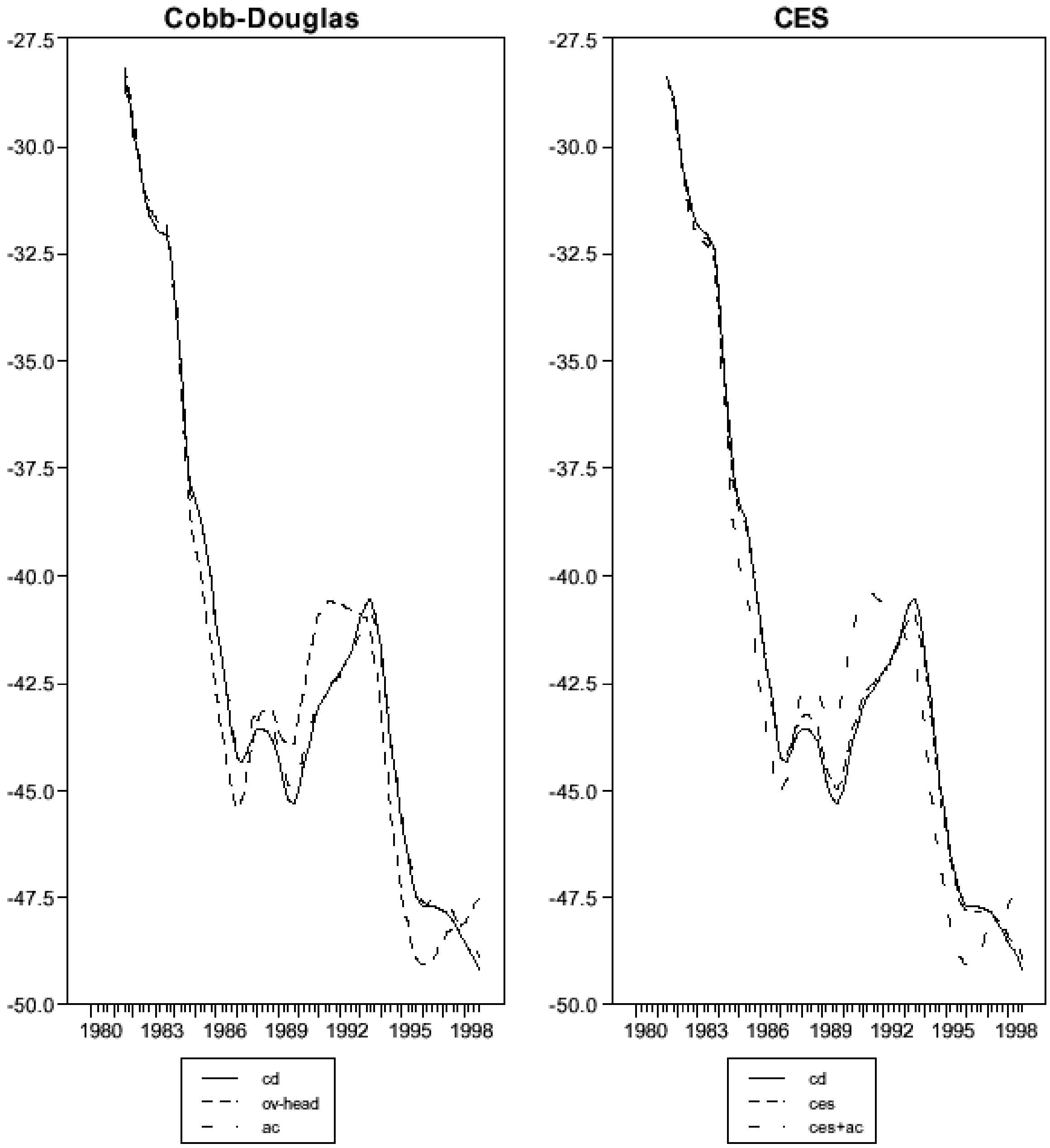

Figure 4a

Inf luence of labour share on estimated price stickiness

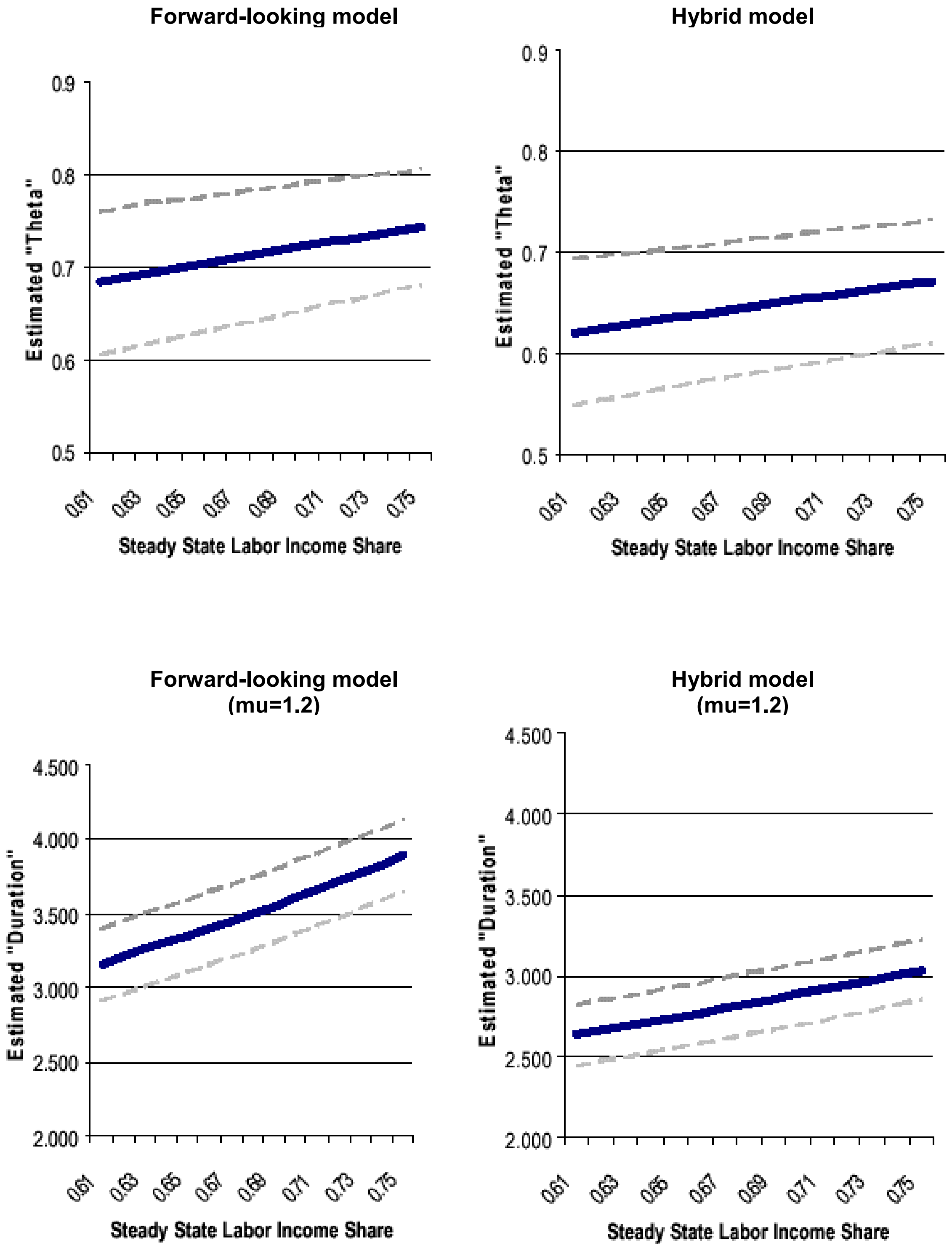

Figure 4b

Influence of markups on estimated price stickiness

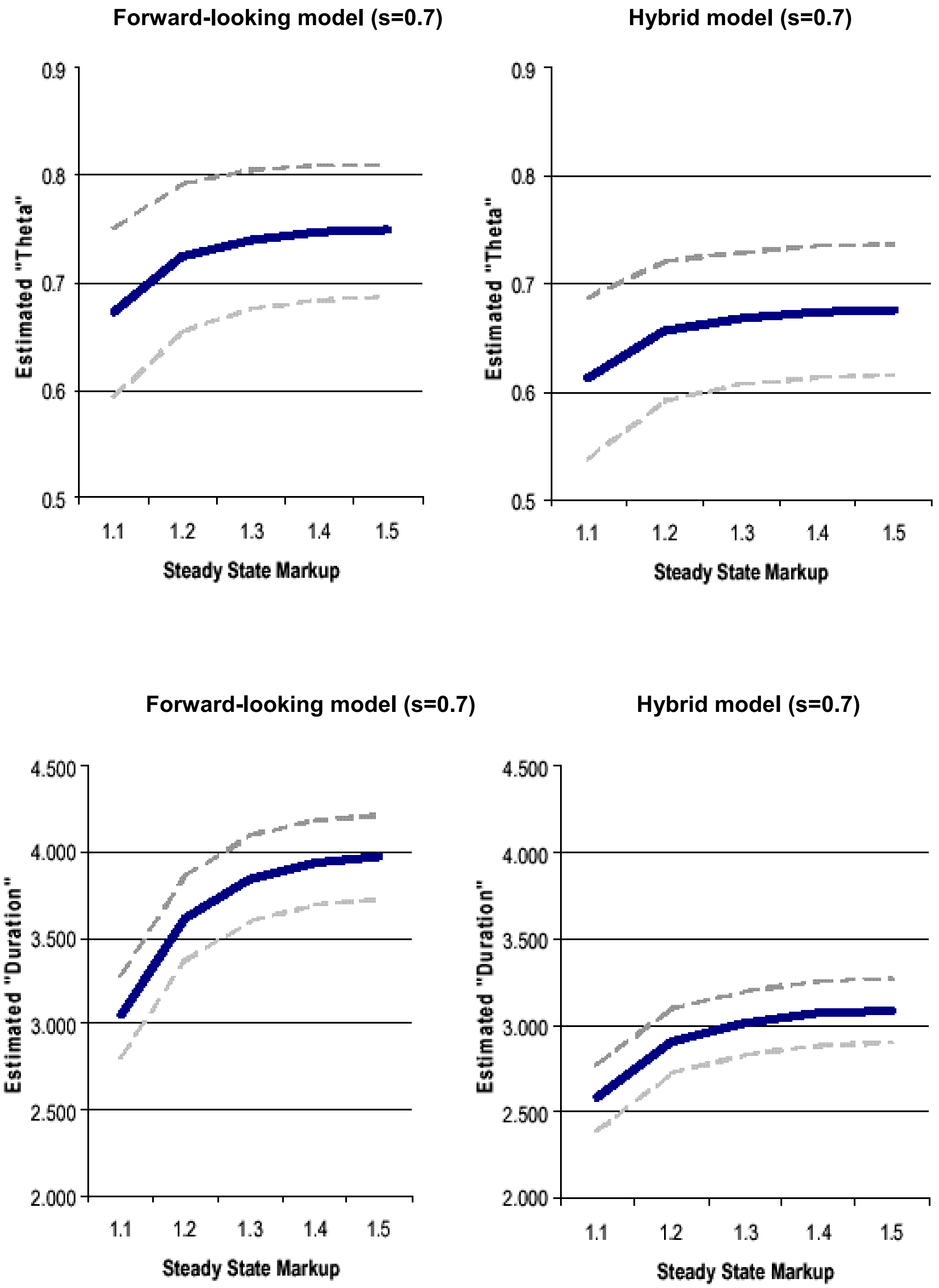

Figure 5a

Inflation: Actual vs Fundamental

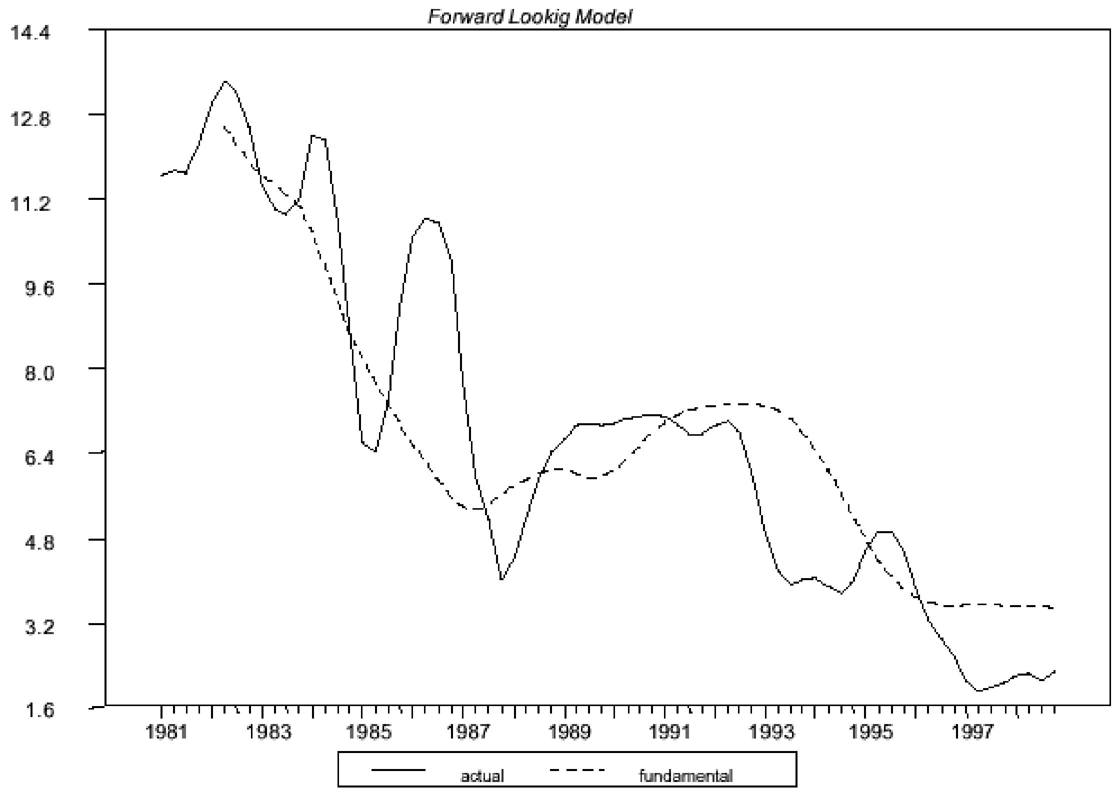

Figure 5b

Inflation: Actual vs Fundamental

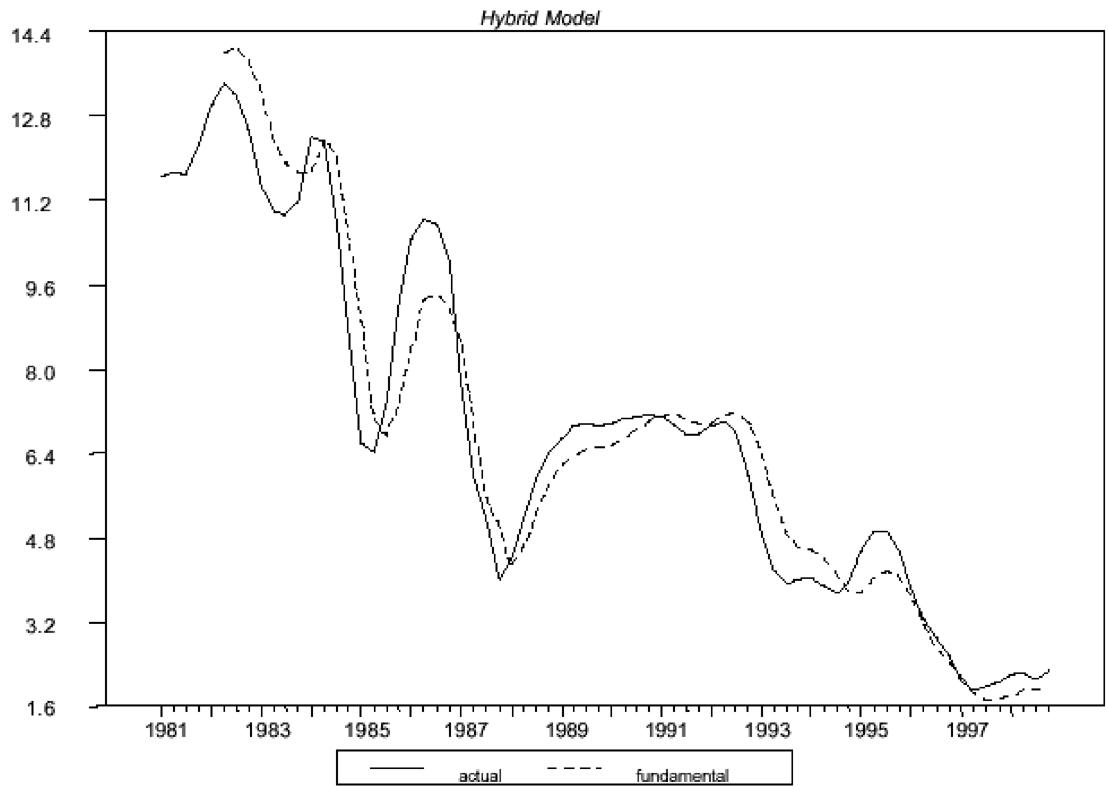

Figure 6a
Inflation and Relative Imput Prices

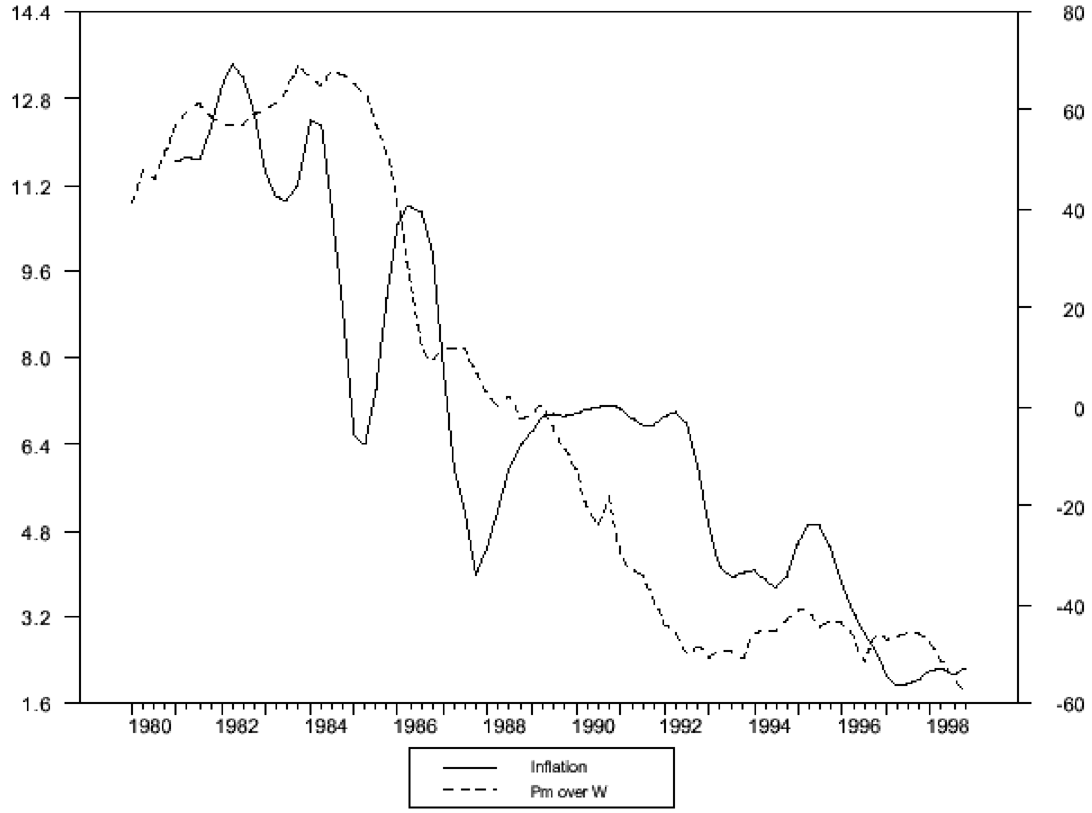

Figure 6b
Real Wages and Import Prices

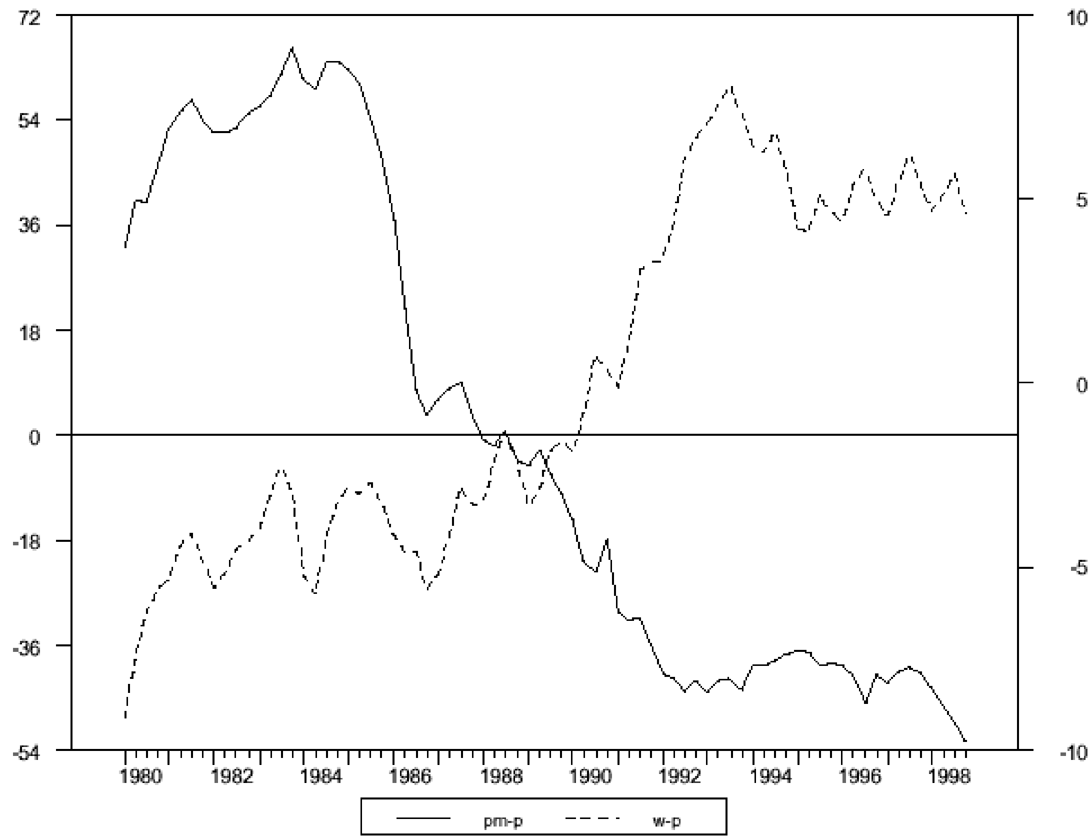

Figure 7

Inflation and alternative marginal
The effect of substitutability between imported materials

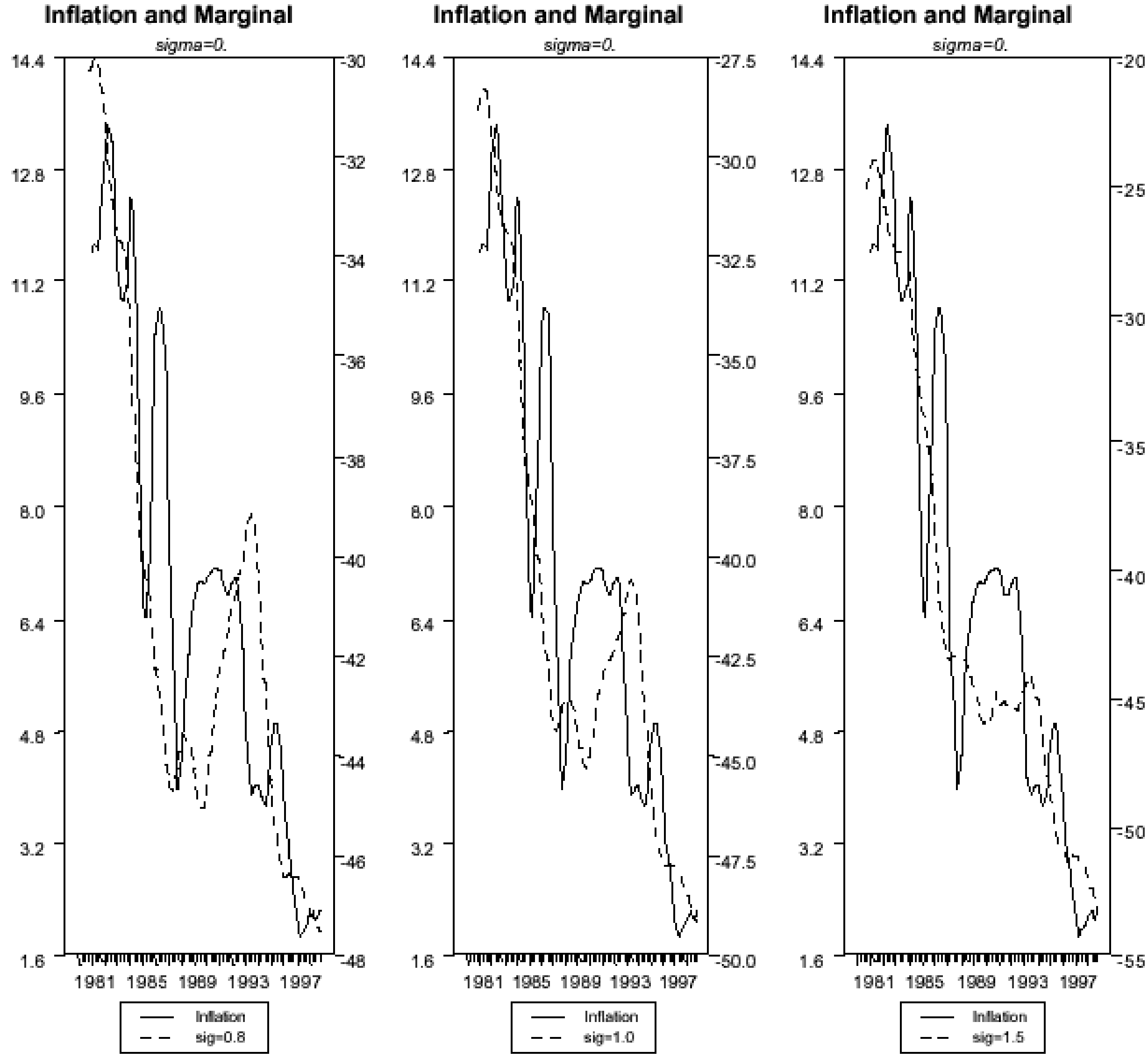

Figure 8
Marginal cost and wage markup

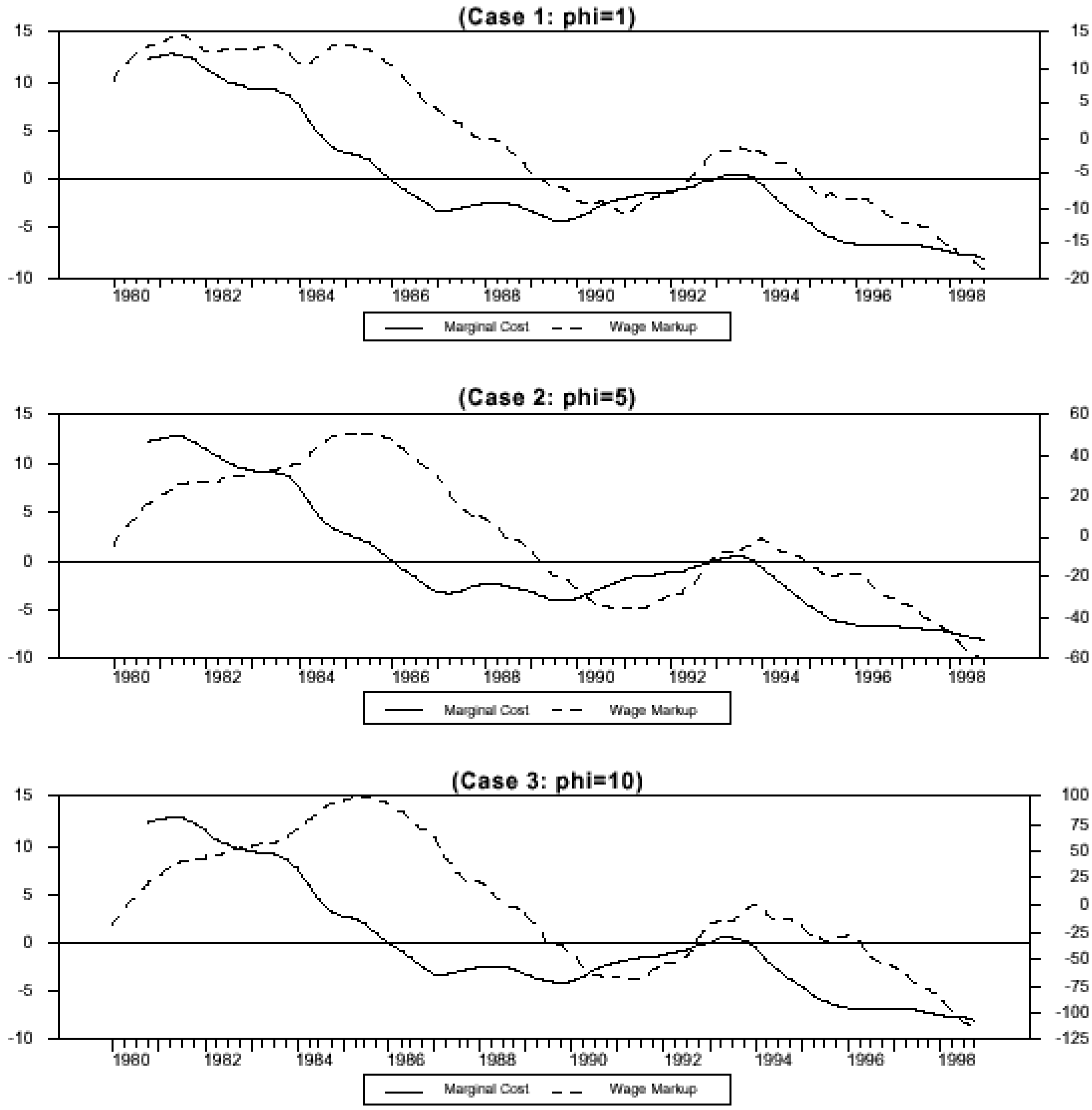

Table 1
Structural estimates: baseline marginal costs

	θ	β	λ	ω	γ_b	γ_f	*D*
$\xi = 1$							
(1)	0.905 (0.011)	0.759 (0.077)	0.033 (0.011)	-	-	-	10.5 (0.116)
(2)	0.835 (0.029)	0.850 (0.124)	0.010 (0.005)	0.709 (0.065)	0.487 (0.017)	0.487 (0.037)	6.1 (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 (0.011)	0.759 (0.077)	0.033 (0.011)	-	-	-	10.5 (0.116)
(2)	0.835 (0.029)	0.850 (0.124)	0.010 (0.005)	0.709 (0.065)	0.487 (0.017)	0.487 (0.037)	6.1 (0.176)
CD with overhead labour							
(1)	0.912 (0.012)	0.781 (0.064)	0.028 (0.010)	-	-	-	11.1 (0.133)
(2)	0.839 (0.032)	0.846 (0.161)	0.009 (0.005)	0.725 (0.085)	0.493 (0.017)	0.483 (0.047)	6.2 (0.200)
CES							
(1)	0.902 (0.011)	0.745 (0.078)	0.035 (0.012)	-	-	-	10.2 (0.112)
(2)	0.835 (0.027)	0.829 (0.0129)	0.011 (0.005)	0.700 (0.067)	0.488 (0.017)	0.482 (0.041)	6.1 (0.165)
CD with labour adjustment costs							
(1)	0.904 (0.011)	0.757 (0.074)	0.034 (0.011)	-	-	-	10.4 (0.114)
(2)	0.835 (0.027)	0.859 (0.120)	0.009 (0.004)	0.719 (0.068)	0.489 (0.017)	0.488 (0.036)	6.1 (0.164)
CES with labour adjustment cost							
(1)	0.912 (0.013)	0.788 (0.058)	0.027 (0.009)	-	-	-	11.1 (0.144)
(2)	0.836 (0.038)	0.860 (0.189)	0.010 (0.006)	0.737 (0.098)	0.496 (0.017)	0.483 (0.053)	6.1 (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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