Targeting alternative measures of inflation under uncertainty about inflation expectations and exchange rate pass-through

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1. Introduction

It has become increasingly common among central banks to specify the operational goal of monetary policy as the maintenance of price stability. For example, the European Central Bank (ECB) recently announced that its goal for monetary policy is to keep inflation below two percent per annum over the medium term. In translating the operational goal into practice, it must be decided which price index is to be targeted. Theory suggests that if the primary cost of inflation arises from consumers' uncertainty regarding the future purchasing power of their incomes, then monetary policy should strive to stabilise a utility-constant consumer price index. In the absence of such ideal indices, central banks have opted to target some available index of consumer prices.

As consumer price indices are independently calculated by statistical agencies, they are seen as credible targets for policy. This is perhaps their primary advantage. However, the disadvantage of targeting consumer prices is that the aggregate index is often affected by price movements in sub-components that do not reflect the 'underlying' trend in inflation. Setting policy at all times based upon movements in aggregate consumer prices could then lead to sub-optimal outcomes. In recognition of this problem, central banks do not in practice strive to meet their CPI inflation targets at all times (see Debelle (1997)). Instead, operational flexibility is afforded to the central bank, arising in two main guises. The first is to target CPI inflation subject to 'caveats' for price movements in the index that are seen as extraordinary (for example, as in New Zealand and Canada). The second is to allow the central bank to meet the inflation target over a somewhat flexible period of time (for example, in the 'medium' term at the ECB, and 'over the cycle' at the Reserve Bank of Australia).

A central bank afforded operational flexibility in policy making, explicitly or implicitly, needs to take into account what is often termed underlying or 'core' inflation. Many alternative methodologies have been proposed to measure core inflation. The key concept behind these measures is that the central bank should counter only *persistent* sources of inflationary pressures, as these become ingrained into inflation expectations. Consequently, the inflation control problem is difficult to manage if core inflation 'gets away' from the inflation target. In contrast, by definition temporary inflation shocks will not have ongoing effects, and therefore the consequences for the monetary authority of ignoring them are less severe.

In the macro model that lies at the heart of the Reserve Bank of New Zealand's *Forecasting and Policy System*, FPS, core inflation is defined as the rate of inflation in the price of domestically produced and consumed goods. This rate of inflation is driven principally by the deviation of aggregate demand for goods and services from the economy's supply capacity. However, for small open economies, movements in the nominal exchange rate, via their direct effect on the price of imported goods, cause a significant part of the variation in consumer price indices. The model's definition of CPI inflation incorporates these direct exchange rate effects, while the core inflation measure does not.

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If exchange rate movements affect only the *level* of the CPI, and not inflation expectations, then exchange rate pass-through constitutes the type of shock that core inflation measures aim to remove. In this case, *a priori,* we would expect that 'looking through' these short-lived effects would lead to superior macroeconomic outcomes. This is examined in Svensson (1998), where a model of a small open economy is used to compare 'flexible' policy rules that target CPI inflation, against those that target domestic price inflation. Svensson's results largely confirm our intuition - the variance in CPI inflation and the real exchange rate is lower when targeting CPI inflation, whilst the variance in real output and nominal interest rates are lower when targeting domestic price inflation.

We might expect that agents face a signal extraction problem in the real world as to how much of observed inflation constitutes 'core' inflation. Given this problem, we do not know exactly how agents form their expectations of inflation. Hence, there is no guarantee that agents' perceptions of core inflation are the same as that of the monetary authority. In Conway *et al.* (1998), stochastic simulations of FPS are used to explore the implications of this uncertainty in the context of CPI versus core domestic price inflation targeting. The result found in Svensson (op. cit.) was largely upheld. That is, whether direct exchange rate price effects influence inflation expectations or only the level of CPI inflation, and regardless of whether the monetary authority perceives this correctly, targeting domestic inflation reduces the variability in all macro variables except for CPI inflation.

This paper extends the work presented in Conway *et al*. in several dimensions. Firstly, following recent development of the FPS core model, the stochastic disturbances applied are a more complete representation of the shocks the New Zealand economy has faced historically. Secondly, we examine the performance of the model economy under a broader range of policy rules. Finally we add another important dimension of uncertainty to the problem – that of the speed of exchange rate pass-through. Reflecting conventional 'stylised facts', the exchange rate transmission channel of monetary policy in FPS affects CPI inflation more quickly than the aggregate demand transmission channel. Nevertheless, the exchange rate transmission channel is still slow relative to other stylised models such as that in Svensson (1998). This reflects only New Zealand's *recent* experience. The transmission of exchange rate or foreign price movements into domestic import prices has been quite variable over time. Given this uncertainty about the speed of exchange rate pass-through, coupled with uncertainty about how agents form their inflation expectations, we examine whether it is still the case that preferable macroeconomic outcomes are attainable under domestic price inflation targeting.

Our results suggest that under the standard forward-looking inflation targeting policy rule used in FPS – a rule that is used to prepare the Bank's economic projections – it is indeed still the case that targeting core inflation results in superior macroeconomic outcomes. We also examine the performance of the model economy under three alternative, descriptively accurate policy rules.[1] In particular, we consider an inflation-targeting rule that is less forward-looking than the standard FPS rule, an inflation-targeting rule that explicitly seeks to smooth output, and the standard 'Taylor rule'. Under a policy rule with a shorter policy horizon than the standard FPS rule, it is found that targeting core inflation reduces variability in output, core inflation, *and* CPI inflation, at a cost of higher instrument variability, relative to targeting CPI inflation. The results under the forward-looking inflation targeting rule with an explicit concern for smoothing output are similar to those found with the standard FPS policy rule, except that core inflation variability is largely the same regardless of whether CPI or core inflation is targeted. Finally, the results under the Taylor rule run against the qualitative results seen under the forward-looking policy rules. The Taylor rule that targets output and core inflation results in *more* variability in output and the real exchange rate relative to the Taylor rule that targets output and CPI inflation.

[1] These rules are descriptively accurate in the sense that they can explain movements in actual policy over history quite well.

The remainder of the paper is structured as follows. In Section 2 a very brief description of FPS, and the technique employed for performing stochastic simulations of the model, are presented. In Section 3, alternative methodologies for constructing core inflation are outlined and we discuss how the model's definition of core inflation fits within these methodologies. Section 4 contains a discussion of exchange rate pass-through in New Zealand. The stochastic simulation results are presented in Section 5. Section 6 contains a brief summary and conclusion.

2. The FPS core model[2]

2.1 The core model

The FPS core model describes the interaction of five economic agents: households, firms, government, a foreign sector, and the monetary authority. The model has a two-tiered structure. The first tier is the underlying steady-state structure that determines the long-run equilibrium to which the model will converge. The second tier is the dynamic adjustment structure that traces out how the economy converges towards that long-run equilibrium.

The long-run equilibrium is characterised by a neo-classical balanced-growth path. Along that growth path, consumers maximise utility, firms maximise profits and government achieves exogenously-specified targets for debt and expenditures. The foreign sector trades in goods and assets with the domestic economy. Taken together, the actions of these agents determine expenditure flows that support a set of stock equilibrium conditions underlying the balanced growth path.

The dynamic adjustment process overlaid on the equilibrium structure embodies both "expectational" and "intrinsic" dynamics. Expectational dynamics arise through the interaction of exogenous disturbances, policy actions and private agents' expectations. Policy actions are introduced to re-anchor expectations when exogenous disturbances move the economy away from equilibrium. Because policy actions do not immediately re-anchor private expectations, other real variables in the economy must follow disequilibrium paths until expectations return to equilibrium. To capture this notion, expectations are modelled as a linear combination of a backward-looking autoregressive process and a forward-looking model-consistent process. Modelling expectations in this way partially addresses the critique, initially raised in Lucas (1976), that examining alternative policy actions in reduced form econometric models gives misleading conclusions.[3]

Intrinsic dynamics arise because adjustment is costly. The costs of adjustment are modelled using a polynomial (up to fourth order) adjustment-cost framework (see Tinsley (1993)). In addition to expectational and intrinsic dynamics, the behaviour of both the monetary and fiscal authorities also contributes to the overall dynamic adjustment process.

On the supply side, FPS is a single-good model. That single good is differentiated in its use by a system of relative prices. Overlaid on this system of relative prices is an inflation process. Although inflation can potentially arise from many sources in the model, inflation in domestic goods prices is determined fundamentally by the difference between the economy's supply capacity and the demand for goods and services. Further, the relationship between goods markets disequilibrium and inflation

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[2] See Black *et al*. (1997) for a full account of the FPS.

[3] The Lucas critique states that the estimated parameters of reduced-form models are dependent on the policy regimes in place over the estimation period. Consequently, simulating reduced-form models in which behaviour is invariant to policy actions produces misleading policy conclusions. Although FPS has partially addressed the Lucas critique, a more explicit modelling of agents' learning behaviour would be required to fully address it.

is specified to be asymmetric. Excess demand generates more inflationary pressure than an identical amount of excess supply generates deflationary pressure.

The monetary authority effectively closes the model by enforcing a nominal anchor. Its behaviour is modelled by a forward-looking reaction function that moves the short-term nominal interest rate in response to projected deviations of inflation from an exogenously-specified target rate. Although the reaction function is *ad hoc* in the sense that it is not the solution to a pre-defined optimal control problem as in Svensson (1996), its design is not arbitrary. The forward-looking nature of the reaction function takes account of the lags in the economy between policy actions and subsequent implications for inflation outcomes. Further, the strength of the policy response to projected deviations in inflation implicitly embodies the notion that the monetary authority is not single-minded in its pursuit of the inflation target. Other factors such as the variability of its instrument and the real economy are also of concern.

2.2 Stochastic simulations of the core model[4]

Performing stochastic simulations requires a distribution from which to draw the shocks that are applied to the model economy. In small macroeconometric models, the distributions of the shocks applied to the model are usually based upon the properties of the residuals from the estimated equations (see, for example, Fillion and Tetlow (1994) for an application of this approach). Given the paucity of data in New Zealand, and the size of the model, FPS has been calibrated. Consequently, there are no historical errors from which we can draw shocks to use for stochastic simulations of the model. Instead, impulse response functions (IRFs) from an estimated VAR are used to define disturbances to the FPS core model. These disturbances include shocks to:

- world output
- world commodity prices
- domestic demand
- core inflation
- the real exchange rate.

The impulse response functions arising from the VAR are used to determine the serial and cross correlation structure of the macro disturbances. This is the primary advantage of using the VAR model – the shocks applied in the stochastic simulation experiments presented in Section 5 do not have independence arbitrarily imposed.[5]

As discussed in Conway *et al.* (1998), there are two main weaknesses that arise in using the VAR to define the macro disturbances. The first is that the data could not support a large enough VAR to capture foreign interest rate and inflation effects. To rectify this problem, an extension has recently been made to the FPS core model. The core model now contains an endogenous foreign sector consisting of an aggregate IS curve, a Phillips curve, a policy reaction function, a long-term interest rate equation and a terms of trade relationship. Given this extension, shocks to world output and commodity prices now directly influence foreign inflation and interest rates. As such, the behaviour of the model economy under stochastic simulations is arguably now more realistic.

The properties of the foreign model have been calibrated using the behaviour of New Zealand's terms of trade as suggested by the VAR, evidence regarding commodity price variability over United States

[4] See Drew and Hunt (1998a) for a complete description on how stochastic simulations of the FPS core model are performed.
[5] Note however that the disturbances are seeded, so that for each experiment considered an identical battery of shocks hit the core model.

business cycles,[6] and the properties of the FRB/US model as outlined in Brayton and Tinsley (1996). (See Appendix 1 for further details and an illustration of the properties of the foreign sector of the FPS core model).

The second main difficulty with using the VAR is that there is insufficient stochastic information in the New Zealand potential output series to produce sensible impulse response functions when it is included. As such, there are no permanent disturbances in the stochastic simulation experiments, implying that important sources of macro variability in the New Zealand economy may be missing in the analysis. Mitigating this is the fact that innovations in the economy's level of productive capacity will in part be captured by the shock terms of the other variables of the system. Stochastic innovations in the domestic price level, for example, can be partially attributed to temporary aggregate supply shocks. Furthermore, as seen in Drew and Hunt (1998b), the moments of key macro variables generated by the FPS core model are reasonably close to the relevant historical moments.

3. Alternative measures of core inflation and FPS

3.1 Alternative measures of core inflation

With the advent of inflation targeting by several central banks around the world, there has been increasing recognition and acceptance of the idea that it may be preferable to stabilise a measure of inflation other than the simple mean inflation rate in the 'general' level of consumer prices. A "core inflation" measure, if more closely influenced by monetary policy, may comprise a superior target inflation rate.

Measures of core inflation aim to exclude temporary shocks and leave only shocks that 'permanently' affect inflation[7]. These latter shocks have the potential to feed through into inflationary expectations, and thus into a generalised inflation process. Temporary shocks, by comparison, tend to be out of line with 'typical' price changes and might be expected to have little or no effect on inflation expectations. The core component is therefore the component of inflation that the monetary authority should focus on controlling.

There are a number of different methods of extracting underlying inflation from measured inflation. These can be generally classified under statistical and model-based approaches. Statistically-based procedures apply some type of filter to exclude from the CPI index 'unusual' price movements. Model-based procedures impose some economic theory onto the problem of extracting core inflation.

The simplest statistically-based approach is simply to exclude from the series those prices that move significantly differently from the general level of prices. This can be done on a quarter-by-quarter basis, based on actual price changes, or, more commonly, by removing the same prices each quarter. Such prices typically include very volatile series, such as fresh food and oil prices, or prices that are little affected by demand, such as those set administratively by government.

The problem with the approach identified above is that it is relatively *ad hoc*, and may be subject to changes in definition. If this is the case then the measure is not externally verifiable, and hence may be seen as a non-credible policy target. An alternative statistically-based procedure that does not suffer from this problem is to rank price changes within a CPI regimen using a weighting scheme that affords less influence to extreme price movements than a simple mean. Roger (1995, 1997)

[6] This relationship was taken in part from evidence contained in Hunt (1995).
[7] Under inflation targeting, all shocks to prices are allowed to be only levels effects in the long run. Over the near term, the distinction is really about the degree of persistence in prices.

investigates median-based and trimmed mean measures for New Zealand.[8] A similar approach is to weight price changes according to their estimated information content with respect to the 'true' general rate of inflation. Dow (1993) assigns weights to price changes by solving a static filtering problem, and alternatively by using a Kalman filter, to produce an index with less volatility. The idea behind the calculation is that there is an underlying 'average' inflation rate, unaffected by relative price shocks and affecting all prices evenly.

Quah and Vahey (1995) use a VAR identified by long-run restrictions to extract core inflation.[9] Specifically, they assume that observed changes in consumer price inflation are the result of two types of disturbances, uncorrelated with each other. The first has no impact on real output in the medium to long run, while the second has unrestricted effects on both measured inflation and real output, but is assumed not to affect core inflation. That is, core inflation is defined as that part of inflation that has no medium to long-run impact on output. This reflects the notion of a vertical long-run Phillips curve in output and inflation. An advantage of this measure is that it is based on economic theory, but a drawback is that the addition of a new data point requires re-estimation. The historical series is therefore subject to revision, which makes it an undesirable target inflation rate.

In the literature, these different measures of core inflation use varying terminology, being defined in terms of 'level' or 'rate' shocks, 'permanent' versus 'temporary' shocks, 'typical' versus 'extreme' shocks, or 'demand' versus 'supply' shocks. Despite these different approaches, the key aim of all the measures is to extract a measure of that component of CPI inflation that can be most closely influenced by monetary policy, yet still purport to represent 'the price level' in an economy. This does come at a cost, however: a conceptual difficulty with any core inflation measure is that there may be valid information regarding the future path of core inflation contained within the excluded price movements. This reflects the fact that we do not know exactly how agents form their expectations of inflation.

3.2 Core inflation in FPS

In the Reserve Bank of New Zealand's Forecasting and Policy System (FPS) the counterpart of core inflation is inflation in the price of domestically produced and consumed goods and services (domestic price inflation). This rate of inflation is determined according to a Phillips curve relationship:

$$\begin{aligned}\pi_t = (1-\alpha)\mathbf{B}_1(L)\cdot\pi_t + \alpha\cdot\pi_t^e + \mathbf{B}_2(L)\left(y_t - y_t^p\right) + \mathbf{B}_3(L)\left(y_t - y_t^p\right)^+ \\ + f(tot) + g(w) + h(ti),\end{aligned} \tag{1}$$

where π represents domestic price inflation, π^e represents expected inflation, y represents output, y^p represents potential output, α is a coefficient, $\mathbf{B}(L)$ denotes a polynomial in the back-shift operator, $(\cdot)^+$ is an annihilation operator (in this case filtering out negative values of the output gap), $f(tot)$ is a function of the terms of trade, $g(w)$ represents a function of the real wage, and $h(ti)$ a function of indirect taxes.

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[8] Rather than simply choosing the median, an alternative percentile can be chosen if it as seen as desirable for credibility reasons that the measure should have the same mean as the published CPI. For example, Roger finds that the 56th or 57th percentile is appropriate for New Zealand.

[9] Gartner and Wehinger (1998) use Quah and Vahey's methodology to estimate core inflation for selected European Union countries. They find that inflation is primarily demand-driven, and that therefore the resulting core inflation indicator could potentially be useful when formulating monetary policy.

Inflation expectations are given by a linear combination of past and model-consistent values of *domestic price inflation*:

$$\pi_t^e = (1-\gamma)\mathbf{B}(L)\cdot\pi_t + \gamma\cdot\mathbf{C}(F)\cdot\pi_t \qquad (2)$$

where γ is a coefficient and $\mathbf{C}(F)$ is a polynomial in the forward-shift operator.

Full CPI inflation, by comparison, incorporates direct exchange rate effects. The base-case version of FPS is structured such that direct exchange rate effects on import prices affect only the level of the CPI. That is, direct exchange rate effects in the CPI do *not* impact on inflation expectations. CPI inflation is built up by adding imported consumption goods price inflation to inflation in domestic prices:

$$\pi_t^{cpi} = \pi_t \cdot \mathbf{B}(L)\cdot\left(pc_t / pc_{t-1}\right) \qquad (3)$$

where π_t^{cpi} represents CPI inflation and pc is the consumption price deflator relative to the price of domestically-produced and consumed goods. The consumption price deflator is a linear combination of the prices of both domestically-produced and imported consumption goods. The latter term includes the direct price effects of movements in the exchange rate.

The base-case version of the model implies that there is little persistence in inflation arising from direct exchange rate effects. Foreign price shocks and real exchange rate movements have only very small effects on the domestic price level. If the price of exports increases, for example, resources will shift away from the production of goods for domestic consumption, towards the production of exports. This will have supply implications for the domestic market, and hence domestic prices. Similarly, an increase in import prices, due to either a foreign price shock or exchange rate depreciation, will increase the cost of a significant number of inputs to production, thereby also affecting the domestic price level through supply-side effects. However, the magnitude of such effects is extremely small in the FPS model relative to the direct CPI price effects of such foreign shocks.

In addition to exchange rate movements, domestic price inflation in FPS is also largely insulated from the first round effects of changes in consumption taxes and government charges. The measure *is* affected directly by wage pressures, the output gap and inflationary expectations, a characteristic well-suited to a core inflation measure, as these can be influenced by monetary policy. Inflation in domestic prices in the FPS model can therefore be interpreted as a measure of core inflation.

3.3 Uncertainty and core inflation in FPS

It is likely to be the case that agents in the real world are unable to distinguish how much movement in the CPI is attributable to exchange rate effects, how much other 'temporary' shocks, and how much reflects core inflationary pressures.[10] If this is the case, then there is uncertainty over how agents form their expectations of inflation. To examine the implications of this uncertainty, two model structures for inflation expectations are considered. The first structure is the standard characterisation of expectations seen in equation (2) above. The second structure is as follows:

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[10] In New Zealand, this assumption may be reasonable since the data is unable to reveal whether or not direct exchange rate effects influence agents' expectations of generalised inflation. This is presented formally in Conway and Hunt (1997), who find that when both first and second differences of the exchange rate are included as explanatory variables in a standard Phillips curve relationship, both are significant.

$$\pi_t^e = (1-\gamma)\mathbf{B}(L)\cdot \pi_t^{cpi} + \gamma \cdot \mathbf{C}(F)\cdot \pi_t^{cpi} \qquad (4)$$

That is, inflation expectations are made a function of historical CPI inflation, and model-consistent expectations of future CPI inflation. Movements in the exchange rate or foreign prices under this specification of inflation expectations then directly enter into inflation expectations, and consequently, also affect core inflation.

If the exchange rate affects both the level of CPI inflation *and* inflation expectations, then the exchange rate channel of policy is potentially a powerful lever for the monetary authority to use. However, if the monetary authority sets policy believing that it can affect inflation expectations via the exchange rate channel, and this turns out to be incorrect, we might expect that potentially undesirable macroeconomic outcomes could occur. Alternatively, what are the macroeconomic outcomes of setting policy believing that the exchange rate only has price *level* effects, when in fact it also affects core inflation via inflation expectations? These issues are examined in section 5 of this paper. Before we turn to this however, the influence of uncertainty about the speed of exchange rate pass-through onto CPI inflation is discussed.

4. Exchange rate pass-through in New Zealand

In open economies, the exchange rate plays an important role in the monetary policy transmission process, particularly under an inflation-targeting regime. By utilising the impact of exchange rate movements on import prices, monetary authorities have a relatively fast and direct channel through which changes in policy can feed through into inflation. Indirectly, movements in the exchange rate can also affect inflation through economic activity and inflation expectations, as per the interest rate channel.

The emphasis placed by the monetary authority upon the direct versus the indirect transmission channel can be thought of as a reflection of its policy horizon. For example, a monetary authority targeting CPI inflation with a relatively short horizon will rely more on the direct channel. During the early period of inflation targeting at the RBNZ, the concern was to build credibility. Given the uncertainty regarding the relationship between interest rates and inflation, the Bank used primarily movements in the exchange rate to maintain CPI inflation within its target band.[11] Policy was set to ensure that the trade-weighted exchange rate remained within a ‘comfort zone’ consistent with keeping inflation on target. The width of the exchange rate comfort zone was determined by estimates of the degree of pass-through from exchange rate movements to CPI inflation.

A substantial amount of research has been carried out at the RBNZ to determine the strength of exchange rate effects on CPI inflation given its importance in the policy process. Most of this research involved estimating ‘mark-up’ equations based on a cost-plus view of price setting. These equations specify inflation as a function of economic activity, unit labour costs, world import and export prices and the exchange rate. The degree of exchange rate pass-through is measured by the sum of the coefficients on the exchange rate variables. This work is surveyed by Beaumont *et al*. (1994), who find that the *magnitude* of exchange rate pass-through into CPI inflation over the medium run is quite stable at around -0.3 (i.e. a 1 percent appreciation reduces inflation by 0.3 percent).[12] This

[11] See Orr *et al.* (1998) for a discussion of the role of the exchange rate in New Zealand monetary policy. More recently, the role of the exchange rate has expanded to incorporate the indirect effects on inflation through economic activity and inflation expectations also.

[12] The ‘medium-run’ is defined to be around 2 years. More disaggregated analysis by Winkelman (1996) shows that the degree of exchange rate pass-through varies greatly between commodities.

finding is consistent with the share of consumption allocated to imported items in FPS.[13] However, the *speed* of the pass-through varies considerably. In particular, recent empirical evidence suggests that exchange rate pass-through is slower presently than it was in the early 1990s.[14]

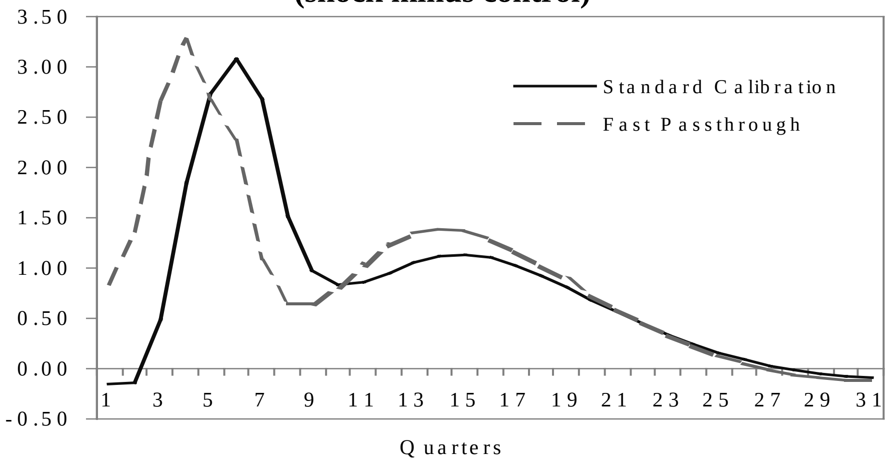
Reflecting recent empirical evidence, the transmission of a shock to the exchange rate into CPI inflation is slower in FPS than the mark-up equation previously used to generate the Bank's medium-term inflation projections. This is shown in Table 1 below.[15]

Table 1 Impact of Temporary Exchange Rate Shock

	Mark-up equation	***FPS***
Peak effect after	3 Quarters	6 Quarters
Proportion of cumulative 18 month impact achieved after 1 year	78 %	25 %

It may be the case, however, that in the future exchange rate pass-through is quicker than that currently calibrated into FPS. To examine the implications of the exchange rate pass-through speed uncertainty, a faster pass-through is calibrated in the FPS core model to be more consistent with that estimated in the mark-up equation. This is illustrated in Figure 1 below which presents the impact of a 1-quarter exchange rate shock under the standard FPS calibration, and an alternative faster pass-through calibration. Both the standard calibration of the exchange rate pass-through and the alternative calibration are used in the stochastic simulation experiments presented next.

Figure 1: Impact of Exchange Rate Shock on CPI Inflation (shock minus control)



[13] Twelve percent of consumption goods are imported directly and the remaining 17 percent are imported intermediate goods, used to produce consumer goods in New Zealand.
[14] This is discussed in Orr *et al.* (1998). Note that it *may* also be the case that the magnitude of exchange rate pass-through has also declined, all else equal, implying that the CPI is less influenced by movements in the exchange rate today than historically. Examining uncertainty about the magnitude of policy transmission effects (or policy multipliers) is outside the scope of this paper, but part of the Bank's current research agenda.
[15] In order to compare meaningfully the properties of the FPS GE model with the partial equilibrium mark-up equation, the endogenous evolution of relevant FPS variables were used as inputs into the mark-up equation.

5. Results

5.1 Overview of the experiments

Before discussing the results it is useful to provide a 'roadmap' of the experiments conducted for this paper. Stochastic simulations of the model economy are performed under both domestic price and CPI inflation targeting. In the simulation experiments two sources of uncertainty are considered:

1) Uncertainty over whether exchange rate effects enter into agents' inflation expectations; combined with
2) Uncertainty over the speed of the pass-through from domestic import consumption prices into CPI inflation.

Table 2 below shows the complete dimension of the problem. For the first source of uncertainty two model structures, as presented in Section 3, are considered: exchange rate effects are level effects (L) or they affect inflation expectations (E). Similarly, for the second source of uncertainty two model structures, as presented in Section 4, are considered: exchange rate pass-through is normal (N) or it is fast (F). The monetary authority targets core inflation (πc), or CPI inflation (πcpi). In setting policy to meet the inflation target, it believes the real world is given by B, which may or may not conform to the true representation of the world, given by R.

For each source of uncertainty there are then four distinct (B/R) cases to consider. As in Conway *et al.*, in order to capture uncertainty about how the exchange rate affects expectations, we examine cases where the monetary authority sets policy on the belief that the exchange rate affects:

1) only the level of the CPI, when in reality it affects inflation expectations (L/E);
2) inflation expectations, when in reality it affects only the level of the CPI (E/L);
3) only the level of the CPI, and this is true in reality (L/L); and,
4) inflation expectations, and this is true in reality (E/E).

Similarly, for uncertainty regarding exchange rate pass-through the monetary authority sets policy on the belief that exchange rate pass-through is:

1) normal when in reality it is fast (N/F);
2) fast when in reality it is normal (F/N);
3) normal, and in reality it is normal (N/N); and,
4) fast, and in reality it is fast (F/F).

Table 2: Outline of Stochastic Simulation Experiments

	L/L		L/E		E/E		E/L	
N/N	πc	πcpi	πc	πcpi	πc	πcpi	πc	πcpi
F/F	πc	πcpi	πc	πcpi	πc	πcpi	πc	πcpi
N/F	πc	πcpi	πc	πcpi	πc	πcpi	πc	πcpi
F/N	πc	πcpi	πc	πcpi	πc	πcpi	πc	πcpi

Key:

πc The monetary authority targets core inflation
πcpi The monetary authority targets CPI inflation

L The exchange rate affects only the level of the CPI
E The exchange rate affects inflation expectations
N Exchange rate pass-through is normal
F Exchange rate pass-through is fast

B/R The authority sets policy assuming world **B**, but the real world is given by **R.**

The two sources of uncertainty are *not restricted* to be mutually exclusive, as there may well be interesting dynamics that arise from the interaction of the uncertainties. Hence, the total number of cases to consider is 16. For each case, the authority can target core inflation or CPI inflation. The total number of experiments conducted is therefore 32 for each policy rule examined.[16]

[16] In practice, examining the macro variability of the model economy under the alternative configurations of the 'real' world is computationally very expensive. A forward solution of endogenous model variables is conducted at each point in time, conditional upon the information set at that point in time. Using the methodology described in Drew and Hunt (1998a), approximately 300,000 simulations are conducted for each rule employing the "stacked-time" algorithm for forward-looking non-linear models (see Armstrong *et al.* (1995)). With this in mind, employing grid-search techniques to search for so called 'efficient policy rules' was not possible given time constraints.

The analysis is restricted to examining the performance of the model economy under four descriptively accurate policy rules:

I. The **standard FPS policy rule**, used in the formulation of the Reserve Bank's economic projections, is a forward-looking inflation forecast-based rule. This policy rule is characterised as follows:

$$rn_t = rn\_eq + 1.4 * \sum_{k=6}^{8} (tpdot_{t+k} - 1.5) \quad (4)$$

where: rn_t is the actual nominal 90 day interest rate at time t,
rn_eq is the equilibrium 90 day interest rate,
$tpdot_{t+k}$ is the projection for inflation at time t, k quarters into the future,
1.5 is the target rate of inflation, representing the mid-point of the inflation target-band for New Zealand monetary policy.

II. An **inflation-targeting rule with a shorter policy horizon** than the standard rule. This policy rule is identical to that presented in (4), except that k = 2 to 4. Our motivation for examining this rule is that it may be more indicative of the way policy was run in the early period of inflation targeting at the Reserve Bank.[17] Furthermore, it is closer to the 'strict' inflation targeting rules discussed in Svensson (1998).

III. The **standard 'Taylor' rule**. This rule has been found to be descriptively accurate for the conduct of policy in the United States (see Taylor (1993)). The formulation of this rule is as follows:

$$rn_t = rn\_eq + 0.5 * (tpdot_t - 1.5) + 0.5 * (ygap_t) \quad (5)$$

where $ygap_t$ is the deviation of output from potential at time t. The weights of 0.5 on inflation and output deviations from the target and potential respectively are as in Taylor (1993).

IV. A rule with the same policy horizon and weight on inflation as the standard FPS rule, but also with a weight of 0.5 on contemporaneous deviations of output from potential. We can think of this as a **'forward-looking' Taylor rule**.

Finally, to evaluate the performance of the model economy under the alternative inflation targets, the root mean squared deviations (RMSDs) of output, the nominal interest rate, the real exchange rate, core inflation, and CPI inflation are compared.[18] Significance tests are conducted by constructing *t*-test statistics to examine the hypothesis that differences between the RMSDs over the alternative inflation targets are not significantly different from zero.[19] We turn now to the results.

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[17] See Orr *et al.* (1998).

[18] RMSDs are calculated rather than SDs because in a model such as FPS with a non-linear Phillips curve, under stochastic simulations the long-run average outcome for output will be less than the deterministic level of potential output and the average outcome for inflation will be above target. RMSDs penalise deviations from the deterministic level and target and hence 'reward' outcomes that are closer. See Laxton *et al.* (1994) for further elaboration on this point.

[19] In other terms, the second moments of the model economy are evaluated only. As Luppi (1998) shows, the welfare benefit of stabilising the economy in terms of consumption utility is very small relative to the welfare benefits of permanently increasing an economy's growth potential. Although not explicitly incorporated into the analysis, we would argue that reducing the volatility in macro variables such as inflation, interest rates, the exchange rate, and output *may* also permanently increase an economy's supply capacity. Furthermore, it is certainly the case that most political pressure placed upon central bankers in the conduct of monetary policy concerns the management of the economy over the business cycle.

5.2 Results

5.2.1 The standard FPS policy rule

The first set of results, presented in the N/N block in Table 3 below, repeat the analysis presented in Conway *et al.* (1998). The stochastic behaviour of the model economy is evaluated under the alternative inflation targets, given uncertainty about the way in which exchange rate movements affect inflation expectations. Exchange rate pass-through is normal and the monetary authority correctly perceives this.

As we might expect, given the richer structure of the external sector in the present FPS core model, the results are quantitatively different from those seen in Conway *et al*. The qualitative story remains unaltered however: targeting core domestic price inflation results in lower macroeconomic variability for all variables considered with the exception of CPI inflation. Furthermore, whether targeting domestic price inflation or CPI inflation, there is *less* variability in the macro variables when expectations of core inflation are a function of CPI inflation. This is seen in comparing columns 1 with 2, and 3 with 4. These results stem from the fact that in a small open economy, the exchange rate is to some degree influenced by the policy instrument via uncovered interest parity (UIP). Since CPI-based expectations include the effects of exchange rate movements, this means that the monetary authority now finds it *easier* than before to sway expectations because of the effect of UIP in exchange rate dynamics. Effectively, this gives the monetary authority more control over inflation. On average, the relative importance of this channel is greater than the effect of the exchange rate and external price shocks that are hitting the economy.

The impact of exchange rate movements on inflation expectations creates an interesting dynamic when the monetary authority misperceives these effects. The worst outcome for both CPI and core inflation variability, under both core and CPI inflation targeting, occurs when the authority believes inflation expectations are CPI-based and in fact they are not (the E/L case). In this case the authority consistently overestimates the impact of the transmission of policy onto inflation, and consequently, is not vigorous enough with policy to achieve the inflation control it achieves in the absence of the misperception. Conversely, the lowest inflation variability occurs when the monetary authority believes expectations are not CPI-based and they in fact are (L/E). In this case, the authority sets policy quarter-by-quarter in a manner that gives it more control over inflation than it had counted upon. The variability of all macro variables is in fact lower than if expectations are formed in line with central bank beliefs (L/L). In *Conway et al.* (1998) it is shown this result is not a general result. Instead, it reflects the fact that the standard FPS policy rule is not an 'efficient policy rule': lower variability in inflation and output can be obtained by being more aggressive with the policy instrument (see Appendix 2 for details). For all rules on the efficient policy frontier, as we might expect, the monetary authority makes no mistakes about the structure of the model economy.

Table 3: Performance of the model economy under the standard FPS rule

		L/L		L/E		E/E		E/L	
		πc	πcpi	πc	πcpi	πc	πcpi	πc	πcpi
N/N	rmsd y	2.74	3.22*[a]	2.58	2.97*[a]	2.59	2.91*[a]	2.78	3.18*[a]
	rmsd rn	3.55	3.87*[a]	3.41	3.54*[a]	3.15	3.26*[a]	3.36	3.62*[a]
	rmsd z	4.45	4.98*[a]	4.42	4.93*[a]	4.23	4.59*[a]	4.26	4.64*[a]
	rmsd πc	1.48	1.59*[a]	1.31	1.40*[a]	1.39	1.48*[a]	1.58	1.70*[a]
	rmsd πcpi	1.11	1.05*[b]	0.96	0.91*[b]	1.02	1.00	1.19	1.18
F/F	rmsd y	2.74	3.31*[a]	2.57	3.01*[a]	2.60	2.94*[a]	2.80	3.23*[a]
	rmsd rn	3.55	4.09*[a]	3.43	3.69*[a]	3.20	3.37*[a]	3.38	3.74*[a]
	rmsd z	4.45	5.21*[a]	4.40	5.16*[a]	4.24	4.73*[a]	4.27	4.77*[a]
	rmsd πc	1.48	1.64*[a]	1.31	1.44*[a]	1.40	1.55*[a]	1.59	1.77*[a]
	rmsd πcpi	1.11	1.09	0.99	0.95*[b]	1.03	1.05	1.21	1.23*[a]
N/F	rmsd y	2.74	2.99*[a]	2.57	2.92*[a]	2.58	2.87*[a]	2.78	3.17*[a]
	rmsd rn	3.55	3.72*[a]	3.43	3.49*[a]	3.18	3.25*[a]	3.36	3.61*[a]
	rmsd z	4.45	4.71*[a]	4.41	4.91*[a]	4.21	4.56*[a]	4.24	4.61*[a]
	rmsd πc	1.48	1.53*[a]	1.31	1.38*[a]	1.39	1.47*[a]	1.58	1.70*[a]
	rmsd πcpi	1.11	1.08*[b]	0.99	0.90*[b]	1.03	0.98*[b]	1.20	1.17*[b]
F/N	rmsd y	2.74	3.32*[a]	2.58	3.07*[a]	2.62	3.00*[a]	2.80	3.25*[a]
	rmsd rn	3.55	4.10*[a]	3.41	3.76*[a]	3.18	3.41*[a]	3.38	3.76*[a]
	rmsd z	4.45	5.23*[a]	4.41	5.18*[a]	4.26	4.77*[a]	4.29	4.81*[a]
	rmsd πc	1.48	1.64*[a]	1.31	1.45*[a]	1.40	1.56*[a]	1.59	1.77*[a]
	rmsd πcpi	1.11	1.09	0.96	0.95	1.03	1.08*[a]	1.20	1.25*[a]

[a] ([b]) indicates that variability under core inflation targeting is less (more) than under CPI inflation targeting at the 95 percent level of confidence.

The second, third, and fourth set of results, shown in the F/F, F/N and N/F blocks, show that under the standard FPS policy rule, the additional factor of alternative exchange rate pass-through speeds does not substantively alter the conclusions reached in *Conway et al*. For all cases, the variability in output, the interest rate, the exchange rate and core inflation is lower under core inflation targeting than under CPI inflation targeting. In fact, in contrast to the case of normal exchange rate pass-through, there are four cases (as highlighted) where CPI inflation variability is *also lower* under core inflation targeting. Under the standard FPS policy rule, then, our results further strengthen the case for targeting core inflation over CPI inflation.

The four cases that result in higher CPI inflation variability when targeting CPI inflation, occur when exchange rate pass-through is perceived to be fast (F/F or F/N), and exchange rate movements are perceived to affect expectations (E/E or E/L). In these cases, the monetary authority believes that it has a channel with which it can quickly affect both CPI inflation, through price level effects, and core inflation, via inflation expectations. Under core inflation targeting the authority counts upon the latter channel; under CPI inflation targeting it counts upon both. Whether or not the beliefs are correct, core inflation targeting results in lower CPI inflation variability.

When the authority, in fact, has neither channel but does not realise it (the F/N E/L case), under both CPI and core inflation targeting the monetary authority consistently sets policy too loosely relative to when it knows the true state of the economy. Hence, both CPI and core inflation variability is higher than in the correct-information N/N L/L case. However, under CPI inflation targeting policy is set even *more* loosely.[20] In fact, the highest variability for CPI inflation under the standard FPS rule is then observed. Similarly, when the authority makes no mistakes about inflation expectations, but believes exchange rate pass-through is faster than it actually is (the F/N E/E case), policy is again set too loosely under CPI inflation targeting, and higher CPI inflation variability results.

The more puzzling cases are when the authority correctly perceives exchange rate pass-through is fast (F/F), and rightly or wrongly believes that movements in the exchange rate affect inflation expectations (E/E or E/L). Under these cases, regardless of the inflation target, the authority believes it can sway inflation expectations via movements in the exchange rate. As such, we might expect that the general result that CPI inflation variability is lower under CPI inflation targeting would hold. However, it does not. This may reflect the fact that the standard FPS policy rule is not an efficient policy rule. Alternatively, it may reflect that under the standard FPS policy horizon, the monetary authority is unable to exploit fully a fast exchange rate transmission channel. This issue is examined next.

5.2.2 The short-horizon policy rule

The standard policy rule used in FPS sets policy given forecast deviations of inflation from the target 6, 7, and 8 quarters ahead. Over this horizon, policy affects inflation primarily through the output gap channel. Therefore, even under CPI inflation targeting the transmission of exchange rate movements into CPI inflation is 'looked-through' to some extent. With a shorter policy-horizon of 2 to 4 quarters, movements in the exchange rate affect CPI inflation more over the horizon in which policy is reacting to forecasted inflation deviations from target. Hence under CPI inflation targeting the authority relies upon the direct exchange rate transmission channel to a greater extent. This may afford the authority better control over CPI inflation. It is of interest then to examine the macroeconomic implications of targeting core versus CPI inflation when the authority has a less forward-looking policy horizon; that is, when it is trying to stabilise inflation more quickly.

The results of the stochastic simulation experiments are presented in Table 4 below. Relative to the results observed for the standard FPS policy rule, it is seen that policy is far more aggressive. This can be seen by comparing the variability in the nominal interest rate, for any configuration of the model economy and any inflation target, in Table 4 with Table 3. This result reflects that if policy seeks to stabilise inflation at a shorter-horizon, it needs to be aggressive. In being more aggressive, the monetary authority reduces the variability in CPI inflation when targeting CPI inflation, and both

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[20] Note that setting policy 'more loosely' does not imply that the RMSD of policy variables will be less. In fact, as observed in table 3, the RMSD of the nominal interest rate and the exchange rate is higher under the CPI inflation targeting cases. Setting policy consistently too loosely implies that the authority does not act strongly or soon enough to inflation deviations from the target. As such, greater secondary cycles are put through the model economy and policy instruments stay away from control for longer. The RMSD statistic explicitly penalises this.

CPI and core inflation, when targeting core inflation. However, the cost of this is greater output variability. This result is observed more generally in a host of other research including Black *et al.* (1997), Svensson (1998), and Drew and Hunt (1998b).

An interesting result observed is that for the short-horizon policy rule, policy is far *more* aggressive under core inflation targeting relative to CPI inflation targeting, where instrument variability is around 1.5 percentage points higher.[21] This result stems from the fact that when targeting CPI inflation at short horizons, the monetary authority can rely more upon the direct price effects of exchange rate movements onto CPI inflation. Hence it does not need to be as aggressive with policy as if it were targeting core inflation, which excludes these effects.

In being more aggressive under core inflation targeting, the monetary authority not only reduces core inflation variability relative to the CPI inflation targeting rules, but also reduces CPI inflation variability.[22] This result is substantively different from the broad result obtained under the standard policy rule. Furthermore, although the monetary authority is more aggressive under core inflation targeting, output variability is *still less* than that observed under CPI inflation targeting for any configuration of the model economy and monetary authority beliefs. This result re-enforces the efficacy of targeting core over CPI inflation. That is, even when exchange rate pass-through is fast, within the policy horizon of the monetary authority *and* affecting core inflation expectations, when targeting CPI inflation the monetary authority induces unnecessary volatility into the economy by reacting to the price level effects of movements in the exchange rate.

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[21] If the RMSD of the nominal interest rate is 1.5 percentage points more under core inflation targeting, then the 95 per cent confidence band about the interest rate is +/-3 percentage points greater than that under targeting CPI inflation. This is of a magnitude likely to be of concern for any real world monetary authority.

[22] There is one case in table 4 where CPI inflation variability is actually lower when targeting CPI inflation (the L/E and N/F case as highlighted). We see this result as an anomaly that would possibly not be robust under a broader range of policy rules.

Table 4: Performance of the model economy under the short-horizon rule

		L/L		L/E		E/E		E/L	
		πc	πcpi	πc	πcpi	πc	πcpi	πc	πcpi
N/N	**rmsd y**	3.29	3.72*[a]	3.10	3.26*[a]	2.94	3.16*[a]	3.17	3.62*[a]
	rmsd rn	5.61	4.40*[b]	5.50	3.81*[b]	4.99	3.81*[b]	5.18	4.40*[b]
	rmsd z	5.52	4.95*[b]	5.48	4.81*[b]	5.12	4.58*[b]	5.18	4.74*[b]
	rmsd πc	1.30	1.71*[a]	1.15	1.42*[a]	1.19	1.45*[a]	1.37	1.75*[a]
	rmsd πcpi	0.75	0.93*[a]	0.67	0.74*[a]	0.70	0.82*[a]	0.81	1.04*[a]
F/F	**rmsd y**	3.29	3.90*[a]	3.04	3.32*[a]	2.90	3.19*[a]	3.19	3.67*[a]
	rmsd rn	5.61	4.48*[b]	5.46	3.73*[b]	4.90	3.74*[b]	5.14	4.35*[b]
	rmsd z	5.52	5.12*[b]	5.44	4.93*[b]	5.02	4.58*[b]	5.10	4.73*[b]
	rmsd πc	1.30	1.85*[a]	1.11	1.51*[a]	1.18	1.52*[a]	1.39	1.84*[a]
	rmsd πcpi	0.75	0.96*[a]	0.73	0.75	0.68	0.82*[a]	0.81	1.06*[a]
N/F	**rmsd y**	3.29	3.75*[a]	3.04	3.19*[a]	2.87	3.10*[a]	3.15	3.61*[a]
	rmsd rn	5.61	4.46*[b]	5.46	3.76*[b]	4.91	3.80*[b]	5.15	4.42*[b]
	rmsd z	5.52	4.99*[b]	5.45	4.75*[b]	5.05	4.53*[b]	5.14	4.71*[b]
	rmsd πc	1.30	1.73*[a]	1.11	1.39*[a]	1.16	1.42*[a]	1.37	1.76*[a]
	rmsd πcpi	0.75	0.88*[a]	0.73	0.67*[b]	0.68	0.74*[a]	0.81	0.98*[a]
F/N	**rmsd y**	3.29	3.91*[a]	3.10	3.42*[a]	2.98	3.26*[a]	3.20	3.69*[a]
	rmsd rn	5.61	4.49*[b]	5.50	3.82*[b]	4.99	3.77*[b]	5.17	4.34*[b]
	rmsd z	5.52	5.15*[b]	5.47	4.99*[b]	5.09	4.64*[b]	5.15	4.77*[b]
	rmsd πc	1.30	1.85*[a]	1.15	1.54*[a]	1.21	1.55*[a]	1.38	1.84*[a]
	rmsd πcpi	0.75	1.03*[a]	0.67	0.83*[a]	0.71	0.90*[a]	0.82	1.12*[a]

[a] ([b]) indicates that variability under core inflation targeting is less (more) than under CPI inflation targeting at the 95 percent level of confidence.

5.2.3 The Taylor rule

The Taylor rule differs from the previous policy rules examined for two key reasons. Firstly, only observed *contemporaneous* information is used to guide policy. Therefore, the monetary authority's beliefs about the structure of the real world are irrelevant. Policy is set mechanically in response to the actual deviations of output and inflation from their targets. In contrast, under the inflation-targeting rules examined previously, the monetary authority exploits its knowledge of the economy to project the future outlook of the economy in order to set policy. Even given the uncertainties examined in this paper, the monetary authority is still better informed about the structure of the economy than is likely in the real world.[23] As such, we might expect that superior macroeconomic outcomes would be attainable when policy is forward looking.[24]

The second point of difference between the Taylor rule and the inflation targeting rules, is the obvious fact that weight is placed not only on inflation deviations from the target, but also on deviations of output from potential. As such policy *explicitly* seeks to smooth output. In contrast, inflation forecast-based rules only *implicitly* smooth output via the output gap channel of policy, given shocks to demand. A core inflation-targeting rule does this to a *greater* extent than a CPI inflation-targeting rule as the core inflation rule works primarily via the output gap channel, rather than the direct exchange rate channel. That is, shocks to aggregate demand move core inflation and output in the same direction. Hence stabilising core inflation has the ancillary benefit of stabilising output in a world where demand shocks are important. This is one of the reasons why under the inflation targeting rules examined previously, output variability is lower under core inflation targeting.

Turning to the results, in Table 5 below there are only four cases considered, given that the authority's beliefs about the real world are irrelevant. These cases are that exchange rate pass-through is:

1. normal and exchange rate movements affect only the level of CPI inflation
2. fast and exchange rate movements affect only the level of CPI inflation
3. normal and exchange movements affect inflation expectations
4. fast and exchange movements affect inflation expectations

Whatever the structure of the world, the qualitative results presented in Table 5 are the same. Output and exchange rate variability is marginally *higher* under core inflation targeting, whilst core and CPI inflation variability is lower. Variability in the policy instrument is largely the same under either core or CPI inflation targeting.

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[23] In the real world the monetary authority must also contend with uncertainty about the current state of the economy and more generalised model uncertainties than those considered here.
[24] This result is seen in Drew and Hunt (1998b), even when the monetary authority makes errors about the level of potential output.

Table 5: Performance of the model economy under the Taylor Rule

		L/L		E/E	
		πc	πcpi	πc	πcpi
N/N	rmsd y	2.39	2.34*[b]	2.36	2.31*[b]
	rmsd rn	3.39	3.39	3.22	3.21
	rmsd z	4.24	4.15*[b]	4.28	4.19*[b]
	rmsd πc	2.69	2.76*[a]	2.44	2.50*[a]
	rmsd πcpi	2.49	2.58*[a]	2.23	2.31*[a]
F/F	rmsd y	2.39	2.34*[b]	2.37	2.32*[b]
	rmsd rn	3.39	3.37	3.34	3.31*[b]
	rmsd z	4.24	4.10*[b]	4.32	4.17*[b]
	rmsd πc	2.69	2.74*[a]	2.53	2.57*[a]
	rmsd πcpi	2.49	2.58*[a]	2.34	2.39*[a]

[a] ([b]) indicates that variability under core inflation targeting is less (more) than under CPI inflation targeting at the 95 percent level of confidence.

The fact that variability in output is higher under core inflation targeting runs directly against the results obtained under the previous two policy rules examined. This result at first glance seems counterintuitive. As discussed, setting policy to stabilise core inflation will stabilise output under shocks that also affect aggregate demand. It is true that setting policy in response to temporary shocks to the Phillips curve will move output in the opposite direction. However, given the previous stochastic simulation results it must be the case that *on average* the shocks to demand are more important than shocks to the Phillips curve.

To shed some light on the Taylor rule results a simple deterministic demand shock is presented under both core and CPI inflation targeting, for both the Taylor rule and the standard FPS rule. The results of these simulations are given in Appendix 3. The dashed lines are the outcomes under core inflation targeting, the solid lines outcomes under CPI inflation targeting. All outcomes are expressed as deviations from control. For the Taylor rule with a core inflation target, the paths for both CPI and core inflation deviate less from control than under CPI targeting, while the paths for the real exchange rate and the output gap appear to deviate more. In contrast, for the standard FPS rule, it is clear that the output gap and domestic price inflation is less variable under core inflation targeting in the case of the demand shock.

The results under the deterministic demand shock are then similar to the results observed under the stochastic simulation experiments. It would therefore appear that the differences between the Taylor results and the inflation targeting results stem from the differing response of the monetary authority to shocks to demand. These responses are fundamentally a function of the policy horizon of the monetary authority. Under the Taylor rule with a CPI inflation target, the monetary authority sees more quickly the impact of its policy actions on CPI inflation, via the impact of the exchange rate. It therefore eases policy slightly more rapidly than under the core inflation Taylor rule. The real exchange rate returns to control more quickly and the cycle in output is less. However, as policy is effectively looser, both CPI and core inflation variability are higher.

Conversely, under a Taylor rule with a core inflation target the authority does not see the impact of its policy actions until later, as policy works through the slower output channel. Policy is kept tighter for longer, and via UIP the real exchange rate deviates from control for a longer period.

In contrast, when the authority is forward-looking, by definition it sets policy based upon the projected outlook of the economy. With a core inflation target under the demand shock, it sees through the temporary effect of the exchange rate appreciation on CPI inflation and keeps policy initially tighter for longer. Further out, it is able to ease back on monetary conditions more quickly than under the CPI inflation target. That is, by being forward-looking and targeting core inflation the authority more quickly arrests the inflationary consequences of the demand shock.

In comparison to the forward-looking inflation targeting rules, both CPI and core inflation variability is far greater under both Taylor rules examined. For example, the variability of CPI inflation under the CPI inflation targeting Taylor rule is roughly 2.5 times greater than that of the standard CPI inflation targeting policy rule. In contrast, output variability under the Taylor rule is consistently lower than under the forward-looking rules, although not by the same order of magnitude as that observed for CPI inflation variability. This result is observed more generally in Drew and Hunt (1998b), where a broader range of policy rules are examined that that presented here.

In summary, under the core inflation targeting Taylor rule output variability is higher relative to the CPI inflation targeting Taylor rule. This result is a function of the policy horizon of the monetary authority. It may also be because the standard Taylor rule is not efficient (See Drew and Hunt (1998b)), hence it will be interesting to see in future research whether the result still holds when considering efficient policy rules. The benefit of including an output gap term into the policy reaction function, is however, clearly seen. We turn now to examine a rule that combines features of both types of rules examined thus far; that is, a rule that is forward-looking in inflation, but also has a concern for the current output gap.

5.2.4 Inflation forecast-based rule with explicit output smoothing

In Table 6 below, the results of targeting core versus CPI inflation are seen in the context of a rule that is forward-looking in inflation, but also has a concern for the current output gap. The broad result from these experiments is that output and instrument variability is lower when targeting core inflation, whilst CPI inflation variability is slightly higher. These results match those observed for the standard FPS policy rule and hence oppose the results observed under the Taylor rule examined here. An interesting point of departure from the standard results, however, is that core inflation variability is largely the same regardless of whether CPI or core inflation is targeted. This reflects the fact that by including an output argument into the policy reaction function, forward-looking CPI inflation targeting becomes closer to core inflation targeting. The analysis presented here, however, suggests that this is true only up to a point. It is still the case that the monetary authority is better able to stabilise output and its instruments by not reacting as strongly to exchange rate effects.

The hybrid nature of the policy rule examined here is clearly seen in comparison of the results with the previous policy rules examined. Relative to the Taylor rule, inflation variability is far lower. Relative to the inflation targeting rules, output variability is lower. As in Drew and Hunt (1998b), this result suggests that a forward-looking inflation-targeting rule could be well complemented by also having a concern for current output.

Two further points of comparison with the previous policy rules examined are also worth mentioning. Firstly, the four cases identified using the standard policy rule (in section 5.2.1), in which under core inflation targeting CPI inflation variability is also reduced, are overturned here. That is, the more robust general result that under core inflation targeting, CPI inflation variability is slightly higher, holds. Secondly, the specification of inflation expectations qualitatively affects the outcome of the stochastic experiments in the same way as observed under the other forward-looking policy rules examined. That is, better macroeconomic outcomes are observed when movements in the exchange rate do affect inflation expectations. Again, reflecting that the policy rule is not efficient, the best outcomes for inflation, and often output, are observed when the authority acts as if the exchange rate affects only the level of CPI inflation when it in fact affects inflation expectations (L/E). The worst results for output and inflation are observed in the converse case (E/L).

Table 6: Performance of the model economy under an inflation forecast-based rule with explicit output smoothing

		L/L		L/E		E/E		E/L	
		πc	πcpi	πc	πcpi	πc	πcpi	πc	πcpi
N/N	rmsd y	2.50	2.81*a	2.38	2.69*a	2.37	2.59*a	2.60	2.84*a
	rmsd rn	3.80	3.97*a	3.75	3.83*a	3.43	3.50*a	3.58	3.71*a
	rmsd z	4.40	4.84*a	4.39	4.85*a	4.22	4.55*a	4.32	4.63*a
	rmsd πc	1.42	1.43	1.27	1.25*b	1.33	1.34	1.46	1.50*a
	rmsd πcpi	1.12	1.02*b	0.99	0.85*b	1.02	0.95*b	1.10	1.06*b
F/F	rmsd y	2.50	2.84*a	2.37	2.66*a	2.39	2.62*a	2.53	2.82*a
	rmsd rn	3.80	4.28*a	3.77	4.13*a	3.48	3.71*a	3.55	3.89*a
	rmsd z	4.40	5.03*a	4.38	5.02*a	4.24	4.72*a	4.25	4.73*a
	rmsd πc	1.42	1.45*a	1.28	1.29	1.33	1.38*a	1.49	1.55*a
	rmsd πcpi	1.12	1.06*b	1.03	0.95*b	1.05	0.99*b	1.20	1.14*b
N/F	rmsd y	2.50	2.80*a	2.44	2.64*a	2.37	2.56*a	2.51	2.77*a
	rmsd rn	3.80	3.97*a	3.79	3.78*b	3.46	3.49*a	3.53	3.67*a
	rmsd z	4.40	4.83*a	4.46	4.81*a	4.21	4.53*a	4.21	4.55*a
	rmsd πc	1.42	1.43	1.24	1.24	1.33	1.33	1.49	1.52*a
	rmsd πcpi	1.12	1.05*b	0.97	0.86*b	1.05	0.96*b	1.20	1.12*b
F/N	rmsd y	2.50	2.85*a	2.38	2.70*a	2.40	2.67*a	2.53	2.83*a
	rmsd rn	3.80	4.28*a	3.75	4.16*a	3.46	3.74*a	3.56	3.91*a
	rmsd z	4.40	5.05*a	4.38	5.03*a	4.26	4.76*a	4.28	4.77*a
	rmsd πc	1.42	1.44	1.27	1.30*a	1.33	1.39*a	1.50	1.55*a
	rmsd πcpi	1.12	1.04*b	0.99	0.92*b	1.02	0.99*b	1.17	1.14*b

*a (*b) indicates that variability under core inflation targeting is less (more) than under CPI inflation targeting at the 95 percent level of confidence.

6. Summary and conclusion

This paper has sought to address whether preferable macroeconomic outcomes are attainable under core as opposed to CPI inflation targeting when there is uncertainty about exchange rate pass-through and/or uncertainty about how agents form their expectations of inflation. To answer this question, stochastic simulations of the model economy are performed and the macroeconomic stability of the economy is assessed. Under the standard FPS policy rule, the broad result is that targeting core inflation reduces the variability in output, the interest rate and the exchange rate, and that of core inflation itself. However, CPI inflation variability is, in most instances, slightly more variable. Under a policy rule with a shorter policy horizon than the standard FPS rule, it is found that targeting core inflation reduces variability in output and both core and CPI inflation; however, instrument variability is higher. The results under a forward-looking Taylor rule are similar to those found with the standard FPS policy rule, except that core inflation variability is largely the same regardless of whether CPI or core inflation is targeted. Finally, the results obtained under the standard core inflation targeting Taylor rule are that core and CPI inflation variability is lower, whilst output and exchange rate variability is higher.

In summary, as in Svensson (1998), the results are somewhat dependent upon the formulation of the policy rule. If policy is forward-looking there is broad support targeting core inflation over CPI inflation. Under the Taylor rule, the efficacy of targeting core inflation is less clear as output and exchange rate variability is higher.

The motivation for examining the behaviour of the economy under the policy rules presented in this paper is that they are descriptively accurate representations of actual policy practice. The results, however, may not be general even for the FPS model economy. To answer this question our future research agenda will be to perform grid-search techniques to search for efficient policy rules.

References

Armstrong, J., R. Black, D. Laxton and D. Rose (1995), "A robust method for simulating forward looking models", Part 2 of *The Bank of Canada's New Quarterly Projection Model*. Technical report No. 73. Ottawa: Bank of Canada.

Beaumont C., V. Cassino, and D. Mayes (1994), "Approaches to modelling prices at the Reserve Bank of New Zealand", Reserve Bank of New Zealand *Discussion Paper* G 94/3.

Black, R., V. Cassino, A. Drew, E. Hansen, B. Hunt, D. Rose and A. Scott (1997), "The Forecasting and Policy System: the core model", Reserve Bank of New Zealand *Research Paper* No. 43.

Brainard, W. (1967), "Uncertainty and the effectiveness of policy", *American Economic Review*, Vol. 57: 411-425.

Brayton, F. and P. Tinsley, (1996), "A Guide to FRB/US: A Macroeconomic Model of the United States". *Finance and Economics Discussion Series* No. 42, Federal Reserve Board, Washington.

Conway, P., A. Drew, B. Hunt, and A. Scott. (1998), "Exchange rate effects and inflation targeting in a small open economy: a stochastic analysis using FPS", *BIS Conference Papers*, Vol. 6.

Conway, P. and B. Hunt (1997), "Estimating potential output: a semi structural approach", Reserve Bank of New Zealand *Discussion Paper* G97/9, Wellington.

Dow, J.P. (1993), "Measuring inflation using multiple price indexes" University of California Department of Economics *Working Paper* 93-16

Debelle, G. (1997), "Inflation targeting in practice", IMF *Working Paper* No. 35, Washington, D.C.

Drew, A. and B. Hunt, (1998a), "The forecasting and policy system: stochastic simulations of the core model". Reserve Bank of New Zealand *Discussion Paper* G98/6.

Drew, A., B. Hunt, (1998b), "Efficient simple policy rules and the implications of uncertainty about potential output", Paper presented to the RBNZ Conference on Policy and Uncertainty, June 1998 (conference volume forthcoming).

Dwyer, J. and Lam, R. (1995), "The two stages of exchange rate pass-through: implications for inflation". *Australian Economic Papers.*

Fillion, J. and R. Tetlow, (1994) "Zero inflation or price level targeting? Some answers from stochastic simulations on a small open-economy macro model" in *Economic Behaviour and Policy Choice under Price Stability*, Bank of Canada Publication.

Gartner, C. and Wehinger, G. (1998), "Core inflation in selected European countries". Oesterreichische National Bank *Working Paper* 33.

Hunt B., (1995), The effects of foreign demand shocks on the Canadian economy: an analysis using QPM." *Bank of Canada Review,* Autumn, 23-32, Bank of Canada, Ottawa.

Laxton, D., Rose, D., and Tetlow, B. (1994) "Monetary Policy, Uncertainty, and the Presumption of Linearity", Bank of Canada *Technical Report* No. 63

Lippi, F. (1998) Comments on "Exchange rate effects and inflation targeting in a small open economy: a stochastic analysis using FPS", *BIS Conference Papers,* Vol. 6.

Lucas, R.E. Jr. (1976), "Econometric policy evaluation: a critique", in K. Brunner and A. Meltzer (eds.), *The Phillips Curve and the Labour Market*, Carnegie-Rochester Conference on Public Policy, Vol. 1, 19-46.

Orr A., A. Scott, and B. White (1998) "The exchange rate and inflation targeting", Reserve Bank of New Zealand *Bulletin*, September 1998.

Quah D. and S. Vahey. (1995), "Measuring core inflation". *The Economic Journal* 105*:1130-1144.*

Roger, S. (1995), "Measures of underlying inflation in New Zealand, 1981-1995". Reserve Bank of New Zealand *Discussion Paper* G95/5.

Roger, S. (1997), "A robust measure of core inflation in New Zealand, 1949-1996." Reserve Bank of New Zealand *Discussion Paper* G97/7.

Svensson, L.E.O. (1996), "Inflation forecast targeting: implementing and monitoring inflation targets", Institute for International Economic Studies *Seminar Paper* No. 615, Stockholm.

Svensson, L.E.O. (1998), "Open-economy inflation targeting", forthcoming Reserve Bank of New Zealand *Discussion Paper*, Wellington.

Taylor, J. (1994), "The inflation-output variability tradeoff revisited", in J. Fuhrer (ed.), *Goals, Guidelines, and Constraints Facing Monetary Policy Makers*, Conference Series No. 38. Boston: Federal Reserve Bank of Boston: 21-38.

Taylor, J. (1993), "Macroeconomic policy in a world economy: from econometric design to practical operation", *Norton* 1993, New York and London.

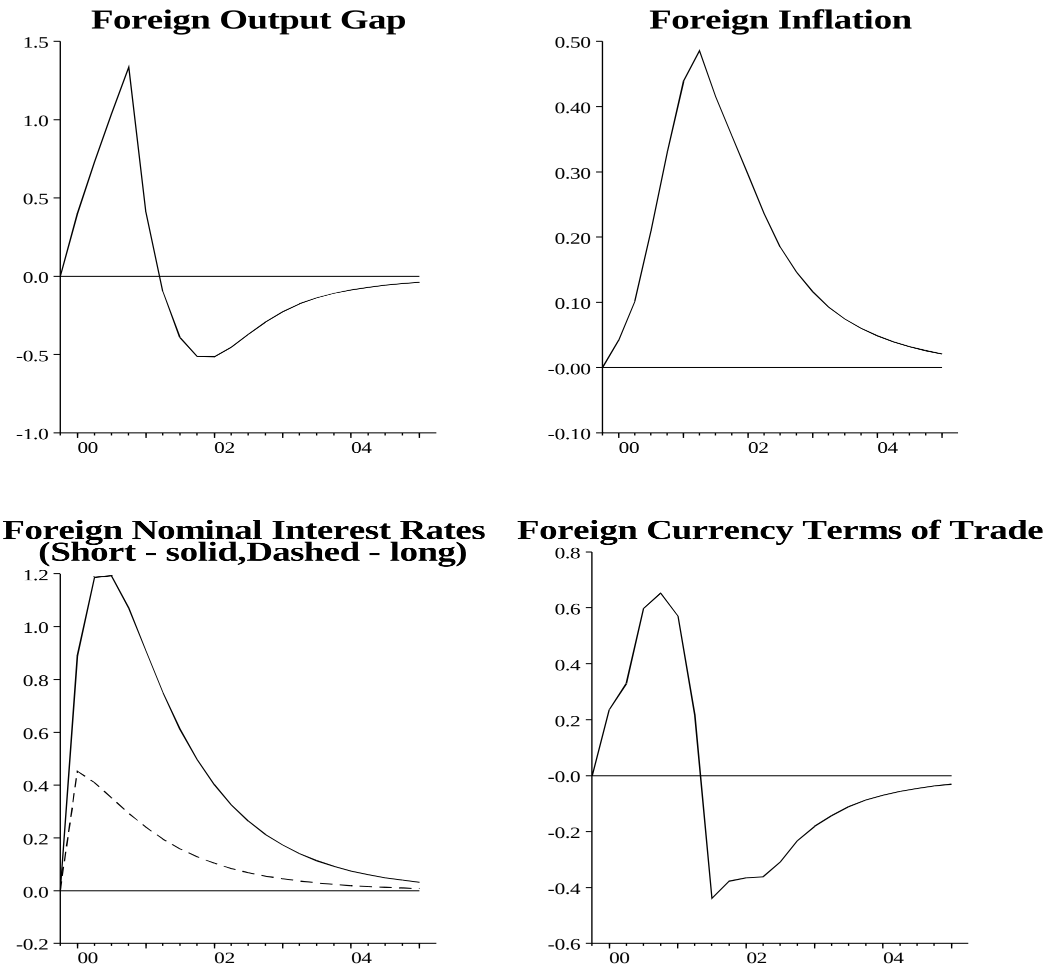
Tinsley, P.A. (1993), "Fitting both data and theories: polynomial adjustment costs and error-correction decision rules", Unpublished paper. Division of Statistics and Research, Board of Governors of the Federal Reserve System, Washington.

Winkelman, L. (1996), "A study of pass-through elasticities for New Zealand import markets" Reserve Bank of New Zealand *Discussion Paper* G96/5.

Appendix 1 The endogenous foreign sector

The response of the foreign sector to a demand shock is traced out in the figure below. Two points are worth noting. Unlike the FPS core model, the foreign Phillips curve is symmetric in goods market disequilibrium. The sacrifice ratio has been calibrated to be 2. This is roughly the mid-point of the range of sacrifice ratios (1.3 to 2.6) that result in FRB/US under the alternative structures for expectations and disinflation credibility assumptions presented in Brayton and Tinsley (1996). A forward-looking inflation-targeting policy reaction function determines the short-term nominal interest rate, while the behaviour of the foreign long-term interest rate is given by the expectations theorem. The behaviour of the foreign-currency terms of trade relevant for New Zealand has been calibrated to match the behaviour of New Zealand's terms of trade as suggested by the VAR.

Foreign Demand Shock
(Shock minus Control)



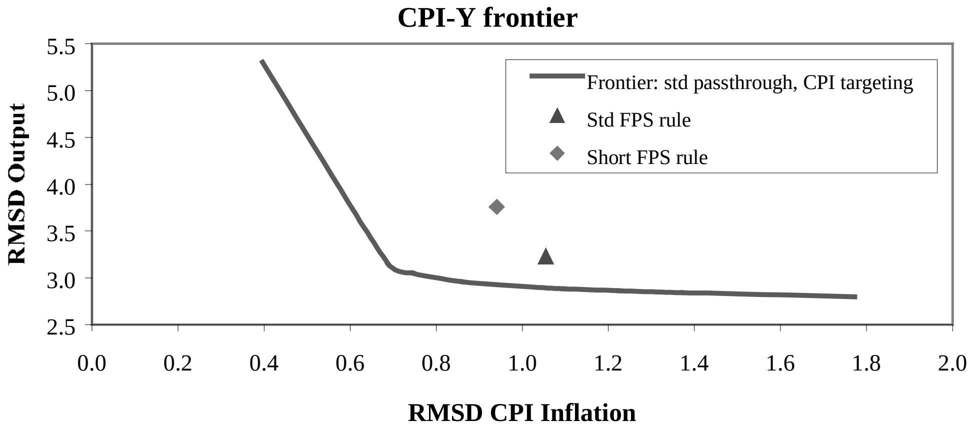
The changes in the stochastic properties of the New Zealand economy that result from endogenising the foreign sector under the standard FPS reaction function are evident in the Table below. The variability of real output remains virtually unchanged. However, the variability of inflation and the real exchange rate falls and the variability of the nominal short-term interest rate rises. The direction of these changes is quite intuitive. Because the foreign short-term interest rate is now variable over the cycle, the domestic interest rate must do more of the work. Given the positive correlation between foreign and domestic business cycles, movements in the domestic short rate and the foreign short rate are positively correlated (on average), producing less variability in the exchange rate via the UIP condition. Additionally, the response of the foreign monetary authority in order to return foreign inflation to control also helps to return domestic inflation to control via import and export prices.

Root Mean Squared Deviations

	Output	Exchange rate	Nominal interest rate	CPI Inflation
Exogenous foreign sector	3.19	5.24	3.59	1.19
Endogenous foreign sector	3.22	4.97	3.89	1.05

Appendix 2 Efficient Policy Frontiers

As defined in Taylor (1994), efficient policy rules are those rules that deliver the lowest achievable combinations of inflation and output variability, given the structure of the model economy under consideration and the stochastic disturbances applied. In the graph below, the efficient policy frontier is traced out for forward-looking CPI inflation targeting policy rules.[25] The two policy rules of the same class examined in this paper are also shown. These rules lie to the north east of the efficient policy frontier. This illustrates that the policy rules examined are not efficient: other policy rules exist that the monetary authority could use to achieve lower combinations of both output and inflation.



The policy rules that lie upon the efficient policy frontier tend to penalise forecast inflation deviations from target far more vigorously than the standard FPS policy rule, or the alternatives presented in this paper. This is illustrated in the second graph below which shows the trade-off between instrument and inflation variability. Note that the policy rules presented here all have relatively low instrument variability. This finding is common in the extensive literature on policy rules (see Drew and Hunt (1998b)). That is, it is often found that descriptively accurate policy rules, such as the Taylor rule, fare poorly in terms of the inflation/output variability trade-off, but well in terms of instrument variability. In other words, policy makers have a high revealed preference for being cautious in adjusting policy. The classic Brainard (1966) article offers a plausible insight into this revealed preference: if there is also uncertainty about policy multipliers, it may better to act cautiously.

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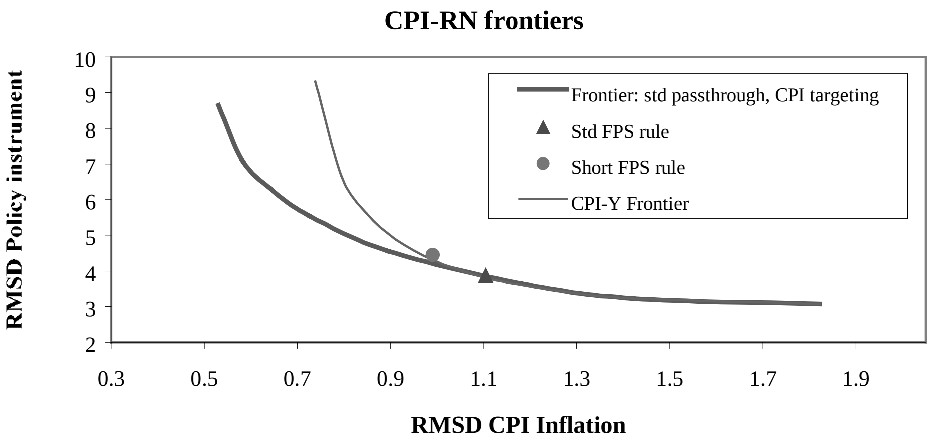
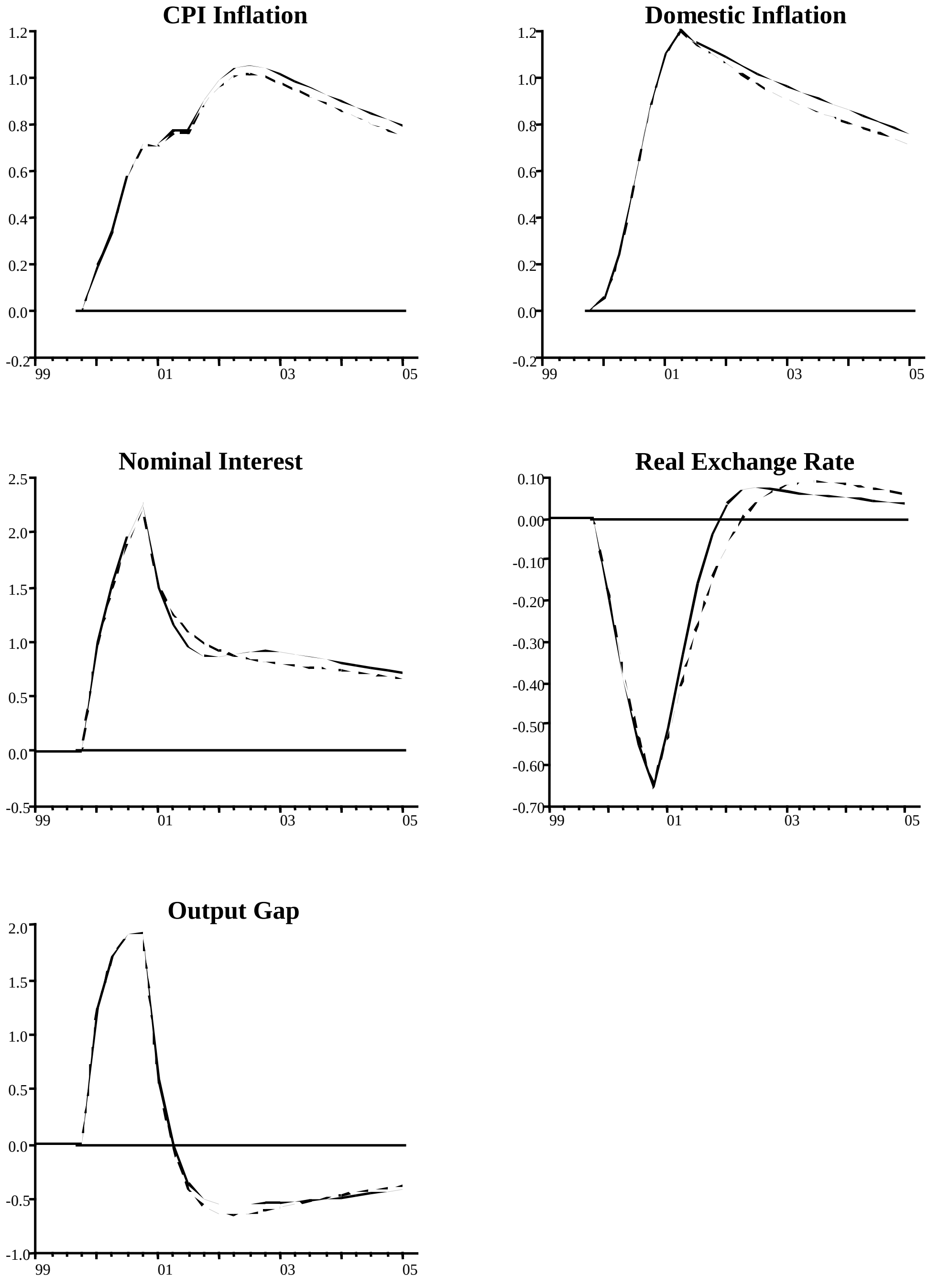
[25] See Drew and Hunt (1998b) for a description of the techniques employed to trace out efficient policy frontiers, and a general discussion on the stochastic behaviour of the FPS model under alternative policy rules.


CPI-RN frontiers
RMSD Policy instrument
RMSD CPI Inflation
10
9
8
7
6
5
4
3
2
0.3
0.5
0.7
0.9
1.1
1.3
1.5
1.7
1.9
Frontier: std passthrough, CPI targeting
Std FPS rule
Short FPS rule
CPI-Y Frontier

Appendix 3 Deterministic Demand Shocks

Demand Shock

(Under Standard Taylor Rule)



Demand Shock

(Under Standard FPS Rule)