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Exchange rate effects and inflation targeting in a small open economy: a stochastic analysis using FPS

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Abstract

In this paper, stochastic simulations of the Reserve Bank of New Zealand's new macroeconomic model, FPS, are used to examine the issue of which price index should monetary policy stabilise in a small open economy. Under the class of policy rules considered, targeting a measure of domestic inflation, which does not include the direct effects of exchange rate movements on the price of imported goods, results in lower variability in real output, nominal interest rates, the exchange rate and domestic price inflation. The result is robust if direct exchange rate effects influence agents' expectations of generalised inflation and if the policy maker is uncertain about how direct exchange rate effects influence expectations. Tracing out efficient policy frontiers under the two alternative targets illustrates that for a given level of CPI variability, output variability can be significantly reduced by targeting domestic price inflation.

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1 Introduction

Specifying the objective of monetary policy as a well-defined target or target range for the rate of inflation is becoming increasingly common among central banks (for example, New Zealand, Canada, United Kingdom, Sweden, Finland, Australia and Spain). 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. For small open economies, movements in the nominal exchange rate often account for a significant part of the variation in these indices via their direct effect on the price of imported goods. This paper examines whether preferable macroeconomic outcomes can be achieved if monetary policy focuses on an index that excludes such direct exchange rate effects on consumer prices.

One argument for targeting indices free of direct exchange rate effects is that the monetary authority should focus primarily on persistent sources of inflation. As outlined in Mayes and Chapple (1995) and Yates (1995), the design of many inflation targeting regimes includes specific exemptions for disturbances that are expected to result in temporary price level movements only. Depending on how agents form expectations of future inflation, direct exchange rate effects coming through import prices may result only in price level shifts. This arises if agents perceive that a portion of the observed inflation in the CPI index is the result of changes in import prices that are driven by recent movements in the exchange rate, and they form their expectations of future CPI inflation by looking through or ignoring these effects.

In Svensson (1998), a model of a small open economy is used to compare CPI inflation and domestic inflation targeting rules. This model characterises direct exchange rate effects on import prices as CPI level effects only. The results from a comparison of policy rules that attempt to minimise the variance in inflation only ("strict" policy rules), suggest that targeting CPI inflation reduces the variance in CPI inflation while increasing the variance in real output, nominal interest rates, the real exchange rate and domestic price inflation. The results from a comparison of policy rules that also smooth the variability in real output ("flexible" policy rules) suggest that CPI targeting results in lower variability for most key macro variables except real output. The difference between these two types of policy rules arises primarily because they use different channels to control inflation. The "strict" rules rely on direct exchange rate effects to control inflation and the "flexible" rules work primarily through the output gap channel. The six-, seven- and eight-quarter ahead targeting horizon used in the base-case reaction functions examined in much of this paper means that the monetary authority is working primarily through the output gap channel to control inflation. Consequently, these results should be compared to the results under the "flexible" rules examined in Svensson (1998).

In this paper, stochastic simulation experiments with the Reserve Bank of New Zealand's *Forecasting and Policy System* model, FPS,[2] are used to extend, in a number of directions, the work presented in Svensson (1998). First, whereas Svensson's model is designed to represent

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[2] FPS is a modern macroeconomic model that sits at the heart of the Reserve Bank of New Zealand's new system for generating official economic projections. A complete description of the model and the system can be found in Black, Cassino, Drew, Hansen, Hunt, Rose and Scott (1997).

a generic small open economy, FPS has been calibrated to match the dynamic properties of a specific economy, New Zealand. A stark difference that arises between these two models concerns the transmission lags of monetary policy – in FPS the lags are far longer, hence inflation control is more difficult for the monetary authority. Second, whereas Svensson's model is linear, the inflation process in FPS is asymmetric in goods market disequilibrium. Third, the way that direct exchange rate effects on import prices enter agents' inflation expectations process is examined, as well as the implications of monetary authority uncertainty about the true expectations process.

The result presented here suggest that targeting domestic inflation relative to CPI inflation reduces the variance in domestic price inflation, output, and the policy instrument; although the variance in CPI inflation is slightly higher, holding all else in the policy reaction function constant. This result holds even if direct exchange rate effects influence inflation expectations, and if the monetary authority is uncertain about this influence. Further, tracing out the CPI inflation/output variability efficient frontier under both CPI inflation and domestic price inflation targeting illustrates that the latter shifts the frontier towards the origin. That is, under domestic price inflation targeting, it is possible to achieve combinations of CPI inflation and output variability that are unambiguously better than those achievable under CPI inflation targeting. Accordingly, for a given variability in CPI inflation, output variability can be reduced by targeting domestic price inflation. Achieving price stability in this way has the ancillary effect of smoothing output. These results match those of Svensson (1998) for "strict" policy rules, but not for "flexible" rules, which are much closer to the class of policy rules considered here. This difference may reflect the different lag structures in the pass-through of exchange rate effects in the two models or the fact that the results presented here do not consider *optimal* rules. Further work will need to be done to reconcile the differences in these results.

The remainder of the paper is structured as follows. In Section 2, a brief overview of the structure of the FPS model is presented along with the methodology for generating the stochastic disturbances. The stochastic simulation results are presented in Section 3. Section 4 contains a brief summary and conclusion.

2　FPS at a glance

The Forecasting and Policy System (FPS) 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 an underlying steady-state structure that determines the long-run equilibrium to which the model will converge. The second tier is a dynamic adjustment structure that traces out how the economy converges towards that long-run equilibrium.

The long-run equilibrium is characterised by a neoclassical balanced growth path. Along that growth path, consumers maximise utility, firms maximise profits and the 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 that underlie 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, 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. 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. While inflation can potentially arise from many sources in the model, it is fundamentally the difference between the economy's supply capacity and the demand for goods and services that determines inflation in domestic goods prices. Further, the relationship between goods markets disequilibrium and inflation is specified to be asymmetric. Excess demand generates more inflationary pressure than an identical amount of excess supply generates in deflationary pressure.[3] Although direct exchange rate effects have a small impact on domestic prices and, consequently, on expectations,[4] they enter into CPI inflation primarily as price level effects.

2.1 Households

There are two types of households in the model: "rule-of-thumb" and "forward-looking". Forward-looking households save, on average, and hold all of the economy's financial assets. Rule-of-thumb households spend all their disposable income each period and hold no assets. The theoretical core of the household sector is the specification of the optimisation problem for forward-looking households. The specification is based on the overlapping generations framework of Yaari (1965), Blanchard (1985), Weil (1989) and Buiter (1989), but in a discrete time form as in Frenkel and Razin (1992) and Black *et al* (1994). In this framework, the forward-looking household chooses a path for consumption – and a path for savings – that maximises the expected present value of lifetime utility subject to a budget constraint and a fixed probability of death. This basic equilibrium structure is overlaid with polynomial adjustment costs, the influence of monetary policy, an asset disequilibrium term, and an income-cycle effect.

The population size and age structure is determined by the simplest possible demographic assumptions. We assume that new consumers enter according to a fixed birth rate and that existing consumers exit the economy according to the fixed probability of death. For the supply

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[3]   Although the body of empirical evidence supporting asymmetry in the inflation process in both New Zealand and elsewhere is growing, the most convincing argument for using asymmetric policy models is the prudence argument present in Laxton, Rose and Tetlow (1994). The evidence for New Zealand is discussed in Black *et al* (1997).

[4]   The direct exchange rate effect on domestic prices is assumed to arise through competitive pressures.

of labour, we assume that each consumer offers a unit of labour services each period. That is, labour is supplied inelastically with respect to the real wage.

2.2   The representative firm

The formal introduction of a supply side requires us to go beyond the simple endowment economy of the Blanchard *et al* framework. The firm is modelled very simply in FPS, but, as with the characterisation of the consumer, some extensions are made to capture essential features of the economy. Investment and capital formation are modelled from the perspective of a representative firm. This firm acts to maximise profits subject to the usual accumulation constraints. Firms are assumed to be perfectly competitive, with free entry and exit to markets. Firms produce output, pay wages for labour input, and make rental payments for capital input.[5] The production technology is Cobb-Douglas, with constant returns to scale.

Profit maximisation is sufficient to determine the level of output, the level of employment, and the real wage. FPS extends this framework in a number of directions as firms face adjustment costs for capital and a time-to-build constraint.

2.3   The government

Government has the power to collect taxes, raise debt, make transfer payments, and purchase output. As with households and firms, the structure of the model requires clear objectives for government in the long run. However, whereas households' and firms' objectives arise through explicit maximisation, we directly impose fiscal policy choices for debt and expenditure. The government's binding intertemporal budget constraint is used to solve for the labour income tax rate that supports the fiscal choices. The interactions of debt, spending and taxes create powerful effects throughout the rest of the model; government is non-neutral.

2.4   The foreign sector

The foreign sector is treated as completely exogenous to the domestic economy. It supplies the domestic economy with imported goods and purchases the domestic economy's exports, thus completing the demand side of the model. Further, the foreign sector stands ready to purchase assets from or sell assets to domestic households, depending on whether households choose to be net debtors or net creditors relative to the rest of the world. Several key prices affecting the domestic economy are also determined in the foreign sector. The foreign dollar prices of traded goods and the risk-free real interest rate are assumed to be determined in the foreign sector.

2.5   The monetary authority

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 well-defined optimal control problem as in Svensson (1996), its design is not

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[5]   We also assume that households own the capital stock.

arbitrary. The forward-looking nature of the reaction function respects the lags in the economy between policy actions and their 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 of the real economy, are also of concern.

FPS is a useful tool for examining the implications of alternative policy reaction functions because agents' expectations are influenced by policy actions. This occurs because 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), which 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.

2.6 Stochastic simulations with FPS

Running stochastic simulations using a calibrated model is not as straightforward as when using an estimated model. For an estimated model, the properties of the residuals from the estimated equations can be used to pin down the distributions for the randomly generated shocks. No such residuals exist for a calibrated model. To generate the shock terms used for the stochastic simulations of FPS we follow a procedure outlined in Drew and Hunt (1998). Essentially, the impulse response functions (IRFs) from an estimated VAR are used to calculate the paths for the shocks appearing in the calibrated model's equations. The shock paths are then randomly drawn, and the model is hit with the shock paths quarter-by-quarter for 100 quarters. This counts as one model 'draw', which we can think of as one repetition of history. In the stochastic simulation experiments in this paper, 100 draws are conducted for each experiment considered. However, it is important to note that the shocks applied in each draw are seeded, hence under each experiment, the model economy is subjected to an identical battery of shocks.

Using the VAR to define shocks to the FPS core model for use in stochastic simulations has attractive features and weaknesses. First, the VAR itself is a reasonably general representation of the economy and as such captures most of the key temporary disturbances. The VAR approach also leads to shock terms that capture both the serial and cross correlations in the data. The shocks are not interpreted as deep structural shocks, but as summary measures of all the deep structural disturbances that impact on the economy at a micro level and, consequently, they should not be expected to be white noise. However, because of the limitations of the New Zealand data, we were unable to estimate a reasonable VAR that include a measure of the supply side. Consequently our application of the VAR technique captures only temporary disturbances. Further, we treat the impulses as if they contain only exogenous disturbances to the economy over the first four quarters. However, even over this horizon the impulses may be capturing some effects from the historical response of policy.

Despite the limitations outlined above, in Drew and Hunt (1998) it is seen that the technique employed results in model-generated moments that are reasonably close to the historical

moments of the New Zealand data. Furthermore, model generated business cycles do conform to NBER definitions of 'the cycle'. This gives us some degree of comfort with the technique employed in this paper to examine the behaviour of the model economy.

3 Targeting domestic inflation versus CPI inflation

3.1 Targeting domestic inflation versus CPI inflation under base-case expectations

The base-case version of FPS is structured such that direct exchange rate effects on import prices only affect the level of the CPI. That is, direct exchange rate effects in the CPI do not impact on inflation expectations. It is worth noting that 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.

In FPS, CPI inflation is built up by adding imported consumption goods price inflation to inflation in domestic prices. Inflation in domestic goods prices is determined according to a Phillips curve relationship:

$$
\begin{aligned}
\boldsymbol{p}_t = {} & (1-\boldsymbol{a})\mathbf{B}_1(L)\cdot\boldsymbol{p}_t + \boldsymbol{a}\cdot\boldsymbol{p}_t^e + \mathbf{B}_2(L)\big(y_t - y_t^p\big) + \mathbf{B}_3(L)\big(y_t - y_t^p\big)^+ \\
& + f(tot) + g(w) + h(ti),
\end{aligned}
\tag{1}
$$

where $\boldsymbol{p}$ represents domestic price inflation, $\boldsymbol{p}^e$ represents expected inflation, y represents output, y^p represents potential output, $\boldsymbol{a}$ 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. In the base-case model, inflation expectations are given by a linear combination of past and model-consistent values of domestic price inflation:

$$
\boldsymbol{p}_t^e = (1-\boldsymbol{g})\mathbf{B}(L)\cdot\boldsymbol{p}_t + \boldsymbol{g}\cdot\mathbf{C}(F)\cdot\boldsymbol{p}_t
\tag{2}
$$

where $\boldsymbol{g}$ is a coefficient and $\mathbf{C}(F)$ is a polynomial in the forward-shift operator. CPI inflation is given by

$$
\boldsymbol{p}_t^{cpi} = \boldsymbol{p}_t \cdot \mathbf{B}(L)\cdot\big(pc_t / pc_{t-1}\big)
\tag{3}
$$

where $\boldsymbol{p}_t^{cpi}$ 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 domestically-produced consumption goods 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. Given this structure, we first examine the stochastic

behaviour of the model economy under two alternative formulations of the monetary policy reaction function. The standard reaction function can be expressed as

$$rs_t - rl_t = rs_t^* - rl_t^* + \sum_{i=1}^{j} \boldsymbol{q}_i \left(\boldsymbol{p}_{t+i}^e - \boldsymbol{p}^T \right), \tag{4}$$

where *rs* and *rl* are short and long nominal interest rates, respectively; rs^* and rl^* are their equilibrium equivalents; $\boldsymbol{p}_{t+i}^e$ is the monetary authority's forecast of inflation *i* quarters ahead, and $\boldsymbol{p}^T$ is the policy target.[6] The number of leads, *j*, and the weights on them, $\boldsymbol{q}_i$, are a calibration choice, and $\boldsymbol{p}^e$ can be defined as any one of a variety of inflation measures.

Our aim is to evaluate which measure of inflation should be targeted. To do this we use the stochastic technique briefly outlined above. Five random shocks are drawn in each period and the model is solved drawing new shocks each period for 100 quarters. This process is repeated for 100 draws and the resulting output averaged into summary measures.

In the first stochastic experiment, the standard reaction function is used. The policy instrument responds to the projected deviations from target of year-over-year CPI inflation six, seven and eight quarters ahead. In the second experiment, the policy instrument responds to projected deviations in the year-over-year inflation in the price of domestically produced and consumed goods. The reaction function and the rest of the model are otherwise identical in both experiments.

The root mean squared deviations of key macro variables are presented in table 2. The results indicate that targeting domestic price inflation reduces the variance in real output, domestic inflation, the nominal short-term interest rate, and the real exchange rate. Slightly higher variance is recorded for CPI inflation. Qualitatively, these results match those presented in Svensson (1998) for "strict" policy rules. However, given that the inflation targeting rule considered here is closer to Svensson's "flexible" policy rules, these results are importantly different.

Table 2   **CPI inflation versus domestic price inflation, RMSDs for base-case model**

	Targets π^{cpi}	Targets π
π	1.50	1.36**
π^{cpi}	1.13	1.15**
y	3.07	2.70**
rs	4.10	3.90**
$rs - rl$	2.50	2.34**
z	5.20	5.14**

** and * denotes that the outcome is significantly different than the outcome under CPI inflation targeting at the 1% and 5% confidence level respectively.

This result is obtained because, under CPI inflation targeting, the monetary authority's actions result in temporary disturbances to CPI inflation being partially offset by opposite movements

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[6]   The terms of the current Policy Targets Agreement, signed between the Governor of the Reserve Bank of New Zealand and the Treasurer, dictate that the Reserve Bank target an inflation *band* of 0-3%. In the base-case version of FPS, the policy target is the mid-point this band, 1.5%.

in domestic price inflation. To achieve these offsetting movements in domestic price inflation, monetary policy generates greater variability in real output than it does when it looks through those temporary disturbances. Consequently, real output and domestic inflation variability are significantly lower under domestic inflation targeting. Policy instruments are also less variable as policy itself is less activist; some temporary disturbances generate milder policy responses.

3.2 An alternative specification for inflation expectations

The stochastic experiments presented in Section 3.1 raise some interesting and challenging questions about inflation targeting in a small open economy. In this section, we test whether the same conclusions still hold under an alternative formulation for inflation expectations.

In the base-case version of FPS, inflation expectations are specified as a function of the core price, the domestic absorption deflator at factor cost. This makes some implicit assumptions about the information that private agents have at their disposal. They correctly perceive that some components of CPI inflation are levels effects only. Alternatively, what if private agents faced a signal extraction problem where they were unable (or unwilling) to decompose CPI inflation into its persistent component and level effects? For New Zealand, this alternative assumption may be reasonable since analysis of the data is unable to reveal whether or not direct exchange rate effects influence agents' expectation of generalised inflation.[7]

In the context of a discussion about the choice of target variable in an open economy, it seems important to consider this variation. At a more fundamental level, the appraisal of the target variable under an alternative specification for expectations is very much in the spirit of McCallum (1990). There, the effects of a proposed rule are simulated under two different specifications of the basic structural relationships.

By adding another dimension to the experiments, we now have two extra scenarios to consider. The problem is how to characterise the "state of the world" when inflation expectation effects arise from exchange rate movements. We do this by modifying the expression for inflation expectations that feeds into the Phillips curve so that it is a function of CPI inflation:

$$p_t^e = (1-g)\mathbf{B}(L)\cdot p_t^{cpi} + g\cdot \mathbf{C}(F)\cdot p_t^{cpi} \tag{5}$$

where g is the same coefficient as before and $\mathbf{C}(F)$ is a polynomial in the forward-shift operator. The same stochastic experiments are run over the two inflation targeting regimes and the results summarised in table 3. (For comparison, the results from the first two experiments are also included.)

A comparison of the third and fourth columns of table 3 tells much the same story as was described in section 3.1. Even when private agents base their expectations on CPI inflation rather than domestic inflation, domestic price inflation targeting is superior if the variability of domestic price inflation, monetary instruments and output is a concern. By effectively filtering

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[7] In Conway and Hunt (1997), both first and second differences of the exchange rate are included as explanatory variables in a standard Phillips curve equation and both are found to be significant.

out some of the shocks hitting the open economy, targeting domestic price inflation results in less activist monetary policy.

Table 3   **CPI inflation versus domestic price inflation,**
           RMSDs when exchange rates have levels or expectations effects

	Levels effects from exchange rate movements		Expectations effects from exchange rate movements	
	Targets π^{cpi}	Targets π	Targets π^{cpi}	Targets π
π	1.50	1.36**	1.42	1.32**
π^{cpi}	1.13	1.15**	1.10	1.09
Y	3.07	2.70**	2.85	2.60**
Rs	4.10	3.90**	3.49	3.40**
$rs - rl$	2.50	2.34**	2.10	2.00**
Z	5.20	5.14**	4.90	4.90

** and * denotes that the outcome is significantly different than the outcome under CPI inflation targeting at the 1% and 5% confidence level respectively.

A surprising result of these simulations comes from a comparison of expectations formation for given inflation targeting regimes (comparing column 1 with 3 and column 2 with 4). One might expect that by making expectations of generalised inflation a function of CPI inflation, the monetary control problem would be made harder, since direct exchange rate effects and external relative consumption price shocks now influence inflation expectations. In fact, whether targeting domestic price inflation or CPI inflation, there is *less* variability in the macro variables when generalised inflation expectations are formed from CPI inflation rather than from domestic price inflation.

These results might appear somewhat counter-intuitive, until one recalls that in a small open economy, the exchange rate is to some degree influenced by the policy instrument. Since CPI-based expectations include the effects of exchange rate movements, this means that the monetary authority now finds it *easier* to sway expectations than before because of the effect of uncovered interest parity in exchange rate dynamics. Through this channel, the monetary authority has additional 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.

4   Monetary authority with mistaken beliefs

The results in the previous section imply that CPI inflation targeting is the preferred choice only when its variability is the sole concern of the monetary authority. Less variability in most other key other macro variables is achieved if domestic price inflation is targeted instead. This result holds, more strongly, if direct exchange rate effects influence agents' expectations of generalised inflation.

In all of these experiments, the monetary authority is assumed to know the true structure of the economy. As discussed, the monetary authority understands the formation of private agents' expectations, and is able to use this knowledge to its advantage when expectations respond to direct exchange rate effects in prices. In this section, the previous simulations are repeated

under alternative assumptions about the accuracy of the monetary authority's perception of the formation of inflation expectations. For example, the monetary authority may believe that expectations of generalised inflation are formed on the basis of domestic price inflation when in fact direct exchange rate effects on prices also influence inflation expectations.

In terms of the stochastic experiment, this "mistake" is made each period. The monetary authority sets monetary conditions on the basis of its belief about the nature of the world, and these monetary conditions are then applied to the "true" model.[8] In the next period, the monetary authority sees that the outcome for the previous quarter was not as it had expected. However, in this period a new set of shocks has also hits the economy, and the monetary authority is unable to unbundle the effects of these new shocks and the excessive or insufficient response of monetary policy in the previous period. Hence there is no learning in this experiment - the monetary authority persists with its view of the world, and sets policy accordingly.[9] The results from these experiments are presented in table 4 (targeting p) and table 5 (targeting p^{cpi}).

The first regularity that holds is that regardless of whether the monetary authority's perceptions of the world are correct or incorrect, domestic price inflation targeting yields lower variability in the key macro variables, except for CPI inflation. This can be seen by comparing each column in table 4 with the respective column in table 5. This illustrates that the results of previous sections are robust to a more realistic specification of information and policy execution.

Within each of the two targeting regimes, there are interesting results. Consistent with the results in section 3.2, comparing the first with the second and the third with the fourth columns in each table illustrates that the control problem is easier if direct exchange rate effects influence expectations of generalised inflation. Interestingly, comparing the misperceptions experiment extends this result so that it holds *no matter how the monetary authority believes private expectations to be formed*. When private expectations are based on CPI inflation, there is less variability in all key series. This result holds for both domestic price inflation targeting and CPI inflation targeting when the monetary authority misperceives the structure of the inflation expectations process.

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[8]   This simulation technique for examining the implications of the monetary authority being uncertain about the true structure of the economy was first used in Laxton, Rose and Tetlow (1994).

[9]   Of course, four of these cases - when the monetary authority's beliefs are true - have already been discussed.

Table 4   **RMSDs from monetary misperception experiments when targeting p**

Belief:	Exchange rates have levels effects only		Exchange rates have expectations effects	
State of the world:	Actually levels	Actually expectations	Actually levels	Actually expectations
π	1.36**	1.24**	1.49**	1.32**
π^{cpi}	1.15**	1.05**	1.24	1.09
y	2.70**	2.6**	2.75**	2.60**
rs	3.90**	3.90**	3.52**	3.40**
$rs - rl$	2.34**	2.47**	2.01**	2.00**
z	5.14**	5.09**	4.96	4.90

** and * denotes that the outcome is significantly different than the outcome under CPI inflation targeting at the 1% and 5% confidence level respectively.

Table 5   **RMSDs from monetary misperception experiments when targeting p^{cpi}**

Belief:	Exchange rates have levels effects only		Exchange rates have expectations effects	
State of the world:	Actually levels	Actually expectations	Actually levels	Actually expectations
π	1.50	1.34	1.63	1.42
π^{cpi}	1.13	1.02	1.25	1.10
y	3.07	2.88	3.07	2.85
rs	4.10	3.97	3.74	3.49
$rs - rl$	2.50	2.56	2.15	2.10
z	5.20	5.12	4.98	4.90

This result suggests that regardless of the true structure of the economy, the monetary authority is better to assume that direct exchange rate effects on prices do not influence inflation expectations. Lower variability in inflation and output results, although with higher variability in instruments. The intuition behind this result is simple: if the monetary authority believes expectations to be a function of domestic price inflation, then it perceives that private agents' do not allow exchange rate effects to enter expectations. Hence it perceives that it will have to do most of its work via the output gap channel.[10] Consequently, it achieves lower variability of inflation and output than it expected, but the misperception results in higher variability in the monetary instruments than would have been the case if it had known the true model.

Essentially, the monetary authority perceives the control problem to be harder than it actually is and it responds more vigorously. Ignoring the increase in instrument variability, the outcome of this "policy error" is a reduction in both inflation and output variability. This outcome illustrates that the base-case FPS rule is not efficient in the sense of Taylor (1994).

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[10]   Apart from direct price effects, movements in the real exchange rate will of course shift the trade balance to some extent. This real economy channel will have effects on the output gap.

The rule does not deliver the lowest combination of output and inflation variability achievable. To test whether the results presented thus far are a function of the base-case rule not being efficient, the next section compares the efficient policy frontiers under domestic price and CPI inflation targeting.

4.1   Comparing the efficient frontiers

The overall improvement in the variability of most of the key macro variables under domestic price inflation targeting is notably stronger than the results found in Svensson (1998). Although the results are consistent with the "strict" policy rules considered in Svensson, the base-case FPS reaction function is closer to Svensson's "flexible" rules in the sense that it does not attempt to return inflation to control as quickly as possible by working through the direct exchange rate channel. Thus, the results presented above more strongly favour targeting domestic price inflation than do those presented in Svensson (1998).

One possible reason for this difference is that the rules used in Svensson are optimal rules in the sense that they solve a well-specified optimisation problem. As noted previously, the base-case policy reaction function in FPS is not an optimal rule in this sense. If a well-specified loss function existed, such a policy reaction function could be solved for using a simulation/grid search approach. However, in the absence of a well-defined loss function we can only talk about "efficient" policy rules. As outlined in Taylor (1994), efficient policy rules are defined to be those rules that deliver the lowest achievable combinations of inflation and output variance given the structure of the model economy under consideration. In order to examine whether the results presented previously are obtained because the reaction function considered is not an efficient rule, we trace out the efficient frontiers for forward-looking inflation-targeting rules of the class used in FPS under both CPI inflation targeting and domestic price inflation targeting.

To find the efficient frontiers, we use a grid search technique. In the base-case version of FPS, the reaction function adjusts the policy instrument in response to the projected deviations of inflation from target six, seven and eight quarters ahead. In the base-case version, the weights on the projected deviations of inflation from target are set at 1.4. To determine the set of efficient policy rules, both the magnitudes of the weights and the forward-looking policy horizon are searched over. The forward-looking policy horizon is a three-quarter moving window starting from one quarter ahead and extending to twelve quarters ahead (ten different horizons in all). The weights range from 0.5 to 20. For each rule considered, the resulting properties of the model are calculated by averaging the results from 100 draws, each of which is simulated over a 25 year horizon.

The output/CPI inflation variance pairs under CPI inflation targeting are graphed in figure 1. The dashed ellipse surrounds the output/inflation trade off that results from holding the weight on the projected deviation of inflation from its target rate fixed at 1 and varying the forward-looking targeting horizon. At point A, the targeting horizon is one, two and three quarters ahead. Moving from point A to point B, the forward-looking horizon is extended to five, six and seven quarters ahead and the variability in both inflation and output are reduced. As the targeting horizon is extended beyond that point, the variability in output is reduced, but only at the expense of increased variability in inflation. For any horizon, increasing the weight up to a point, reduces inflation variability. To reduce both inflation and output variability both the weight and the targeting horizon need to be increased. The results show that the base-case FPS rule lies within the efficient frontier. An efficient outcome is achieved at point C, with a

weight of 7 and a targeting horizon of eight, nine and ten quarters ahead. Under this rule, the resulting RMSDs in inflation from target suggest that inflation can be maintained within roughly a 3 percentage point band 90 percent of the time.[11]

Figure 1   RMSDs in year-over-year CPI inflation and the output gap

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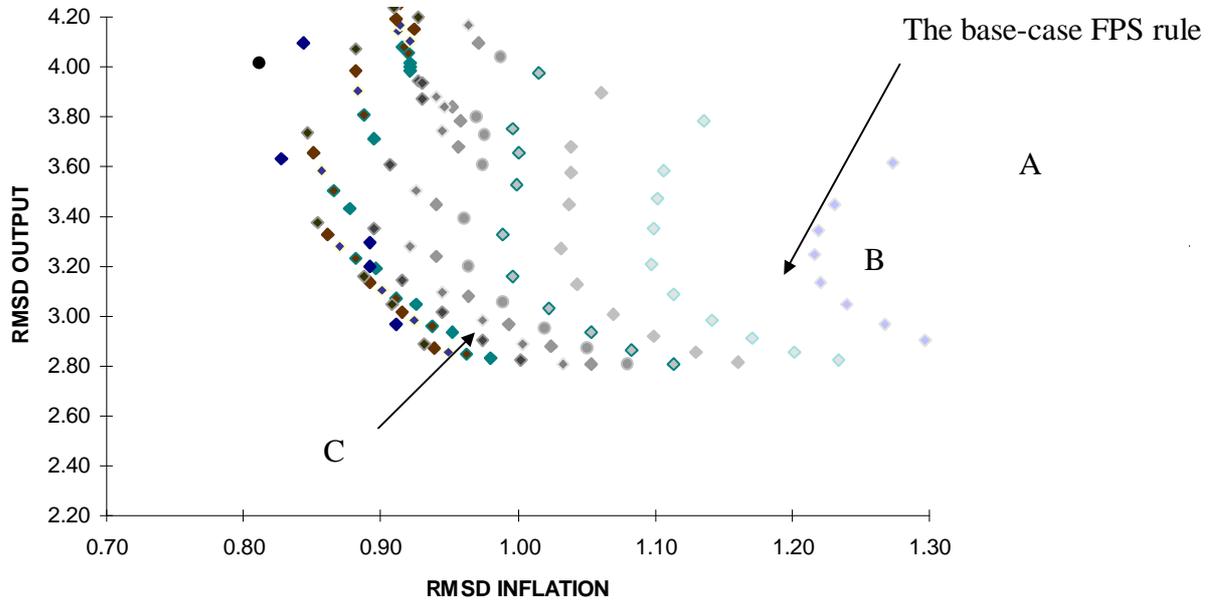
[11]   This is calculated as $0.9 \times 1.67 \times 2$. We note that this is very similar to the results found in Turner (1995) for New Zealand.

In figure 2, the efficient frontier achievable under domestic price inflation targeting (solid line) is compared to that achievable under CPI inflation targeting (dashed). (Graphs illustrating all the outcomes under CPI and domestic price inflation targeting can be found in the appendix) The important point here is that the efficient frontier under domestic inflation targeting lies everywhere below the frontier achievable under CPI inflation targeting. By targeting domestic price inflation, the monetary authority can achieve results that are unambiguously superior to those under CPI inflation targeting.

Figure 2   RMSDs in year-over-year CPI inflation and the output gap
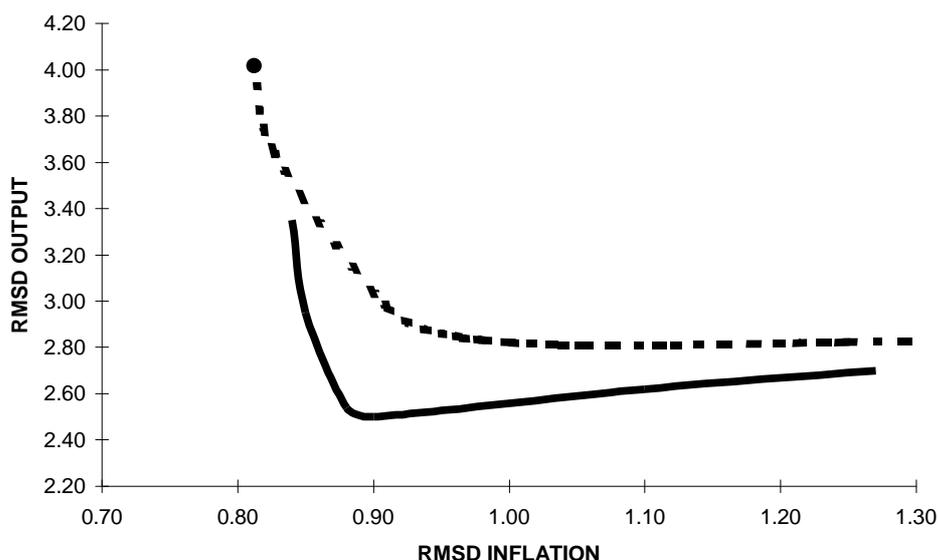
Comparing the two targeting regimes under a single weight and varying the targeting horizon illustrates some interesting points. In figure 3, the results under a rule holding the weight fixed at 1.4 and varying the targeting horizon are compared. The outcomes under CPI inflation targeting are denoted by Xs and diamonds denotes those under domestic inflation targeting. The base-case result presented in the paper (ie with a targeting horizon of six, seven and eight quarters ahead) can be seen as the move from point A to point B. The relative difference between the two targets is maximised under the short horizon rules. As the horizon gets longer, the results under the CPI targeting rules start to approach those under domestic price inflation targeting rules. This reflects the fact that the longer is the targeting horizon, the smaller will be the impact of direct exchange rate effects on CPI inflation. Moving from point A to point C reduces both the variability of inflation and output. However, instrument variability is slightly higher at point C than it is at point A (RMSD of the nominal interest rate is 4.34 versus 4.17 and the RMSD of the exchange rate is 5.27 versus 5.21). Comparing the impact of shortening the targeting horizon illustrates another interesting point. Under CPI inflation targeting, shortening the targeting horizon from ten, eleven and twelve quarters ahead through to five, six and seven quarters ahead reduces inflation variability but only at the cost of increasing output variability. Under domestic inflation targeting, reducing the targeting horizon in the same fashion reduces both inflation and output variability.

Figure 3   **RMSDs in year-over-year CPI inflation and the output gap**
Holding the weight of 1.4 fixed and varying the targeting horizon
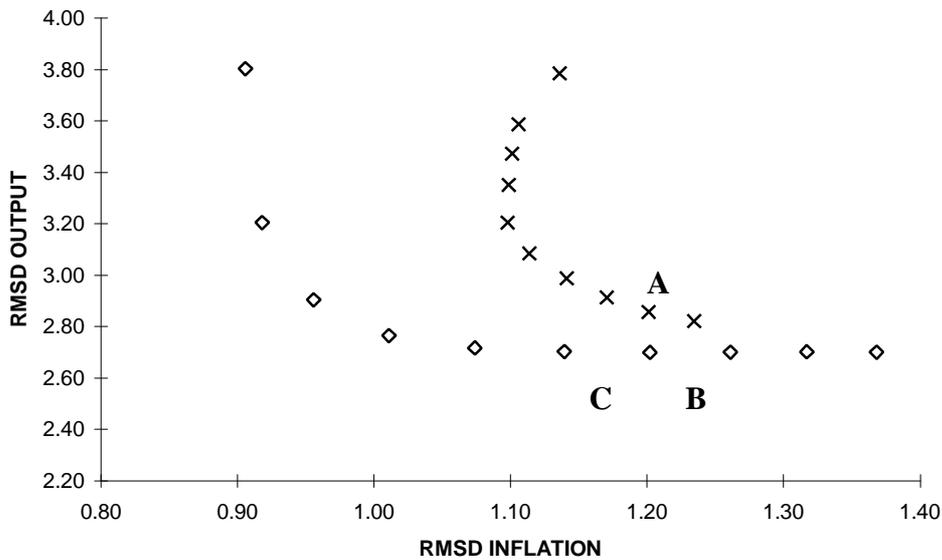
5   Summary and conclusions

The design of an inflation targeting regime has important implications for the macroeconomic outcomes achieved under these regimes. The particular price index that the central bank strives to stabilise is just one dimension of the design of an inflation targeting regime and this paper has examined one aspect of this issue. Specifically, should central banks in small open economies look through direct exchange rate effects when stabilising inflation? Stochastic simulations of the Reserve Bank of New Zealand's macroeconomic model, FPS, have been used to address the question.

The stochastic simulation results suggest that targeting domestic price inflation reduces the variance in real output, nominal interest rates, the real exchange rate and domestic price inflation with very little increase in CPI inflation variability. Further, the result appears to be robust even if direct exchange rate effects influence agents' expectations of inflation and even if the monetary authority misperceives the true expectations process. Tracing out the efficient output/CPI inflation variability frontiers under both CPI inflation and domestic price inflation targeting illustrates that the result is not limited to the base-case FPS reaction function. Targeting domestic price inflation shifts the efficient frontier towards the origin. Under domestic price inflation targeting, the same CPI inflation variability can be achieved with significantly less variability in real output.

Although the robustness tests considered in this paper have supported the initial results, further work should be undertaken. As part of the robustness testing, efficient frontiers under both CPI inflation targeting and domestic price inflation targeting were traced out. However, the class of policy rules considered may be somewhat restrictive. Future work should be done using an efficient reaction function drawn from a broader range of policy rules. In addition, in the stochastic experiments considered there were no permanent shocks. Consequently, there

were no permanent movements in the exchange rate. Experiments that allowed for permanent exchange rate movements may yield different conclusions. Finally, the difference between our results and those found in Svensson (1998) may reflect the different lag structures in the pass-through of exchange rate effects in the two models, or the fact that the results presented here do not consider *optimal* rules. Further work will need to be done to reconcile the differences in these results.

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Appendix: Efficient Frontiers

Figure 1: **Domestic Price Inflation Targeting**
RMSDs in year-over-year CPI inflation and the output gap
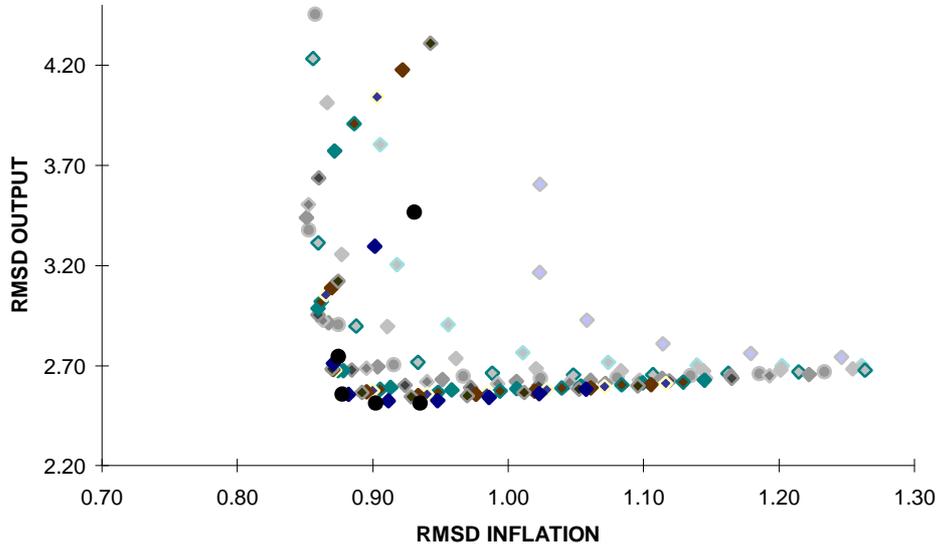
Figure 2: **CPI Inflation Targeting**
RMSDs in year-over-year CPI inflation and the output gap