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Uncertainty about the Length of the Monetary Policy Transmission Lag: Implications for Monetary Policy

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Abstract[1]

This paper examines implications for monetary policy of uncertainty about the length of the monetary policy transmission lag in a stochastic environment. Two key questions are asked. Firstly, which type of inflation-forecast-based rules work well when the central bank does not know the length of the monetary policy transmission lag? The results show that rules that are less aggressive and more forward looking are *more* robust. That is, the performance of these rules are least affected by lag uncertainty. However, it is still the case that relatively more aggressive and less forward looking rules will produce lower inflation variability.

With any inflation forecasting model, policymakers must take a view on how quickly their actions impact on inflation. There will always be a significant degree of uncertainty surrounding this transmission lag such that a central bank is unlikely to get this right all the time. The second question asks: is it better to overestimate or underestimate this transmission lag? When the lag is overestimated (underestimated), the central bank behaves as if inflation is harder (easier) to control than it really is. The results show that a strategy of overestimating is superior to underestimating the lag. In fact, it may be even be a preferred strategy to knowing the true lag.

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1 The opinions expressed in this paper are those of the author, and do not reflect the opinions of the Reserve Bank of New Zealand. The author would like to thank Aaron Drew, Ben Hunt and John McDermott for helpful comments and discussions, Vincenzo Cassino for earlier work, discussant Robert Tetlow of the Federal Reserve Board for his comments, and all participants at the Sveridges Riksbank "Inflation Targeting and Exchange Rate Fluctuations" workshop held in August 1999. All errors and omissions belong to the author.

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1 Introduction

In practice, central banks form a view of how they think the economy behaves – and this view may be formalised in terms of a model – and then develop a strategy that will enable them to achieve their objectives. Given the range of uncertainties about how the economy behaves, achieving policy objectives may often be far more difficult than anticipated. In this paper, I focus specifically on the implications of uncertainty about the length of the transmission mechanism for the stabilisation properties of inflation-forecast-targeting strategies.

Uncertainties facing a central banker have long been recognised and implications for monetary policy have been widely discussed in the literature. For example, in a seminal article, Brainard (1967) argued that when the policymaker is uncertain about the effect of policy actions, it may be optimal to be conservative – that is, move policy instruments by smaller magnitudes than would be the case if there was no uncertainty. However, the answer is not always that simple. Research on alternative forms of uncertainty have produced different results from Brainard. For example, Shuetrim and Thompson (1999) show that uncertainty about the persistence in the economy can lead to optimal policy that is more aggressive than optimal policy under certainty.

Other aspects of model uncertainty that have been examined include: uncertainty about potential output (Drew and Hunt, 1999);[2] policy co-ordination between two countries under model uncertainty (Frankel and Rockett, 1986; Ghosh and Masson, 1988, 1991); uncertainty about whether inflation responds symmetrically or asymmetrically to excess demand and excess supply (Laxton, Rose and Tetlow, 1993); inflation expectations and exchange rate uncertainty (Conway, Drew, Hunt, and Scott, 1998, and Cassino, Drew, and McCaw, 1999).

In addition, there is also a vast theoretical and empirical literature on the monetary policy transmission mechanism.[3] Most of this literature has examined the nature of channels through which monetary policy influences the real and nominal economy, the relative importance of these channels, and whether these channels have changed over the years.[4]

It appears that, so far, there has been relatively little work explicitly examining implications for setting monetary policy under uncertainty about the length of the

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2 See, also: Isard, P, D Laxton and A Eliasson (1998), "Inflation targeting with NAIRU uncertainty and endogenous policy credibility." Paper presented at the Fourth Conference on Computational Economics, Cambridge, United Kingdom.

Smets, F (1999), "Output gap uncertainty: Does it matter for the Taylor rule?" Benjamin Hunt and Adrian Orr (eds.) *Monetary Policy Under Uncertainty* (Wellington, New Zealand).

Wieland, V (1998), "Monetary policy and uncertainty about the natural unemployment rate." Paper presented at the NBER conference on Formulation of Monetary Policy.

3 For introductions to the literature, see the Symposium on the Monetary Transmission Mechanism, *Journal of Economic Perspectives*, Fall (1995) and Berk (1997).

4 These studies have been conducted for different countries and different time periods. See, for example, Mauskopf (1990), Gruen, Romalis and Chandra (1997), Mosser (1992), Britton and Whitley (1997).

transmission lag. Blinder (1997) argues that one of the main sources of central bank error is due to failure to take proper account of the lags in monetary policy. In Haldane (1997), the author examines implications of uncertainty about the transmission lag for the optimal inflation-targeting horizon. Using a simple macro model he showed that, relative to the actual length of the transmission lag, having too short a targeting horizon was likely to have the more damaging impact on inflation control than having an overly long targeting horizon. Intuitively, if the targeting horizon is too short, the central bank is likely to see little response in inflation following policy changes, so further policy actions are likely. However, when inflation does eventually respond, it will react by more than the central bank had originally desired. If, on the other hand, the targeting horizon is beyond the length of the transmission lag, inflation is likely to respond in the same way as it would if the central bank knew the correct transmission lag.

In this paper, I examine transmission lag uncertainty in the context of simple inflation-forecast-based rules – henceforth IFB rules.[5] This class of policy rules is currently used by the Reserve Bank of New Zealand, the Bank of Canada, and the Sveridges Riksbank in their forecasting and policy models.[6] More explicitly, lag uncertainty here refers only to the timing of policy actions. Uncertainty of the effect of policy actions (the Brainard multiplier uncertainty) or the transmission channels of policy are not examined. A *misperceptions* framework – first used by Laxton, Rose and Tetlow (1993)[7] – is used to analyse these policy implications. Under this framework two models are used in tandem, where one model carries a misspecified transmission lag. The central bank operates with the misspecified model and its actions are transmitted through into the 'real' model. The consequences of the central bank being misperceived about the true model structure are then examined.

Two key questions are asked about transmission lag uncertainty. The first is, which type of policy rules will work well when the central bank does not know the length of the actual transmission lag? I answer this question by examining the robustness of efficient IFB rules. Efficient rules are defined to be those that produce the lowest achievable combinations of inflation variability and output variability. Robustness measures how the performance of these rules are affected by lag uncertainty. Robust rules are least affected by uncertainty.

Within the class of IFB rules, the two key strategic decisions to be made are (i) the horizon the central bank chooses to respond to deviations of inflation from target (targeting horizon), and (ii) policy instrument responsiveness to forecasted deviations of inflation from the target rate (response coefficient). Central banks that prefer rules with larger response coefficients and shorter target horizons are typically classified as

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5 This follows the convention adopted by Haldane and Batini (1998), Isard and Laxton (1999), Amano, Coletti, and Macklem (1999).

6 This work is part of the Reserve Bank of New Zealand's research agenda examining the implications for monetary policy under uncertainty. Previous Bank research on uncertainty has examined the issues of shock uncertainty (Drew and Hunt, 1998), uncertainty about the way private agents form their inflation expectations and exchange rate uncertainty (Conway, Drew, Hunt, and Scott, 1998), (Cassino, Drew, and McCaw, 1999), and potential output uncertainty (Drew and Hunt, 1999).

7 This technique is also used in Cassino, Drew, and McCaw (1999); and Drew and Hunt, (1999).

'strict' inflation targeters (Svensson, 1997). That is, the over-riding concern for the central bank is to keep inflation as close to target as possible at all times. There is little, or no concern, for other factors such as output stabilisation. In contrast, central banks that prefer rules with low response coefficients and longer target horizons can be thought of as 'flexible' inflation targeters – they are concerned to some extent with other factors such as output stabilisation. As such, inflation tends to be brought back to target more gradually following any disturbance.

The policy implication of these results are somewhat clouded. On the one hand, the strong result that does emerge is that rules with relatively *small* response coefficients and *long* target horizons tend to be *more* robust under transmission lag uncertainty. Actual outcomes, as quantified by variability statistics, are likely to be closer to expected outcomes if a central bank uses these robust rules. On the other hand, rules with larger response coefficients and shorter horizons produce lower outright inflation variability. In other words, even if the length of the lag is not known, a central bank would achieve lower inflation variability by using a more aggressive and less forward-looking rule. The drawback of these rules is that higher output variability results and that actual outcomes may differ significantly from expected outcomes. In these circumstances, policy has to contend with more surprises. Ultimately, the decision on which type of rule to use will depend on central banks' preferences – whether they are relatively strict or relative flexible inflation targeters.

In any system that is set up for the purposes of inflation control, a view must be taken on how quickly monetary policy actions impact on inflation. In the literature there is a reasonable consensus on the transmission channels of monetary policy. However, there is little consensus on the timing of policy actions. This is not surprising given that the transmission lag depends on a large number of idiosyncratic factors, including the degree of financial liberalisation, an economy's degree of openness and the composition of the private sector's asset holdings. Moreover, there is Milton Friedman's notion that the policy transmission lag will vary over time as economic behaviour and policy regimes change.[8] Given there will always be uncertainty surrounding the length of the transmission lag, a policymaker's view is unlikely to be correct. In practice, a central bank may operate with their view of the transmission lag that is too short – in which case, the transmission lag is underestimated – or too long (overestimating the lag) relative to the actual lag length. The second question asks, is it better for a central bank to overestimate the lag or underestimate it?

To preview these results, the central bank's ability to control output and inflation deteriorates when it underestimates the transmission lag. Surprisingly, the central bank's performance may actually improve if it overestimates the lag. In other words, overestimating the lag is better than underestimating it, and may even be better than getting it right. As explored in the paper, this result depends on the characterisation of the shocks employed and the central bank's information set in the stochastic simulations. However, even accounting for these factors, the results show that the overestimating is still a superior to underestimating the lag and may be as good as knowing the actual lag.

[8] See Friedman, M (1961): "The lag in effect of monetary policy" *Journal of Political Economy*, 69, 447-66.

The remainder of the paper is organised as follows. In section 2, there is a brief description of the core macroeconomic model in the Reserve Bank of New Zealand's forecasting and policy system (FPS). Section 3 describes the transmission lags in the FPS model and illustrates the three versions of FPS that are used in the stochastic simulation experiments. The results on the robustness of IFB rules are presented in section 4. The implications of model misspecification are examined in section 5. Section 6 concludes.

2 The FPS core model at a glance [9]

The core FPS model describes the interaction of five economic agents: households, firms, a foreign sector, the fiscal authority 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 economy converges. 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 the fiscal authority 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 the 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, 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 adjustment cost framework (see Tinsley (1993)). In addition to expectational and intrinsic dynamics, the behaviour of the fiscal authority 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 driven 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 is asymmetric.[10] Excess demand

9 See Black et al (1997) for a more complete description of the FPS model. This section was taken from Drew and Hunt (1999).

10 Although the empirical evidence supporting asymmetry in the inflation process is growing, a convincing prudence argument for using asymmetric policy models is presented in Laxton, Rose and Tetlow (1994).

generates more inflationary pressure than an identical amount of excess supply generates in deflationary pressure.

3 The monetary policy transmission mechanism

3.1 The FPS transmission channels

Monetary policy actions are transmitted through an open economy through several different channels. As outlined in Svensson (1997), the most important are:

(1) the aggregate demand channel through interest rate changes;

(2) the inflation expectations channel; and

(3) the exchange rate channel.

In the FPS model, a monetary policy tightening through a rise in interest rates makes it more expensive to borrow and consume today relative to the future. This causes a reduction in investment and consumption, that is, a fall in aggregate demand. This fall in aggregate demand below the economy's productive capacity eventually reduces inflation. The lags in this transmission channel are due to the time it takes for aggregate demand to respond to changes in interest rates, and the time it takes for inflation to respond to the output gap.

With the inflation expectations channel, forward-looking agents perceive that tighter monetary policy will lead to lower inflation in the future. This reduces expected inflation leading to lower inflation outcomes. Again, there will be lags in the response of inflation expectations to changes in policy, and the response of inflation to changes in inflation expectations.

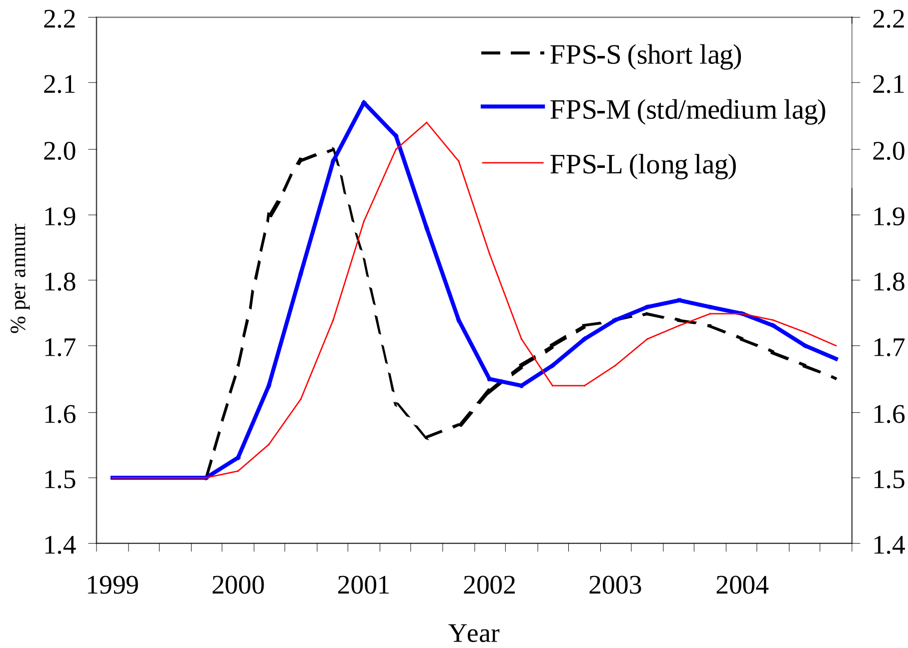
A rise in the real interest rate will lead to an appreciation of the exchange rate through an uncovered interest rate parity relationship embodied in the model. This means that imports become cheaper in New Zealand dollar terms. And since part of the basket of goods and services used in measuring CPI inflation are imports, CPI inflation will fall. There are lags in this so-called *direct* exchange rate channel due to the time it takes for import prices to respond to exchange rate movements, and the time it takes for changes in import prices to flow through into CPI inflation. In addition, there is an *indirect* exchange rate channel that has an influence on inflation. An appreciation of the exchange rate makes New Zealand goods more expensive relative to foreign goods. This reduces the demand for New Zealand exports, and shifts some domestic demand to the now-cheaper import goods. In both cases, aggregate demand for New Zealand-produced goods falls.

3.2 Illustrating the three versions of FPS, each with a different transmission lag

To examine transmission lag uncertainty, stochastic simulations are conducted on three versions of the FPS model.[11] In each version, the transmission lag has been calibrated to a different length. The first version is simply the standard FPS model (denoted FPS-M for medium lag length), where the transmission lag has been calibrated to reflect the stylised facts from data for the New Zealand economy. The second version, denoted FPS-S, has a shorter transmission lag so that inflation responds faster to policy actions. The other version, FPS-L, has a longer lag so inflation responds more slowly to policy actions.

Figure 1 illustrates the impact of a 4-quarter exchange rate shock under the three versions of the FPS model.

Figure 1: CPI inflation under different transmission lags with an exchange rate shock



4 The robustness of efficient IFB rules under transmission lag uncertainty

This section examines which rules work well when the central bank does not know the actual transmission lag. Robustness statistics are computed for efficient IFB rules. Efficient IFB rules are defined as those that produce the lowest achievable combinations of inflation and output variability. The locus of these efficient rules is commonly referred to as the efficient frontier (Taylor (1979)). The robustness statistic measures the variability of a policy rule's inflation-output outcomes once uncertainty has been incorporated.

11 The technique for simulating FPS under stochastic disturbances is presented in Drew and Hunt (1998).

4.1 Description of IFB rules

Under IFB rules, the policy instrument is adjusted in response to a model-consistent projection of the deviation of inflation from its target rate. This class of reaction functions can be expressed as:

$$rgap_t = rgap_t^* + \sum_i^j \theta_i \left(\pi_{t+i}^e - \pi^T\right),$$

where $rgap$ is the gap between the short-term nominal interest rate and the long-term nominal interest rate,[12] $rgap^*$ is its equilibrium equivalent, π_{t+i}^e is the model-consistent projection of annual CPI inflation i quarters ahead, and π^T is the policy target (set at 1.5 percent). The target horizon window from i to j is a calibration choice.

The standard FPS policy rule, used by the Reserve Bank in its quarterly projections, falls within this class of rules with $i = 6$, $j = 8$, and $\theta_i = 1.4$. That is, at time t, the yield gap will be raised by 1.4 percentage points (via a sufficient rise in nominal short-term interest rates) for every 1 percentage point that annual CPI inflation is projected to deviate from the target rate of 1.5 percent over the horizon of 6, 7 and 8 quarters ahead from time t.

4.2 Deriving the efficient frontier

To trace out the efficient frontiers, I use the same technique as employed by Drew and Hunt (1999), which relies on stochastic simulations of the FPS model and a grid search technique over the policy rule coefficients. To determine the set of efficient policy rules, both the magnitudes of the weights (values for θ_i) and the target horizon (values for i) are searched over. The targeting horizon is a three-quarter moving window starting from 1 quarter ahead and extending to 12 quarters ahead (ten different windows in all). The policy reaction weights, θ_i, range in value from 0.5 to 20. The resulting efficient frontiers for each version of the FPS model are graphed in figure 2.[13]

The root mean squared deviation (RMSD) of inflation from its target rate, and the RMSD of output (Y) from potential output are the measures of variability that have been used. The asymmetry in the response of inflation to excess demand and excess supply make this the most appropriate measure of variability to use. As a result of the asymmetric inflation process, on average, inflation is above the target rate and output is below its deterministic steady state under stochastic disturbances.[14] Relative to the

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12 In the FPS model code, the policy reaction function is specified in terms of this yield spread. The implicit policy reaction function can be rewritten to be expressed in terms of a short-term nominal interest rate. Rewriting the reaction function in terms of the short-term nominal interest rate gives identical model properties provided that the response coefficients, θ_i, are scaled up by roughly 30 percent.

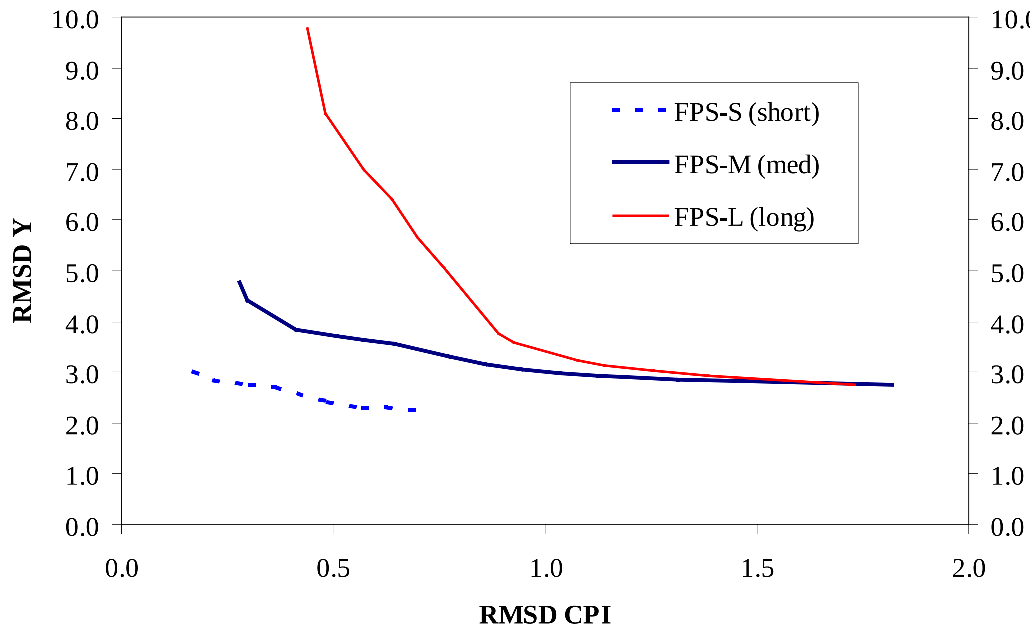
13 The simulation statistics are calculated by averaging the results from 100 draws, where each draw has been simulated over a 25-year horizon.

standard deviation statistic, the RMSD statistic penalises policy rules that result in inflation being more above the target rate, and output being below its deterministic steady-state level.

4.3 Baseline cases - when the central bank knows the correct transmission lag

Figure 2 plots the efficient frontiers derived under certainty for each version of the FPS model. These frontiers are the baseline cases. The summary statistics for these baseline frontiers are listed in appendix 1. The downward sloping nature of these frontiers suggest a trade-off between inflation variability and output variability. That is, along the efficient frontier, lower inflation variability can only be achieved at the expense of higher output variability.

Figure 2: Baseline efficient frontiers - the central bank knows the lag



The best overall macroeconomic outcomes (lowest possible combinations of CPI inflation/output variability) are achieved under FPS-S, where the transmission lag is the shortest. The worse outcomes are obtained under FPS-L, where the transmission lag is the longest. This is reasonably intuitive. A central bank's task of controlling inflation is easier when the policy transmission lag is shorter.

4.4 Incorporating uncertainty about the transmission lag

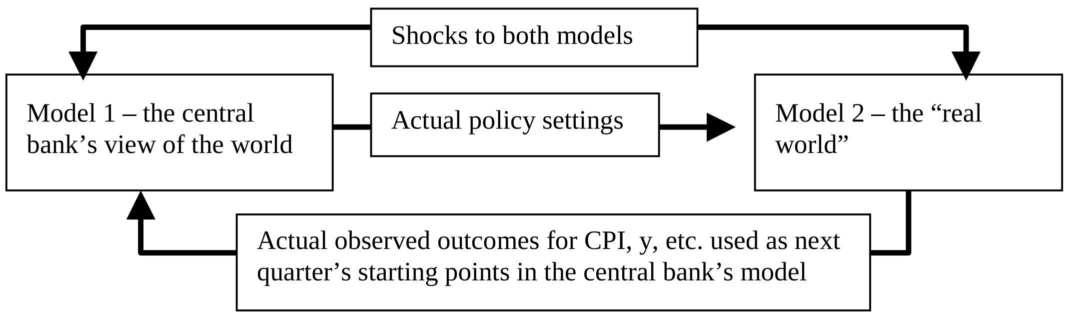
4.4.1 Overview of the experiments

To incorporate uncertainty – or more correctly, misperception – into these experiments, the simulations are carried out on two different models. The first model

[14] For a discussion of why the stochastic steady state for output is below the deterministic equilibrium, see Laxton, Rose and Tetlow (1994).

represents the world the central bank thinks it is controlling. The second model represents the actual world the central bank is in fact controlling. The transmission lag embodied in the first differs from the second. In the simulations, the same shocks hit both models each quarter. The central bank will respond based on its erroneous belief of the world – the first model determines the actual policy settings. These policy settings are then fed into the second model, which determine the actual observed outcomes. These observed outcomes then feed back into the central bank's model as starting points for the next quarter. In this next quarter the central bank may see actual inflation outcomes that are different from expectations. The simulation technique assumes that it cannot determine the source of the forecast error – there is no learning. The central bank simply updates its starting point, persists with its belief about the transmission lag, and sets policy accordingly. This process is represented graphically in figure 3.

Figure 3: The stochastic simulation and misperception framework



Before moving to the results, it is useful to provide a 'roadmap' of all the experiments conducted in this paper. The three efficient frontiers in figure 2 serve as the baseline cases – that is, the baseline cases assume the central bank knows the truth. For each baseline case there are two associated uncertainty cases. These cases are denoted using the notation T/B where the first argument, T, represents the true model, while the second argument, B, represents the central bank's mistaken belief of the world.

If the baseline model is FPS-S, the associated uncertainty cases are: S/M – lag is short but central bank believes it is medium; and S/L – lag is short but believe it is long. Similarly, if the baseline model is FPS-M, then the two uncertainty cases are: M/S – lag is medium but believe it is short; and M/L – lag is medium but believe it is long. Finally, if the baseline model is FPS-L, the two uncertainty cases are: L/S – lag is long but believe it is short; and L/M – lag is long but believe it is medium.

4.5 Measuring the robustness of efficient IFB rules

In practice, it is highly unlikely that the central bank will know the correct transmission lag. But knowing which type of rules are robust to this uncertainty will be of assistance when formulating policy. The performance of robust rules are least affected by uncertainty and are more likely to produce outcomes that match expectations reasonably well. With the benefit of fewer surprises, monetary policy is able to plan ahead with more confidence. Using less-robust rules is likely to result in more surprises so that a central bank may need to constantly revise or reassess its outlook for the economy. Monetary policy in this case runs the risk of focussing more on the past and present rather than the future.

In this paper, robustness is measured by the deviation from the no-uncertainty baseline outcome. Under uncertainty, rules that produce outcomes further away from baseline will be less robust than rules that produce outcomes closer to baseline. A distance function of the following form is a convenient way to quantify robustness:

$$d(x)_i = 100 * \sum_{\substack{j=1 \\ j \neq i}}^{2} \left[\alpha \left(rmsdcpi(x)_j - rmsdcpi(x)_i \right)^2 + \beta \left(rmsdy(x)_j - rmsdy(x)_i \right)^2 \right]$$

where *x* represents a particular rule on an efficient frontier, *i* represents the baseline/certainty outcome while *j* represents the uncertainty outcomes. The ratio α/β represents the degree to which a central bank does not like inflation variability surprises relative to output variability surprises. In this paper $\alpha = \beta = 1$, which means that the central bank does not like inflation surprises equally as much as output surprises. The results are scaled by a factor of 100 and are listed in tables 1, 2 and 3.

Table 1: Results for the efficient IFB rules under the baseline FPS-M model

		Baseline – FPS		**Uncertainty - M/S**		**Uncertainty – M/L**			
θ	**Horizon *I***	**RMSD CPI**	**RMSDY**	**RMSD CPI**	**RMSDY**	**RMSD CPI**	**RMSDY**	**Distance relative to baseline**	**Rank**
0.5	10	1.82	2.75	1.96	2.81	1.70	2.74	**3.8**	**1**
1.0	10	1.45	2.82	1.56	2.95	1.33	2.79	**4.5**	**2**
20.0	4	0.41	3.85	0.55	4.03	0.34	3.86	**5.7**	**3**
1.4	10	1.31	2.86	1.39	3.04	1.19	2.80	**5.7**	**4**
2.0	10	1.19	2.90	1.24	3.14	1.07	2.82	**8.3**	**5**
2.5	10	1.13	2.92	1.15	3.21	1.00	2.83	**10.7**	**6**
3.5	10	1.03	2.97	1.03	3.34	0.92	2.85	**16.3**	**7**
5.0	10	0.94	3.04	0.91	3.51	0.85	2.88	**25.3**	**8**
10.0	4	0.51	3.70	0.72	4.23	0.41	3.75	**33.1**	**9**
7.0	10	0.86	3.15	0.82	3.72	0.82	2.93	**38.3**	**10**
5.0	4	0.64	3.56	0.90	4.17	0.51	3.65	**46.5**	**11**
10.0	10	0.77	3.31	0.74	4.04	0.82	3.11	**57.0**	**12**
7.0	4	0.57	3.63	0.83	4.37	0.45	3.70	**63.0**	**13**

Table 2: Results for the efficient IFB rules under the baseline FPS-S model

		Baseline – FPS-S		**Uncertainty – S/N**		**Uncertainty – S/L**			
θ	**Horizon *i***	**RMSD CPI**	**RMSDY**	**RMSD CPI**	**RMSDY**	**RMSD CPI**	**RMSDY**	**Distance relative to baseline**	**Rank**
7.0	6	0.71	2.26	0.66	2.20	0.59	2.17	**2.9**	**1**
10.0	4	0.49	2.43	0.52	2.11	0.52	2.16	**17.6**	**2**
7.0	2	0.36	2.72	0.43	2.28	0.50	2.28	**40.7**	**3**
20.0	1	0.17	3.02	0.39	2.51	0.53	2.76	**50.4**	**4**
10.0	2	0.30	2.76	0.43	2.26	0.48	2.28	**51.6**	**5**
20.0	2	0.22	2.86	0.43	2.28	0.55	2.42	**68.7**	**6**
20.0	10	0.57	2.31	0.70	1.88	1.02	1.71	**76.6**	**7**

Table 3: Results for the efficient IFB rules under the baseline FPS-L model

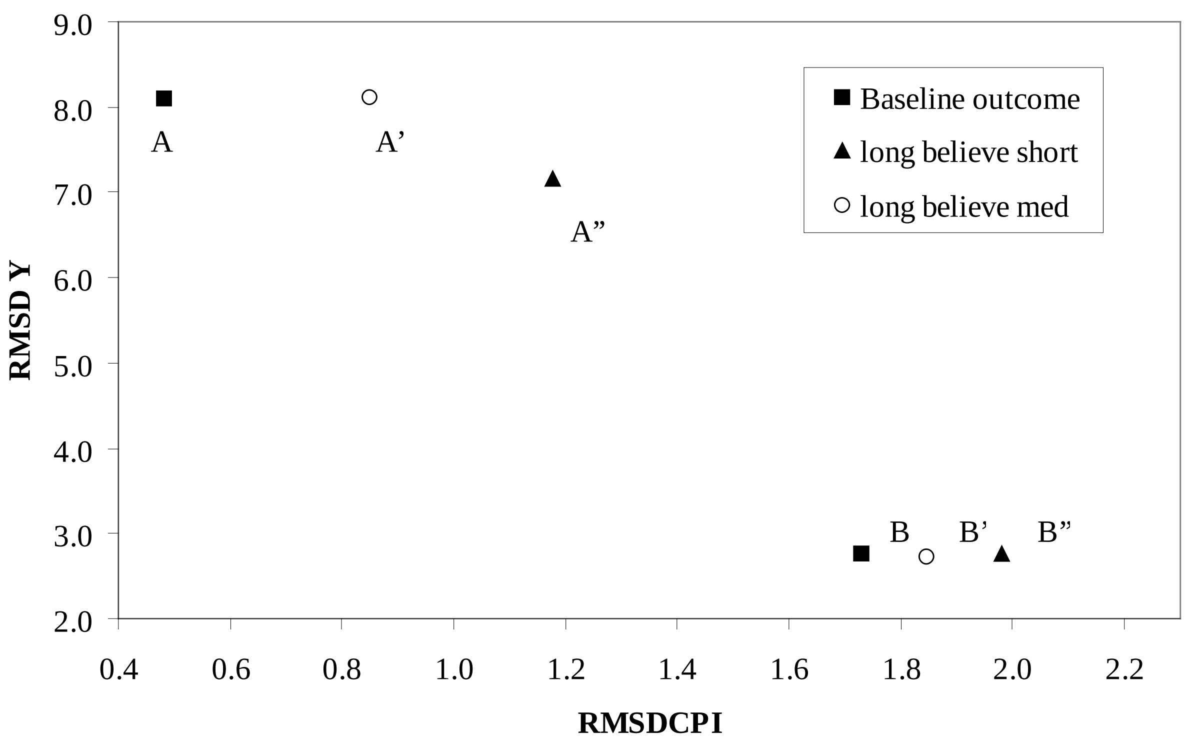
		Baseline – FPS-L		Uncertainty – L/N		Uncertainty – L/S			
θ	Horizon *i*	RMSD CPI	RMSDY	RMSD CPI	RMSDY	RMSD CPI	RMSDY	Distance relative to baseline	Rank
0.5	10	1.73	2.76	1.84	2.73	1.98	2.76	**7.7**	**1**
1.0	10	1.39	2.93	1.51	2.91	1.63	3.02	**8.6**	**2**
1.4	10	1.26	3.02	1.39	3.01	1.50	3.20	**10.8**	**3**
2.0	10	1.14	3.14	1.28	3.13	1.38	3.45	**16.9**	**4**
2.5	10	1.08	3.23	1.22	3.22	1.31	3.65	**25.0**	**5**
5.0	6	0.76	5.06	1.04	4.53	1.33	5.47	**83.6**	**6**
10.0	4	0.57	7.00	0.89	6.58	1.42	7.47	**121.7**	**7**
7.0	6	0.70	5.66	1.00	4.96	1.10	4.88	**134.8**	**8**
5.0	10	0.93	3.58	1.06	3.61	1.15	4.73	**138.7**	**9**
20.0	4	0.48	8.10	0.85	8.12	1.18	7.16	**149.3**	**10**
7.0	4	0.64	6.41	0.92	5.89	1.59	7.54	**253.5**	**11**
7.0	10	0.89	3.77	0.99	3.95	1.11	5.85	**442.8**	**12**

The results indicate rules that are more robust typically have relatively low response coefficients, θ_i, and a relatively long target horizon, i – that is, rules that are less aggressive and more forward looking. These rules would typically be used by relatively flexible inflation targeting central banks.

These results parallel Haldane's (1997) findings. The optimal targeting horizon for a policy rule is a function of the transmission lag. For example, if it takes four quarters for policy actions to feed through into inflation, then ideally the central bank should look four quarters into the future. Rules that have a relatively short target horizon are more likely to have too short a horizon relative to the true transmission lag. With such rules, policy actions are not given sufficient time to fully work through the economy. Hence, in the process of trying to control inflation, it is not surprising to expect that such these rules will produce outcomes that may differ significantly from expectations. Being more aggressive compounds this problem. On the other hand, when long horizon rules are used, policy actions are given the sufficient time to work through the economy and inflation – resulting in fewer surprises.

However, while less aggressive and more forward-looking IFB rules are more robust, more aggressive and shorter horizon rules typically achieve lower outright levels of inflation variability. This point is illustrated in figure 3, which plots the stabilisation properties of the policy rules for the case when the actual transmission lag is specified by FPS-L. Points A, A', and A'' represent the values for the most aggressive and shortest horizon rule with $\theta_i = 20$, and a target horizon of 4, 5 and 6 quarters ahead. Points B, B' and B'' represent the values for the least aggressive ($\theta_i = 0.5$) and most forward-looking IFB rule (target horizon of 10, 11 and 12 quarters ahead). While the spread of B, B' and B'' is much lower, the absolute level of inflation variability is higher than A, A' or A''.

Figure 4: Outcomes for the FPS-L model



In summary, rules with low response coefficients and long target horizons work well under lag uncertainty in that they are more robust. However, the policy implications are not clear. On the one hand, robust rules will deliver outcomes that match expectations more closely. This will assist with future policy formulation as actual outcomes will produce fewer surprises. On the other hand, more aggressive and shorter horizon rules will produce lower overall inflation variability. Under these rules, however, there will be more policy surprises given that actual outcomes are more likely to differ from expectations.

The discussion so far has assumed full policy credibility. But even if this assumption was relaxed, it is not clear how this would alter the conclusions. On one side, with less aggressive and long horizon rules, higher inflation variability over the short term may damage a central bank’s credibility such that the performance of these rules is affected. But on the other side, for a central bank that publishes its economic forecasts – such as the Reserve Bank of New Zealand – its credibility may also be damaged if actual outcomes differ from its published forecasts.

The decision on which rule to use ultimately depends on central banks’ preferences – whether they are relatively strict or flexible inflation targeters.[15] Nevertheless, the one strong result that does arise from this analysis is that forward-looking rules are more robust under uncertainty. This is the same result as in Drew and Hunt (1999) where, even under uncertainty that implies inflation forecasting errors, it is still better to be forward looking.

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15 This analysis and discussion has focussed on the two extremes in order to highlight the differences. Obviously there will be a ‘middle ground’.

5 The efficient frontiers under model misspecification

This section examines whether it is better to overestimate of underestimate the transmission lag. Central banks need to form a view on how quickly policy actions feed through the economy. The actual lag is subject to a significant uncertainty such that the central bank's view is unlikely to be right all the time. The central bank's view may be too short relative to the truth (underestimating the lag) or too long (overestimating the lag). If the central bank underestimates the lag, it will behave as if inflation is easier to control than it really is. In contrast, by overestimating the lag the central bank behaves as if inflation is harder to control.

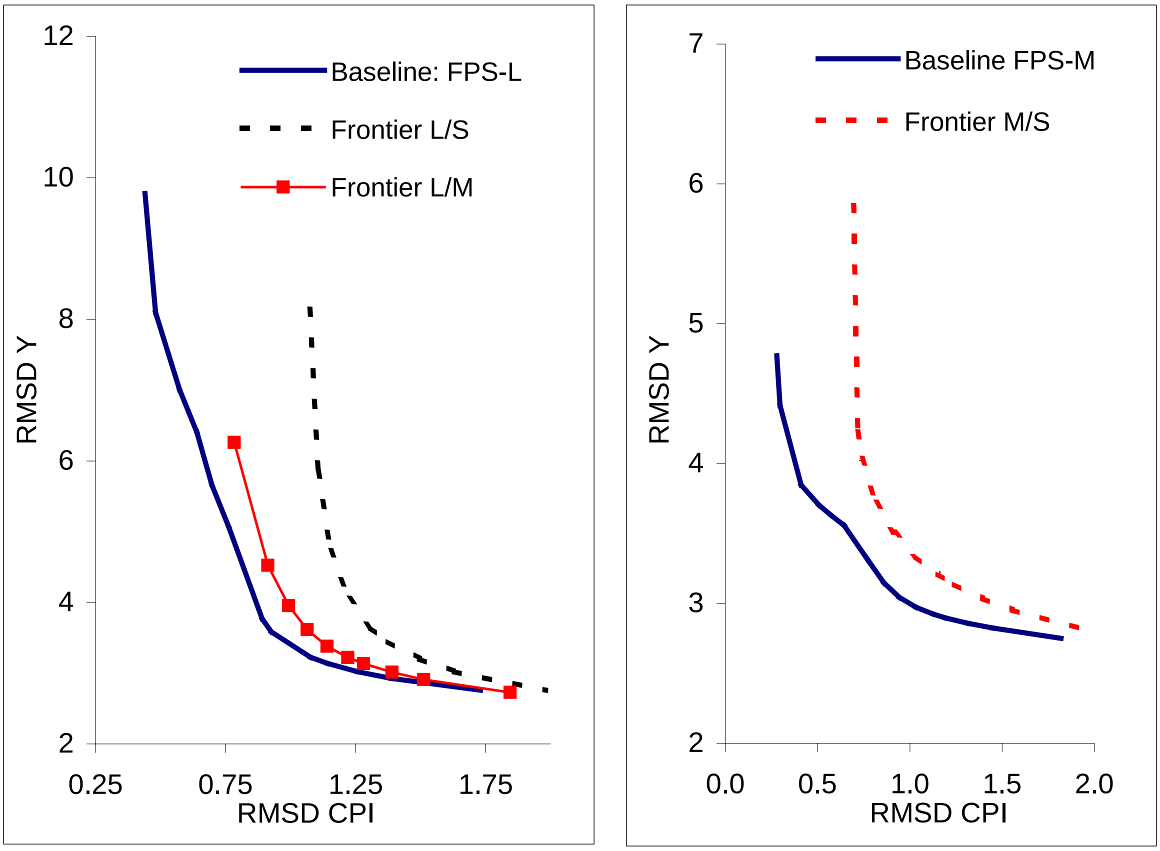
Given this, are the results symmetric for both cases – is there a better mistake to make? To answer this question, I derive the efficient frontiers for each of the uncertainty cases and compare them to the relevant baseline frontier. The frontiers for the uncertainty cases show the best achievable combinations of inflation and output variability when the central bank either underestimates or overestimates the transmission lag. By comparing the position of these misperception frontiers relative to the baseline frontiers, it is possible to determine which of the two mistakes is more costly.

5.2 Results

5.2.1 Underestimating the transmission lag

There are three cases where the central bank underestimates the transmission lag: L/S – lag is long but belief is short; L/M – lag is long but belief is medium; and M/S – lag is medium but belief is short. The resulting L/S and L/M frontiers are compared to the baseline FPS-L frontier and the M/S frontier is compared to the baseline FPS-M frontier – as shown in figure 5. The summary statistics for these frontiers are listed in appendix 2.

Figure 5: The efficient frontiers when the transmission lag is underestimated



When the central bank underestimates the transmission lag, the efficient frontier shifts away from the origin – particularly with respect to inflation variability. This means the central bank's ability to control inflation and output diminishes when it underestimates the transmission lag. Not surprisingly, the greatest relative shift in the frontiers occurs with the left-hand side of the frontiers. The rules on this part of the frontier typically have large response coefficients, θ, and short target horizons – ie less robust rules.

The shift in frontiers away from the origin is not surprising. By underestimating the transmission lag the central bank believes inflation is easier to control than it really is. The initial policy responses are milder than would be the case if the central bank knew the truth. This has two effects: inflation tends to deviate from target by more (thus, higher inflation variability); and inflation becomes more ingrained into inflation expectations. Any policy stance must then be maintained for longer in order to bring inflation back to target due to the asymmetric inflation process. This results in larger cumulative output losses (thus, greater output variability).

This story is borne out in the summary statistics. For example, table 4 compares the L/S outcomes the baseline FPS-L outcomes. With the L/S outcomes, (a) the average quarterly change in short-term interest rates is smaller as measured by the mean absolute change (MAC) statistic; (b) the RMSD values for CPI inflation and output (Y) are higher; and (c) the AR(1) coefficient on the level of short-term rates have increased – indicating an increase in the duration of policy stance.

Table 4: Comparing rules on the FPS-L and L/S frontiers

Weight θ	Horizon *i*	RMSD CPI	RMSD Y	RMSD RN	MAC RN	AR(1) RN	RMSD Z
Baseline – No uncertainty – FPS-L							
7.0	10	0.89	3.77	9.61	644	0.78	6.29
5.0	10	0.93	3.58	7.52	466	0.84	5.91
L/S – underestimating the transmission lag							
7.0	10	1.11	5.85	6.99	334	0.94	9.02
5.0	10	1.15	4.73	5.98	260	0.94	6.76

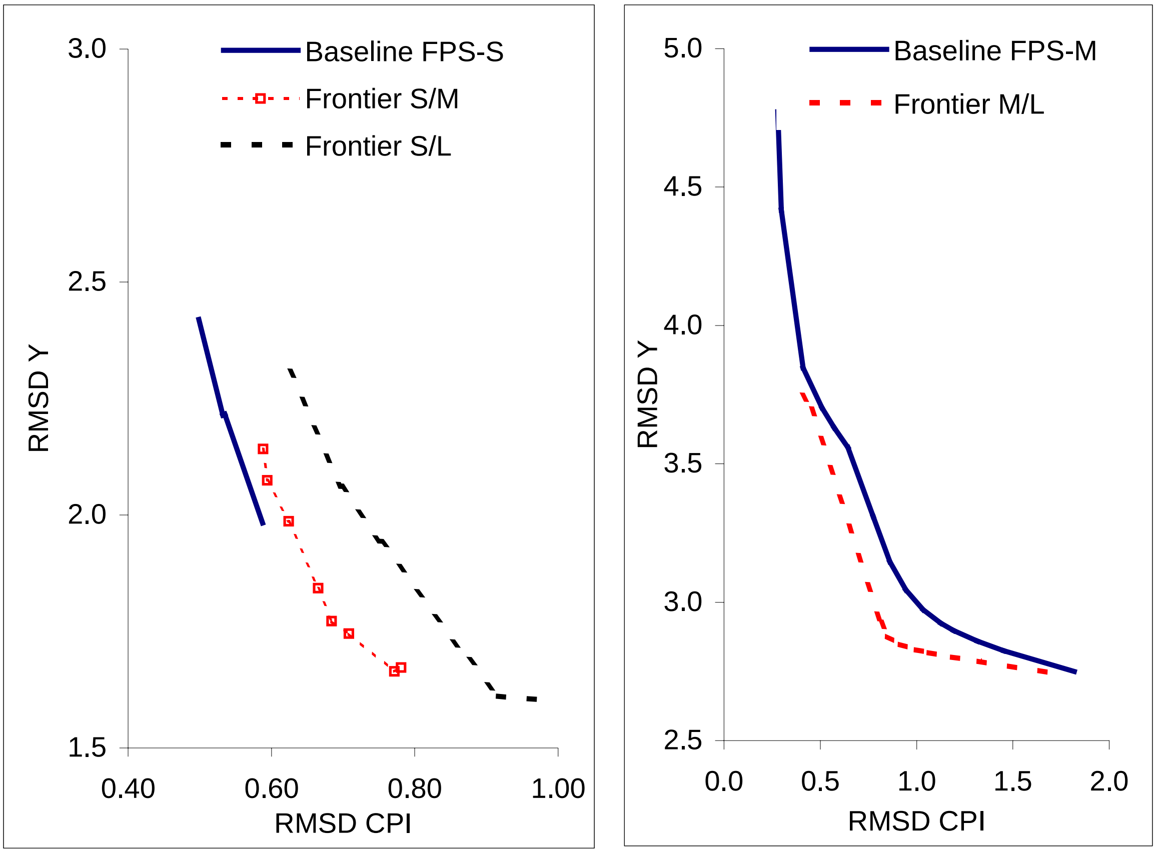
5.2.2 Overestimating the transmission lag

The three cases where this happens is: S/M – lag is short but belief is long; S/L – lag is short but belief is long; and M/L – lag is medium but belief is long. The resulting S/M and S/L frontiers are compared to the baseline FPS-S frontier and the M/L frontier is compared to the baseline FPS-M frontier.

For the baseline case (FPS-S), S/M, and S/L, the stochastic experiments were conducted with the central bank targeting domestic goods price inflation rather than CPI inflation.[16] There were problems with the simulation experiments when the central bank targeted CPI inflation. With the short transmission lag, the exchange rate was having a very strong impact on the CPI inflation variability. As a result, many simulation experiments failed to converge. In FPS, inflation in domestic goods prices excludes the direct exchange rate effects. By targeting this less-volatile measure of inflation, the simulations were able to produce more observable inflation/output variability outcomes. Figure 6 plots the efficient frontiers for these cases. The summary statistics for these frontiers are listed in appendix 2.

16 For a more complete analysis of the difference between CPI targeting and domestic price targeting, see Conway et al (1998) and Cassino et al (1999).

Figure 6: The efficient frontiers when the transmission lag is overestimated



Surprisingly, the M/L frontier is marginally closer to the origin than the baseline frontier. This suggests that in this case the central bank may do better at controlling the economy by overestimating the transmission lag rather than knowing the truth. The S/M and S/L frontiers have shifted south-east. For these cases, CPI inflation variability is higher, but it is possible for the central bank to achieve lower output variability (and lower domestic price inflation variability – see table 5). It is not clear whether these results are better than the baseline as it will depend on a central bank's preferences.

By comparing the relative shift in frontiers from figure 5 and figure 6, we can, however, say that it is better to overestimate rather than underestimate the length of the transmission lag. Unambiguously worse outcomes occur when the lag is underestimated, while potentially better results are possible when it is overestimated. In other words, not only is it better to overestimate than underestimate the lag, but overestimating the lag may be preferred to getting it right. This produces two questions:

(1) Why is overestimating the lag better than underestimating it?

(2) Why are potentially better results achieved when the central bank overestimates the lag than when it knows the truth? Intuition tells us that performance should worsen, not improve, when the policymaker is making a mistake.

The answer to the first question is that the policy error from overestimating the lag is less costly to unwind than the error from underestimating the lag. When the lag is overestimated, the initial policy response is more aggressive than would be the case if the central bank knew the truth because the central bank behaves as if inflation is harder to control. However, these strong policy actions are unwound quickly in later periods when the central bank sees actual inflation falling faster than expected. The statistics listed in table 5 confirms this story. Comparing the S/M outcomes to baseline, note: (a) the larger average quarterly change in short-term interest rates as measured by the mean absolute change (MAC) statistic; and (b) the offsetting fall in the AR(1) coefficient on the level of short-term rates – indicating a fall in the duration of policy stance. As shown in table 4, unwinding the error from underestimating the lag takes longer and is therefore more costly.

Table 5: Comparing rules on the FPS-S and S/M frontiers

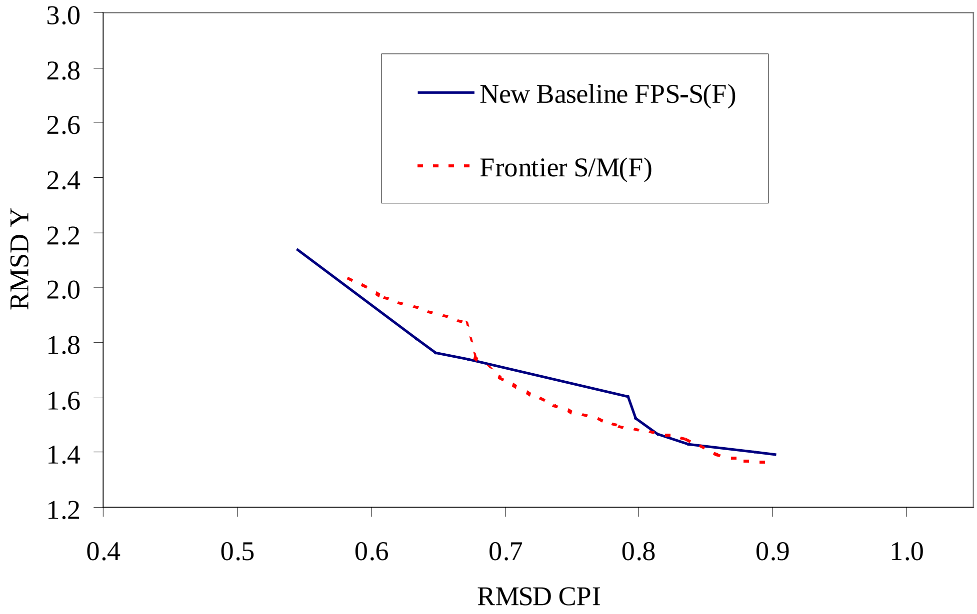
Weight θ	Horizon *I*	RMSD PDOT	RMSD CPI	RMSD Y	RMSD RN	MAC RN	AR(1) RN
No uncertainty Baseline – FPS-S							
5.0	2	0.75	0.53	2.22	8.48	637	0.74
7.0	2	0.69	0.53	2.21	10.11	797	0.68
S/M – overestimating the transmission lag							
5.0	2	0.70	0.68	1.77	10.38	906	0.60
7.0	2	0.67	0.71	1.75	12.79	1197	0.50

This result parallels somewhat the findings in Shuetrim and Thompson (1999), where the authors showed that uncertainty about the persistence of the economy made the optimal policy response more aggressive. Similarly, the authors showed that overshooting in the target variables was less costly than undershooting. Therefore, given uncertainty about persistence in the economy, a strategy of being more aggressive with policy actions would produce lower expected losses because any resulting errors from overshooting could be unwound quickly.

The answer to the second question is a little more complicated. To see why the central bank can potentially do better when it makes the mistake of overestimating the transmission lag, the reader needs to understand a little more about the stochastic simulation experiments. In these experiments, at time *t* the economy is hit by a barrage of shocks. These time-*t* shocks are serially correlated and last for a total of four quarters. For plausibility, the central bank is only allowed to see the contemporaneous effect of these shocks. It then produces an inflation forecast conditional on no further shocks. In other words, the central bank underestimates the inflationary pressures arising from these time *t* stochastic disturbances. "Second-best" outcomes are achieved as the policy responses are milder than if it was allowed to see the full path of the shocks.

This allows for a scenario where better results can be achieved if the central bank can offset the error from underestimating the inflationary pressures coming from these shocks. Overestimating the lag does this as the policy response for any rule is stronger than the baseline response because the central bank believes inflationary pressures are harder to control. To illustrate this point, further experiments have been run. This time, the central bank is allowed to see the full 4-quarter shock path at time *t* rather than just the contemporaneous effect. In other words, the central bank now

Figure 7: Efficient frontiers when the lag is overestimated and the central bank sees full shock path



sees the full inflationary effect from any time *t* shocks. The new overestimated S/M frontier (labelled S/M(F)) is now compared with the new baseline frontier for FPS-S (labelled FPS-S(F)) and plotted in figure 7.

When the central bank sees the full shock path, overestimating the lag does not produce better results knowing the truth. That is, the new overestimated S/M(F) frontier does not dominate the new baseline FPS-S(F) frontier. In fact, the two frontiers are near identical to each other. In other words, even when the central bank can see the full inflationary implications from today's shocks, the results that can be achieved by knowing the true lag can also be achieved when the central bank overestimates the lag. Given that empirical estimates of the transmission lag are imprecise, these results tell us there is a definite bias in favour of operating with a longer lag. So, for example, if the transmission lag is estimated to be around, say, six quarters, a good strategy may be to operate on the assumption that the actual lag is slightly longer.

There is, however, one caveat to overestimating the lag. While inflation and output variability may be similar, interest rate variability is higher, and significantly so in some cases because the central bank behaves as if inflation is harder to control. In simulations, there is no cost attached to higher interest rate variability. In practice, however, this may not be the case. For example, large interest rate changes may severely damage credibility if the central bank is then forced to reverse policy actions soon after.

I would like to emphasise that the results in this section are not simply a by-product of more aggressive policy actions. While policy responses are stronger when the transmission lag is overestimated, it is because the central bank believes inflation is relatively harder to control – the key distinction is that the underlying information set is telling to central bank to respond in a different way than if it knew the truth. If, for example, the central bank knew the correct lag and used a more aggressive rule, the range of achievable outcomes would not be the same as those from using a less aggressive rule but overestimating the lag. By operating with the correct lag it is never possible to 'trick' the central bank into offsetting the error from underestimating the shocks. Because of the endogenous nature of these experiments, more aggressive initial policy responses only serves to produce a lower future inflation forecast resulting in smaller future policy responses.

6 Summary

Uncertainty over the timing of policy actions is one of the many uncertainties facing a central bank. Using stochastic simulations of the Reserve Bank of New Zealand's macroeconomic model, FPS, this paper examined ways in which a central bank could accommodate transmission lag uncertainty. There were two key questions. The first was which policy rules work well under lag uncertainty? The results showed that less aggressive and more forward looking rules were the most robust. That is, lag uncertainty has the least affect on the performance of these rules. By using robust rules, policy actions will deliver fewer surprises so that monetary policy is able to plan ahead with more confidence.

However, this is not the complete picture. The results also showed that rules with larger response coefficients and shorter target horizons still produced lower overall inflation variability. In other words, by using these rules a central bank would do better at controlling inflation than using a more robust rule. Under this strategy, however, output variability is higher and central bank would have to contend with more surprises as actual outcomes are likely to differ from expectations. The risk in having to contend with these surprises is that monetary policy may focus more on the past and present state of the economy rather than the future. Ultimately, the policy rule decision will depend on the preferences of the central bank – whether they are relatively strict or relatively flexible inflation targeters.

The second aspect examined how a central bank should set up the objective of inflation forecasting and control given lag uncertainty. With any model, policymakers must take a view on the timing of policy actions. There will always be a significant degree of uncertainty surrounding this transmission lag such that a central bank is unlikely to get this right. By looking at the balance of risks, one can ask whether it is better to overestimate or underestimate this transmission lag? The results show that a strategy of overestimating is superior to underestimating the lag as the resulting policy errors can be unwound more quickly. In fact, and somewhat surprisingly, it may even be preferred to knowing the truth!

This intriguing result stems from the way the stochastic experiments have been set up and the characterisation of the stochastic disturbances. While stochastic disturbances are serially correlated and last for several quarters, for plausibility, the central bank is constrained to only see the first quarter effect. Better results can then be achieved if the central bank believes inflationary pressures are harder to control, as it offsets the fact that inflation pressures are being underestimated in the first place.

Even allowing the central bank to see the full shock path, the results from overestimating the lag are near identical to those from when the central bank knows the truth. The implication is that, even at the extreme case of allowing the central bank to see the full future inflationary effects from today’s shocks, the same results that can be achieved by operating with the true lag can also be achieved by operating with a lag that is relatively longer.

Given that estimates of the transmission lag are imprecise, the results support the case for overestimating the lag. That is, under uncertainty, it may be prudent for a central bank – regardless of whether it is a strict or flexible inflation targeter – to assume that the inflation control problem is harder rather than easier. It is this line of reasoning that motivates the use of an asymmetric Phillips Curve. Contrary to Brainard’s conservatism principle, when a central bank is uncertain about how quickly its actions impact on inflation, the results from this paper suggest that the bulk of any policy adjustment should occur sooner, rather than later.

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Appendix 1:

The summary statistics for the baseline efficient IFB rules (derived under certainty)

Weight, θ_i	Target horizon, *i*	RMSDCPI Inflation	RMSDY Output	RMSDRN Interest rate	RMSDZ Exchange rate
FPS-M (Standard/Medium Lag)					
20	**1**	0.28	4.77	16.26	8.12
20	**2**	0.30	4.42	14.62	7.50
20	**4**	0.41	3.85	10.71	6.78
10	**4**	0.51	3.70	8.37	6.47
7	**4**	0.57	3.63	7.41	6.29
5	**4**	0.64	3.56	6.61	6.10
10	**10**	0.77	3.31	6.79	6.08
7	**10**	0.86	3.15	5.53	5.66
5	**10**	0.94	3.04	4.78	5.37
3.5	**10**	1.03	2.97	4.26	5.13
2.5	**10**	1.13	2.92	3.89	4.96
2	**10**	1.19	2.90	3.70	4.86
1.4	**10**	1.31	2.86	3.44	4.72
1	**10**	1.45	2.82	3.25	4.61
0.5	**10**	1.82	2.75	3.06	4.43
FPS-S (Short Lag)					
20	**1**	0.17	3.02	8.95	7.13
20	**2**	0.22	2.86	9.05	7.18
10	**2**	0.30	2.76	7.62	6.85
7	**2**	0.36	2.72	6.90	6.64
10	**4**	0.49	2.43	6.93	6.65
20	**10**	0.57	2.31	8.72	6.55
10	**10**	0.62	2.32	5.94	5.90
7	**6**	0.71	2.26	4.89	5.41
FPS-L (Long Lag)					
20	**2**	0.44	9.78	25.98	13.31
20	**4**	0.48	8.10	17.16	10.75
10	**4**	0.57	7.00	12.98	9.19
7	**4**	0.64	6.41	11.13	8.35
7	**6**	0.70	5.66	9.36	7.79
5	**6**	0.76	5.06	7.99	7.06
7	**10**	0.89	3.77	9.61	6.29
5	**10**	0.93	3.58	7.52	5.91
2.5	**10**	1.08	3.23	5.00	5.25
2	**10**	1.14	3.14	4.53	5.10
1.4	**10**	1.26	3.02	3.97	4.89
1	**10**	1.39	2.93	3.60	4.73
0.5	**10**	1.73	2.76	3.19	4.50

Appendix 2:

Summary statistics for the misperception cases - where the central gets the transmission lag wrong

The actual transmission lag is specified by FPS-L							
WEIGHT	**HORIZON**	**RMSDCPI**	**RMSDY**	**RMSDRN**	**RMSDZ**	**RMSDPDOT4**	**MACRN**
Baseline – No uncertainty – Frontier FPS-L							
20.0	2	0.44	9.78	25.98	13.31	3.09	1749
20.0	4	0.48	8.10	17.16	10.75	2.65	1161
10.0	4	0.57	7.00	12.98	9.19	2.40	767
7.0	4	0.64	6.41	11.13	8.35	2.28	618
7.0	6	0.70	5.66	9.36	7.79	2.03	457
5.0	6	0.76	5.06	7.99	7.06	1.91	387
7.0	10	0.89	3.77	9.61	6.29	1.43	644
5.0	10	0.93	3.58	7.52	5.91	1.48	466
2.5	10	1.08	3.23	5.00	5.25	1.58	272
2.0	10	1.14	3.14	4.53	5.10	1.62	236
1.4	10	1.26	3.02	3.97	4.89	1.70	192
1.0	10	1.39	2.93	3.60	4.73	1.79	160
0.50	10	1.73	2.76	3.19	4.50	2.06	116
Uncertainty – the lag is underestimated – Frontier L/S							
10.0	10	1.07	8.14	9.12	13.85	2.98	477
7.0	10	1.11	5.85	6.99	9.02	2.39	334
5.0	10	1.15	4.73	5.98	6.76	2.12	260
3.5	10	1.22	4.05	5.38	5.39	1.98	210
2.5	10	1.31	3.65	5.02	4.59	1.94	177
2.0	10	1.38	3.45	4.86	4.20	1.94	159
1.4	10	1.50	3.20	4.65	3.74	1.97	137
1.0	10	1.63	3.02	4.51	3.45	2.04	120
0.5	10	1.98	2.76	4.34	3.17	2.29	96
Uncertainty – the lag is underestimated – Frontier L/M							
20.0	10	0.78	6.26	8.20	14.26	2.01	749
10.0	10	0.91	4.52	6.41	7.91	1.81	387
7.0	10	0.99	3.95	5.78	6.20	1.74	302
5.0	10	1.06	3.61	5.39	5.23	1.71	253
3.5	10	1.14	3.38	5.10	4.58	1.71	217
2.5	10	1.22	3.22	4.91	4.14	1.74	190
2.0	10	1.28	3.13	4.80	3.91	1.77	174
1.4	10	1.39	3.01	4.66	3.60	1.83	152
1.0	10	1.51	2.91	4.55	3.38	1.90	134
0.5	10	1.84	2.73	4.39	3.13	2.16	105

The actual transmission lag is specified by FPS-M							
WEIGHT	**HORIZON**	**RMSDCPI**	**RMSDY**	**RMSDZ**	**RMSDPDOT4**	**RMSDRN**	**MACRN**
Baseline – No Uncertainty – Frontier FPS-M							
20.0	1	0.28	4.77	8.12	1.42	16.26	1204
20.0	2	0.30	4.42	7.50	1.37	14.62	1187
20.0	4	0.41	3.85	6.78	1.32	10.71	935
10.0	4	0.51	3.70	6.47	1.36	8.37	654
7.0	4	0.57	3.63	6.29	1.38	7.41	541
5.0	4	0.64	3.56	6.10	1.41	6.61	450
10.0	10	0.77	3.31	6.08	1.29	6.79	389
7.0	10	0.86	3.15	5.66	1.34	5.53	303
5.0	10	0.94	3.04	5.37	1.39	4.78	253
3.5	10	1.03	2.97	5.13	1.45	4.26	216
2.5	10	1.13	2.92	4.96	1.52	3.89	189
2.0	10	1.19	2.90	4.86	1.57	3.70	173
1.4	10	1.31	2.86	4.72	1.66	3.44	150
1.0	10	1.45	2.82	4.61	1.77	3.25	131
0.5	10	1.82	2.75	4.43	2.08	3.06	102
Uncertainty – the lag is underestimated – Frontier M/S							
20.0	2	0.70	5.85	8.40	1.98	13.09	711
10.0	4	0.72	4.23	6.98	1.69	7.90	492
10.0	10	0.74	4.04	6.53	1.43	7.79	394
7.0	10	0.82	3.72	6.01	1.46	6.30	307
5.0	10	0.91	3.51	5.61	1.51	5.32	250
3.5	10	1.03	3.34	5.27	1.56	4.59	205
2.5	10	1.15	3.21	5.02	1.63	4.08	174
2.0	10	1.24	3.14	4.88	1.68	3.82	157
1.4	10	1.39	3.04	4.69	1.78	3.49	134
1.0	10	1.56	2.95	4.56	1.89	3.28	118
0.5	10	1.96	2.81	4.38	2.22	3.10	94
Uncertainty- the lag is overestimated – Frontier M/L							
10.0	4	0.41	3.75	6.70	1.24	9.70	790
7.0	4	0.45	3.70	6.48	1.27	8.23	622
7.0	10	0.82	2.93	6.38	1.12	10.48	775
5.0	10	0.85	2.88	5.91	1.19	7.60	517
3.5	10	0.92	2.85	5.57	1.27	5.87	366
2.5	10	1.00	2.83	5.30	1.36	4.87	281
2.0	10	1.07	2.82	5.16	1.42	4.40	241
1.4	10	1.19	2.80	4.96	1.53	3.85	193
1.0	10	1.33	2.79	4.79	1.65	3.50	160
0.5	10	1.70	2.74	4.54	1.97	3.12	114

The actual transmission lag is specified by FPS-S and the central bank targets domestic price inflation (PDOT4)							
WEIGHT	**HORIZON**	**RMSDCPI**	**RMSDY**	**RMSDZ**	**RMSDPDOT4**	**RMSDRN**	**MACRN**
Baseline – No Uncertainty – Frontier FPS-S							
3.5	1	0.50	2.42	6.66	0.79	8.11	531
7.0	2	0.53	2.21	6.64	0.69	10.11	797
5.0	2	0.53	2.22	6.34	0.75	8.48	637
20.0	4	0.59	1.98	6.14	0.71	9.35	789
Uncertainty – the lag is overestimated – Frontier S/M							
2.0	1	0.59	2.14	6.41	0.82	6.58	420
2.5	1	0.59	2.07	6.61	0.75	7.50	510
3.5	1	0.62	1.99	6.92	0.67	9.14	677
3.5	2	0.67	1.84	6.23	0.75	8.37	674
5.0	2	0.68	1.77	6.48	0.70	10.38	906
7.0	2	0.71	1.75	6.75	0.67	12.79	1197
10.0	4	0.77	1.66	5.62	0.83	9.79	981
20.0	4	0.78	1.67	5.85	0.81	14.47	1662
Uncertainty – the lag is overestimated – Frontier S/L							
1.4	1	0.63	2.31	6.73	0.83	5.75	321
1.4	2	0.70	2.06	6.15	0.85	5.47	340
2.0	2	0.75	1.94	6.59	0.73	6.96	486
2.5	4	0.88	1.69	5.64	0.89	6.59	515
3.5	4	0.92	1.61	5.92	0.86	8.37	713
5.0	4	0.98	1.60	6.34	0.86	11.14	1030