The exchange rate – how should we respond?

A new-Keynesian modelling exercise.

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Preliminary Draft – not for quotation

Abstract

Preliminary research at the Reserve Bank of New Zealand has suggested that including exchange rate stabilisation within the goals of monetary policy significantly increases the volatility of inflation, output and interest rates. The benefits of exchange rate stabilisation therefore do not justify the costs. This paper aims to test whether the finding that it is too costly to stabilise the exchange rate is *robust* to various models of exchange rate determination. I construct a baseline new-Keynesian model calibrated to represent the New Zealand economy. The central bank attempts to minimise two alternative loss functions: (i) a standard function that includes inflation, output, and interest rate volatility only; and (ii) an alternative function that includes a preference for exchange rate stability in addition to the arguments in the standard loss function. For each loss function, I assume that the central bank conducts discretionary policy and chooses the optimal, full information monetary policy rule. Under the baseline model, I find that the optimising central bank responds in a similar manner under both loss function specifications. This corroborates the finding that it is very costly to stabilise the exchange rate. However, the crux of the paper is how this result changes when four alternative models of exchange rate determination are considered.

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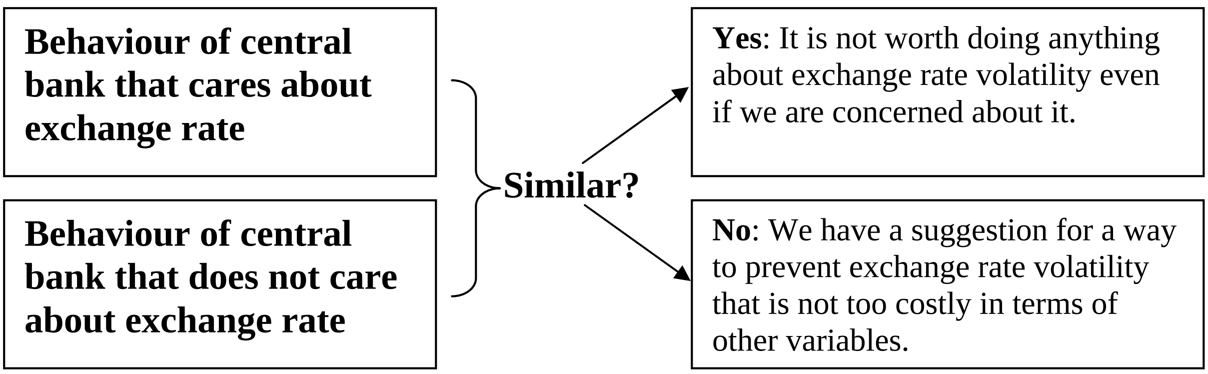
Section 1: Introduction

Two previous research papers at the Reserve Bank of New Zealand, West (2003) and Hampton et al (2003), have suggested that including exchange rate stabilisation within the goals of monetary policy significantly increases the volatility of inflation, output and interest rates. They conclude that the benefits of exchange rate stabilisation do not justify the costs. However, both papers hinged on a UIP formulation of the exchange rate, and investigated the effect of including the exchange rate within a simple monetary policy rule. The current paper aims to test whether the finding that it is too costly to stabilise the exchange rate is *robust*, using the relative tractability of a small new-Keynesian model to evaluate *optimal* monetary policy rules over *several* models of exchange rate determination.

The strategy I employ for testing whether the benefits of monetary policy that attempts to stabilise the exchange rate justifies the costs is to compare the behaviour of two hypothetical central banks: one that is concerned only with inflation and output, and one that is concerned with the exchange rate in addition to inflation and output. Both hypothetical central banks operate within the same model economy and have full and perfect information. For each central bank, I calculate and compare the *optimal* reaction function. I also compare their behaviour when faced with various shocks. If the two optimising central banks behave similarly, one would conclude that the central bank that cares about the exchange rate finds it too costly in terms of output and inflation to attempt to use monetary policy smooth the exchange rate. Alternatively, if the central bank that is concerned with the exchange rate behaves differently, we can safely conclude that the benefits of stabilising the exchange rate outweighed the costs.



The analysis is first carried out on an open, new-Keynesian model of the New Zealand economy. The model features strong forward- and backward-looking inertia, and the exchange rate is determined by uncovered interest rate parity (UIP). Since this model is similar to the one used by West (2003), I expect to confirm the result that it is too costly to attempt to smooth the exchange rate (although in practise I draw some interesting additional conclusions that result from the use of full-information optimal policy).

International empirical evidence is not generally supportive of UIP as the main driver of exchange rate cycles. The main contribution that I hope to make to the literature in this paper is to test whether the previous finding that it is too costly to smooth the exchange rate holds when alternative assumptions about exchange rate determination are made. I specify four alternative models in all, re-examining the results for each model.

Section 2 below outlines the model, and specifies the alternative models. Section 3 begins with a results summary, and then details the results for each model. Section 4 concludes.

Section 2: The model

The small, new-Keynesian model used in this paper was inspired by the model used in Leitemo and Soderstrom (2003) and Svensson (1998). The model is calibrated to represent the New Zealand economy as much as possible – the models estimated in Lees and Sin (2003) and Lees and Warburton (2003) are the main guides to the calibration. However, the role of the exchange rate has been ‘beefed up’ a little relative to the aforementioned empirical studies. Since the focus of this paper is how optimal policy responses change when the model of exchange rate determination changes, the parameterisation of the baseline model is not as important as the *differences* between the baseline and the alternative models.

2.1 Aggregate Demand

The output gap features strong forward and backward looking inertia, and is influenced by monetary policy, the exchange rate, and foreign output.

$$y_t = \beta_1 y_{t-1} + \beta_2 E_t y_{t+1} - \beta_3 (i_{t-1} - \pi_{t-1}) - \beta_4 q_t + \beta_5 y_t^{\,f} + \varepsilon_{yt} \tag{1}$$

where all variables are relative to their steady state equilibria and

y_t = output at time *t*,

i_t = nominal interest rates, controlled by the central bank,

π_t = the rate of inflation,

q_t = the real exchange rate, and

ε_{yt} = random demand shock at time *t*.

E_t denotes a rational expectation at time *t* of the proceeding variable, and the superscript *f* represents foreign variables.

Lees and Sin (2003) note that this aggregate demand equation can be formally derived from a consumption Euler equation that features foreign goods. The forward and backward looking terms are consistent with habit formation on the part of consumers. In theory, the equation should also feature forward looking terms for the exchange rate and for foreign output. However, Lees and Sin (2003) found zero coefficients on these terms in their estimated equation.

Table 1 shows the parameterisation of the aggregate demand equation, where $\sigma_{\varepsilon y}$ is the standard deviation of the demand shock.

Table 1: Aggregate demand equation parameters

Variable	Value	Justification
β_1	0.8	Lees and Sin (2003)
β_2	0.1	Calibrated to give some forward looking inertia
β_3	0.127	Lees and Sin (2003)
β_4	0.1	Calibrated, based on Leitemo and Soderstrom (2003)
β_5	0.22	Lees and Sin (2003)
$\sigma_{\varepsilon y}$	0.8	Lees and Sin (2003)

Note that $\beta_1 + \beta_2 < 1$ implies that the output gap is stationary, and that output returns to equilibrium in the absence of anti-cyclical monetary policy. Inflation and output are therefore self-stabilising in this model.

2.2 Inflation

CPI inflation is given a Phillips Curve equation,

$$\pi_t = \alpha_1 E_t \pi_{t+1} + (1-\alpha_1)\pi_{t-1} + \alpha_2 y_{t-1} + \alpha_3 \pi_t^m + \varepsilon_{\pi t} \tag{2}$$

where π_t^m denotes the inflation rate of imported goods and services and $\varepsilon_{\pi t}$ is a random shock to domestic prices. The long-run Phillips Curve is vertical, and the output gap affects inflation with a one period lag. Note that I have not specified a separate equation for domestic inflation. This allows a shock to *imported* inflation to have flow-on effects on the *general* level of prices, including domestic prices. The exchange rate affects the price of imported goods, through the equation:

$$\pi_t^m = (1-\kappa)\pi_{t-1}^m + \kappa \Delta q_t \tag{3}$$

where $0 < \kappa < 1 =$ the rate of pass through from the exchange rate to import prices.

Table 2 details the parameterisation of the Phillips Curve.

Table 2: Phillips Curve equation parameters

Variable	Value	Justification
α_1	0.5	Leitemo and Soderstrom (2003)
α_2	0.2	Calibrated
α_3	0.35	Approximate proportion of imported goods and services consumed in New Zealand
$\sigma_{\varepsilon\pi}$	0.8	Lees and Sin (2003)

2.3 Foreign sector

The foreign sector is represented by simple stationary processes with persistence for output and inflation, following Svensson (1999). The foreign central bank follows the Taylor Rule, with weights of 1.5 on inflation and 0.5 on output.

$$y_t{}^f = \beta_1{}^f y_{t-1}{}^f + \varepsilon_{y^f t} \tag{4}$$

$$\pi_t{}^f = \alpha_1{}^f \pi_{t-1}{}^f + \varepsilon_{\pi t} \tag{5}$$

$$i_t{}^f = 1.5\pi_t{}^f + 0.5 y_t{}^f \tag{6}$$

The parameterisation of the foreign sector, shown in table 3, also follows Svennson (1999).

Table 3: Foreign sector parameters

Variable	Value	Justification
β_1^f	0.8	Svennson (1999).
α_1^f	0.8	Svennson (1999).
$\sigma_{\varepsilon\pi f}$	0.5	Svennson (1999).
$\sigma_{\varepsilon y f}$	0.5	Svennson (1999).

2.4 Exchange rate

This section specifies a generalised model of the exchange rate. The alternative models are distinguished by parameter changes with the generalised framework. The real exchange is given by:

$$q_t = \tilde{E}_t q_{t+1} + (i_t - E_t \pi_{t+1}) - (i_t{}^f - E_t \pi_{t+1}{}^f) + \gamma y_t{}^f + u_t^q \tag{7}$$

$\tilde{E}_t q_{t+1}$ is the expectation of next period's exchange rate at time *t*, and is not necessarily rational. With $\gamma = 0$ and rational expectations, this represents the familiar UIP condition with a persistent risk premium, u_t^q, where

$$u_t^q = \rho_q u_{t-1}^q + \varepsilon_{qt}, \quad 0 \le \rho < 1. \tag{8}$$

The foreign demand term in equation (7) represents the effect of commodity prices on the exchange rate, where commodity prices are a linear function of foreign demand (γ is non-zero only in the commodity prices model).

2.4.1 Baseline model

In the Base Case, $\tilde{E}_t q_{t+1}$ is rational and $\gamma = 0$, meaning that the exchange rate is determined by the standard UIP condition. Deviations from UIP have a relatively low persistence, $\rho = 0.3$. Moreover, $\kappa = 0.5$, meaning that import prices respond asymptotically to exchange rate changes, with a half-life of one quarter.[1] Note that importers pass changes in the *equilibrium* exchange rate through to prices immediately.

The baseline model is a fairly standard, theoretically driven model of exchange rate determination. However, observed behaviour of the New Zealand exchange rate is difficult to reconcile with this model. This paper aims to test the robustness of previous conclusions that were based on this baseline model of exchange rate determination to changes in the model of the exchange rate. Four alternative models are proposed, each consistent with observed exchange rate behaviour. The models are compared and summarised in table (4), and are detailed in sections 2.4.2 to 2.4.5.

Table 4: Summary of alternative exchange rate models
Blank spaces indicate no change from Baseline model.

	κ	ρ	γ	$E_t q_{t+1}$	Variance of ε_q^t
Base Case	0.5	0.3	0	Rational	0.7
Slow pass-through to import prices	0.1				
Persistent deviations from UIP		0.9			0.1
Exchange rate influenced by commodity prices			0.22		0.69
Adaptive expectations				90% adaptive	0.07

2.4.2 Slow pass-through model

$\kappa = 0.1$ instead of $\kappa = 0.5$.

The true rate of exchange rate pass-through into prices is difficult to measure. In particular, there is evidence to suggest that it has slowed considerably in recent years.[2] The first alternative model tests the effect that much slower pass-through would have on the conclusions.

[1] $\kappa = 0.5$ is consistent with the full sample estimate of Campa and Goldberg (2002), who report that exchange rate pass-through into import prices for New Zealand is 0.47 – 0.58 in the first quarter, and 0.62 – 0.77 in the long run. In the baseline model, the implied exchange rate pass-through into consumer prices for the first two quarters is 0.26. This compares to empirical estimates that range from 0.1 in Lees and Sin (2003) to 0.2 – 0.4 in Munro (2003).

[2] Campa and Goldberg (2002) estimate that exchange rate pass-through into import prices lowed to 0.08 in a post-1999 sample, compared to their 0.47 for a post 1989 sample.

2.4.3 Persistent deviations from UIP

$\rho = 0.9$ instead of $\rho = 0.3$. Variance of $\varepsilon_q^t = 0.1$.

In this model, exchange rate shocks are far more persistent. Note that the variance of ε_q^t is reduced, such that the variance of u_t^q is unchanged from the baseline model.

2.4.4 Commodity prices model

$\gamma = 0.22$

This model postulates that exchange rate deviations from UIP are partly correlated with world commodity prices, and that world commodity prices are a linear function of world demand.[3] In this model, the exchange rate provides the domestic economy with a buffer against foreign shocks.

2.4.5 Adaptive expectations model

This model was first proposed in an internal RBNZ memo, Hargreaves (2003). The model is motivated by the observation that the exchange rate appears to be more sensitive to interest rates than could be justified by UIP (see, for example, Stephens (2004)). This oversensitivity could be explained by partly adaptive expectations. Suppose that exchange rate expectations are based on the current exchange rate, with a small weight on the rational expectation:

$$\tilde{E}_t q_{t+1} = 0.9 q_t + 0.1 E_t q_{t+1} \tag{9}$$

Substituting into equation (7) gives

$$q_t = 0.9 q_t + 0.1 E_t q_{t+1} + (i_t - E_t \pi_{t+1}) - (i_t^{\,f} - E_t \pi_{t+1}^{\;\;f}) + u_t^q \,. \tag{10}$$

Rearranging,

$$q_t = E_t q_{t+1} + 10(i_t - E_t \pi_{t+1}) - 10(i_t^{\,f} - E_t \pi_{t+1}^{\;\;f}) + 10 u_t^q \tag{11}$$

Note that the exchange rate is now 10 times more sensitive to u_t^q. The variance of exchange rate shocks should be reduced by a factor of 10, such that the observed variance of the exchange rate matches that of the baseline model.

[3] See Chen and Rogoff (xxx) or Huang (2004) for empirical evidence that commodity prices affect the New Zealand exchange rate.

2.5 Monetary policy

The central bank is assumed to minimise an intertemporal loss function of the form:

$$\sum_{t=0}^{\infty} \beta^{t} L_{t} \tag{12}$$

where *ß* is the discount factor, and L_t represents the period loss function. As explained in section 1, the aim of this paper is to compare the optimal monetary policy responses of a central bank that cares about the exchange rate to the optimal monetary responses of a central bank that does not care about the exchange rate. This involves running the model under two alternative period loss functions. First, a standard loss function,

$$L_{t} = y_{t}^{2} + \pi_{t}^{2} + 0.25\Delta i_{t}^{2} \tag{13}$$

where the central bank places equal weight on deviations of output and inflation from target, and also has a preference for avoiding sharp changes to the policy instrument, i_t. I argue for a coefficient of 0.25 on changes in the policy instrument because it gives far more realistic policy responses than the literature standard of 0.1. A sensitivity analysis of this parameter choice is shown in the appendix (figure A3). Under the standard loss function, the central bank places no explicit weight on the exchange rate, although it may react to exchange rate shocks in pursuit of its other goals.

Secondly, I posit an alternative loss function, whereby the central bank places explicit weight on the exchange rate

$$L_{t} = y_{t}^{2} + \pi_{t}^{2} + 0.25\Delta i_{t}^{2} + q_{t}^{2}. \tag{14}$$

The relative weight on the exchange rate in the alternative loss function alters the quantitative results, but not the qualitative results.

Section 3: Results

Drawing conclusions from this paper involves analysing and interpreting 200 impulse responses! To aid interpretation, section 3.1 summarises the main results. Section 3.2 then goes into more detail on the results for the baseline model. Sections 3.3 to 3.6 detail and discuss the results of each alternative model only where they differ substantially from the baseline model. Table 5 is a reference summary of the results and conclusions. The second column shows the optimal interest rate reaction to the four shock types in the case of a standard central bank, in the baseline model. The next column shows how the optimal reaction changes when the exchange rate is added to the loss function, again in the baseline model. The final column summarises whether changing the form of the exchange rate equation overturns the conclusion.

Table 5: Summary of results

	Base Case Reaction	Change in reaction if CB cares about exchange rate.	Do alternative models overturn result?
Price shock	Raise then gently ease	Very little	No
Output shock	Raise then gently ease	More gradual – but the difference is small.	Adaptive Expectations
Exchange rate shock	No reaction	Aggressive initial easing	Persistent Deviations, Adaptive Expectations
Foreign shock	Small tightening cycle	Very little	No

3.1 Results summary

The general result is that it is not worth using interest rates to try to smooth the exchange rate, except where interest rates can be expected to have a massive influence over the exchange rate.

The key results of the baseline model are that

1) A central bank that cares about the exchange rate should react more gradually to demand shocks than a central bank with a standard loss function. However, the difference in the optimal reactions of the two central banks is too small to be considered a "significant" difference (see figure 1).
2) The alternative central bank should react to pure exchange rate shocks, while the standard central bank should not (see figure 2).
3) The two central banks behave in very a very similar manner when confronted with price shocks.

Figure 1: Interest rate reactions to demand shock, baseline model

Standard Loss Function - - - - - - - Alternative Loss Function

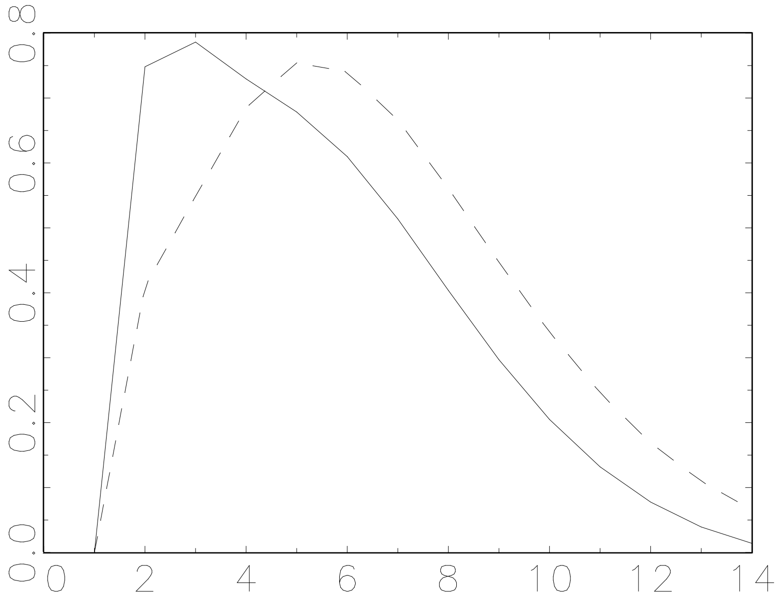
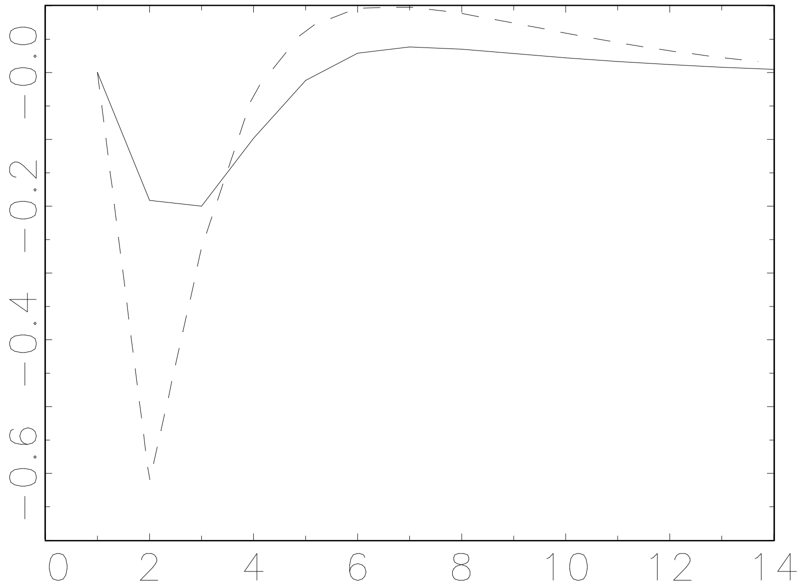


Figure 2: Interest rate reactions to exchange rate shock, baseline model

Standard Loss Function - - - - - - - Alternative Loss Function



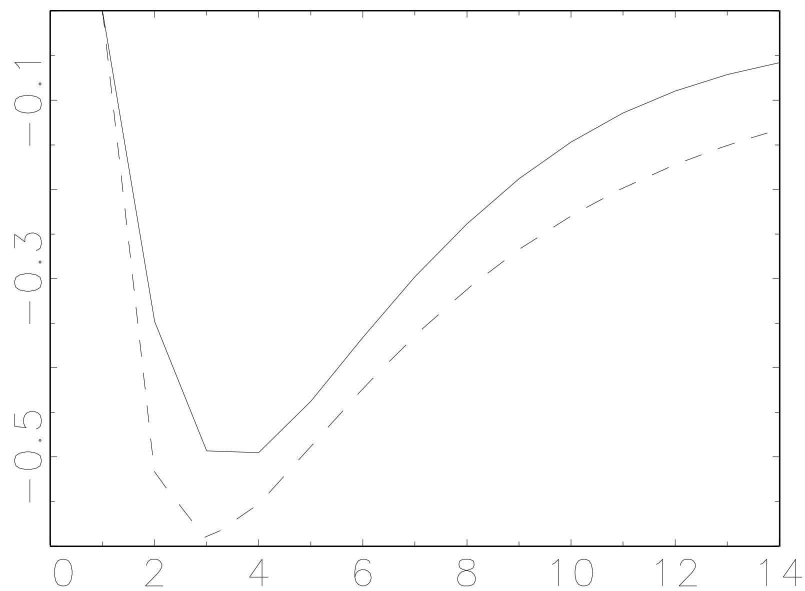
Looking at the baseline model alone, we would largely support the results of West (2003) and Hampton et al (2003) with one key exception. Under full information, a central bank that cares about the exchange rate should react to “pure” exchange rate shocks, while a standard central bank should not. Of course, the applicability of this result to the real world is limited by a central bank’s ability to distinguish pure exchange rate shocks from other moves in the exchange rate.

Changing the model of the exchange rate alters the results in the following ways

1) If exchange rate shocks are very persistent, then *both* central banks should react to pure exchange rate shocks (see figure 3).
2) If the exchange rate moves with New Zealand commodity prices, then *both* central banks should allow it to perform its shock absorber function, and need not move interest rates in the face of foreign demand shock.
3) In the adaptive expectations model, the results change substantially. In nominal interest-rate terms, the alternative central bank reacts more aggressively to all types of shocks, and both central banks react strongly to pure exchange rate shocks. This results from the fact that the central bank has far more influence over exchange rates in this model.

Figure 3: Interest rate reaction to exchange rate shock, persistent deviations model

——— Standard Loss Function - - - - - - - Alternative Loss Function



Some alternative models also illustrated a major cost of targeting the exchange rate that has not been captured by the previous literature – that including the exchange rate within the goals of monetary policy affects inflation expectations. Since agents know that the central bank is less single-minded in its inflation target, they *expect* larger deviations of inflation from target. These expectations will be self-fulfilling to some extent. Consequently, the alternative central bank receives less help from favourable expectations, and has far more work to do in returning inflation to target. It therefore suffers disproportionately large increases in inflation variability in return for modest decreases in the exchange rate cycle.

Finally, the commodity prices model illustrates that the central bank should be careful to allow the exchange rate to perform its shock absorber function in the face of foreign shocks, even if it is concerned about exchange rate variability.

Section 3.2: Baseline model results

3.2.1 The standard central bank

Figure 4 shows the impulse responses for four shocks to the baseline model. The shocks occur in period 1. In each case, the solid line represents the impulse responses under the standard loss function, while the dotted lines show the impulse responses when the exchange rate is included in the reaction function (henceforth, alternative reaction function). We begin by making some observations on the standard central bank, represented by the solid lines.

With a standard reaction function, the baseline model has sensible impulse responses. A one standard deviation price shock causes the central bank to tighten by 80 basis points (bp). The tightening cycle lasts around 10 quarters, and causes a negative output gap that peaks at around 0.19 per cent. The increase in real interest rates causes the exchange rate to appreciate initially and then to depreciate, in line with the UIP relationship.

The standard central bank responds to a demand shock with a tightening cycle that peaks at 80bp. This quickly offsets the positive output gap. Note that the central bank must run a negative output gap for a period, in order to return inflation to target. The response of inflation to a demand shock is a good illustration of the lag structure of this model. The immediate effect on inflation is a small fall, due to the exchange rate appreciation (which, in turn, is caused by the interest rate increase). Subsequently, there is a long period of positive inflation, caused by the lagged effect of the demand shock, and by the persistence of inflation itself.

In the case of an exchange rate shock, the standard central bank reacts only slightly. It prefers to allow the exchange rate to readjust autonomously. Lowering interest rates would offset the exchange rate spike, but due to the lagged effect of monetary policy, would not help with the *immediate* impact on inflation or output. Furthermore, lowering interest rates would cause the economy to overheat later. Since the standard central bank does not target the exchange rate per se, its most prudent course of action is to “look through” exchange rate shocks.

The standard central bank tightens monetary policy only slightly in response to a foreign demand shock (14 bp, compared to 80 bp for a domestic demand shock). The impulse responses are similar to those of a domestic demand shock, only more muted.

3.2.2. Does the alternative central bank behave differently?

An optimising central bank that cared about the exchange rate would not behave much differently to an optimising central bank with a standard loss function, except in the case of a pure exchange rate shock. The results of the baseline model agree with the findings of West (2003) and Hampton et al (2003) – using interest rates to smooth the exchange rate is too costly to justify.

Table 6 below compares the optimal reaction functions of the standard central bank and the alternative central bank. Each number represents the percentage-point reaction of interest rates to a 1% increase in the relevant variable. Note that a full information optimal reaction function allows the central bank to react differently to a shock and to a deviation from target. Some readers may be more familiar with simple policy rules, which do not allow the central bank to draw this distinction. Table 6 shows that the alternative central bank is more gradualist in the face of output shocks, and is more activist in responding to exchange rate shocks.

Due to the interrelationships between the variables, interpreting full-information optimal reaction functions is not always straightforward. In many cases, it is also instructive to directly compare the impulse responses from the alternative central bank to those of the standard central bank, as shown in figure 4.

Table 6: Optimal reaction functions, baseline model.

	Output shock	Inflation Shock	Exchange Rate Shock	Output (lagged)	Inflation (lagged)	Exchange Rate (lagged)	Imported Inflation (lagged)	Interest Rate (lagged)	Foreign Output	Foreign Inflation
	ε_{yt}	$\varepsilon_{\pi t}$	ε_{qt}	y_{t-1}	π_{t-1}	q_{t-1}	π^m_{t-1}	i_{t-1}	y^f_t	π^f_t
Standard loss function	0.94	0.91	-0.23	0.93	0.57	0.45	0.77	0.28	0.19	0.57
Alternative loss Function	0.51	1.05	-0.73	0.62	0.59	0.55	0.92	0.08	0.10	0.91

The alternative central bank behaves in a very similar fashion to the standard central bank in the case of a price shock.

In the case of an output shock, the central bank that cares about the exchange rate is more gradualist than the standard central bank. This reduces the initial exchange rate spike. The alternative central bank more muted exchange rate and interest rate cycles, at the cost of more inflation and output variability. It is very difficult to assess whether or not the policy responses are "significantly different." Casual inspection suggests that the difference between the two reactions is very small. Section 3.2.3 below shows that the degree of difference in the behaviour of the two central banks depends on two main factors:

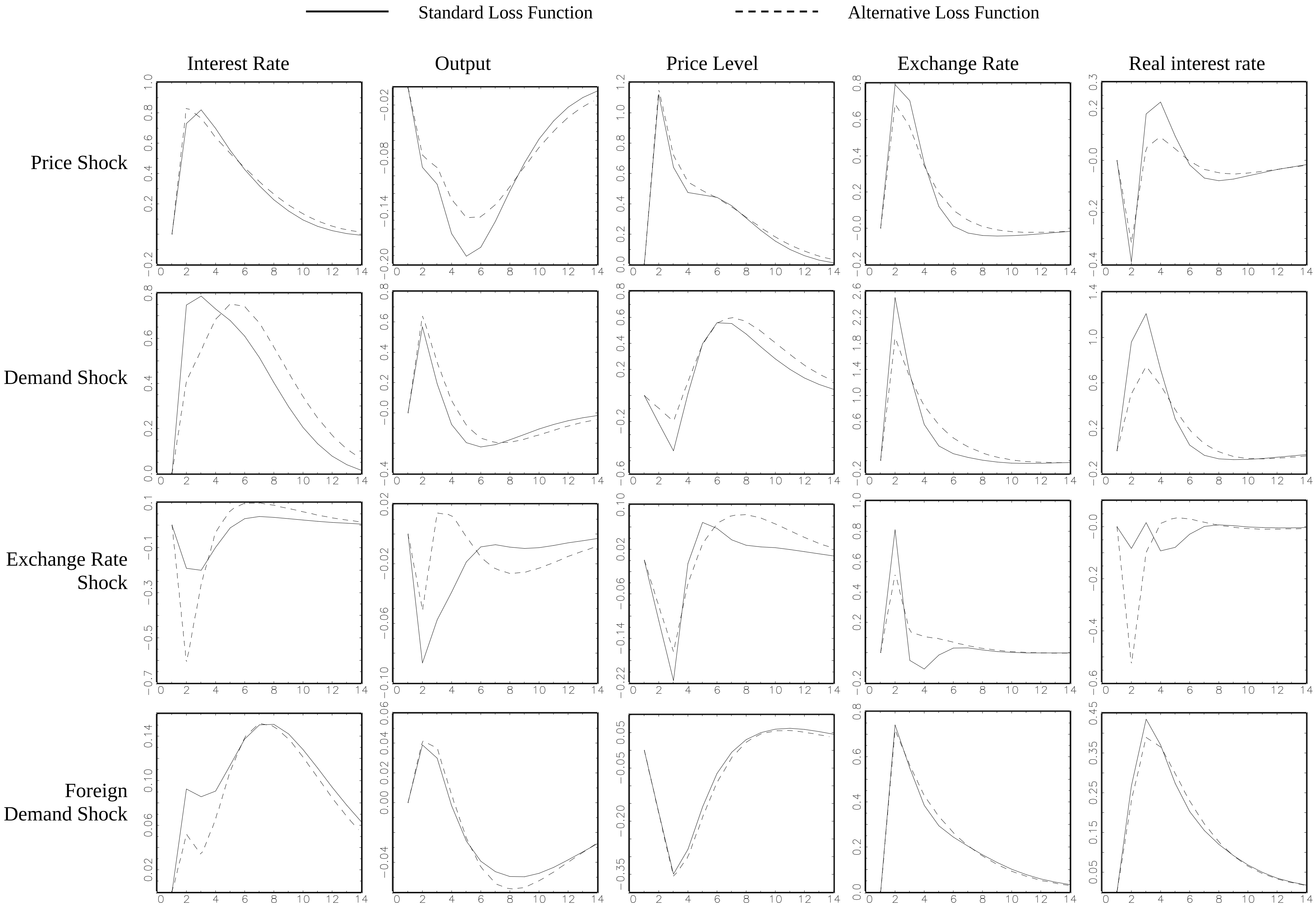
i) A higher penalty on changes in the interest rate in the loss function induces the standard central bank to be more gradualist, reducing the difference between the two central banks.

ii) The more self stabilising the model is, the lower the "cost" of gradualism in terms of inflation and output. Under a more self-stabilising specification, the more the alternative central bank can afford additional gradualism.

The central bank that cares about the exchange rate drops interest rates sharply in the face of a pure exchange rate shock, while the standard central bank does not react much. This is a significant departure from the results of West (2003) and Hampton et al (2003). The reason we find such a different result is that the previous authors allowed only for *simple* policy rules. Simple policy rules cannot distinguish pure exchange rate shocks from exchange rate movements that are consistent with economic fundamentals. An optimal central bank operating under full information can make the distinction perfectly, and can respond perfectly. While this is a crucial finding, its applicability to the real world is limited by a real-world central bank's ability to distinguish pure exchange rate shocks from movements in exchange rate fundamentals.

The alternative central bank behaves in a slightly more gradual manner than the standard central bank in the case of a foreign demand shock, but as in the case of a demand shock, the difference in the reactions is very small.

Figure 4: **Baseline Model -** Impulse responses



3.2.3 Why does less aggressive policy lead to less exchange rate appreciation?

In the baseline model, more gradualist monetary policy attenuates the exchange rate cycle. In some macroeconomic models that assume UIP, less aggressive monetary policy would not attenuate the exchange rate cycle, or may even exacerbate it (this is the case in our alternative expectations model). This is because less aggressive policy responses require the central bank to hold interest rates high for a longer period in order to return inflation to zero (in figure 4, the less aggressive tightening cycle is indeed more protracted). Whether the *total* tightening required is more, or less, under a gradual response may depend from model to model.

The size of the initial exchange rate spike that results from a tightening cycle is determined by the *total* tightening when UIP, rational expectations, and full information are assumed. [explain why only if necessary]. The corollary is that since the initial spike is lower, the alternative central bank must tighten interest rates by less *in total* than the standard central bank – yet inflation still eventually returns to zero. This suggests that inflation is self stabilising to some extent. This occurs in my model for two reasons:

1. The output gap is a stationary variable, meaning it tends toward zero in the absence of monetary policy. A more gradual tightening cycle allows the output gap more time to close autonomously. The alternative central bank effectively waits for the self-stabilising nature of the economy to do some of its stabilisation work for it.
2. Forward looking expectations also work in the central banks favour, making inflation self stabilising to some extent. Again, the same principle applies – a more gradual monetary policy allows more time for these innate forces to help the central bank.[4]

The appendix shows some sensitivity analysis around the dynamic assumptions in the model.

3.3 Slow pass-through model results

In table 7, the shaded areas show where the optimal reaction functions under the slow pass-through model differ from those of the baseline model.

The impulse responses of figure 5 show that slowing the rate of pass-through in the model changes the impulse responses significantly – most shocks generate less inflation. However, slower pass-through does not alter the conclusion of the baseline model. The standard and the alternative central banks behave very similarly, except in the case of a pure exchange rate shock.

[4] Note, however, that this does not amount to a free lunch. If the central bank were to try to exploit these favourable expectations, agents would immediately adjust their expectations, and they would no longer be favourable.

Table 6: Optimal reaction functions, slow pass-through model.

	Output shock	Inflation Shock	Exchange Rate Shock	Output (lagged)	Inflation (lagged)	Exchange Rate (lagged)	Imported Inflation (lagged)	Interest Rate (lagged)	Foreign Output	Foreign Inflation
	ε_{yt}	$\varepsilon_{\pi t}$	ε_{qt}	y_{t-1}	π_{t-1}	q_{t-1}	π^{m}_{t-1}	i_{t-1}	y^{f}_{t}	π^{f}_{t}
Standard loss function	0.94	1.19	-0.27	0.99	0.71	0.13	1.61	0.24	0.34	0.49
Alternative loss Function	0.98	1.30	-0.66	1.04	0.77	0.15	1.83	0.00	0.53	0.67

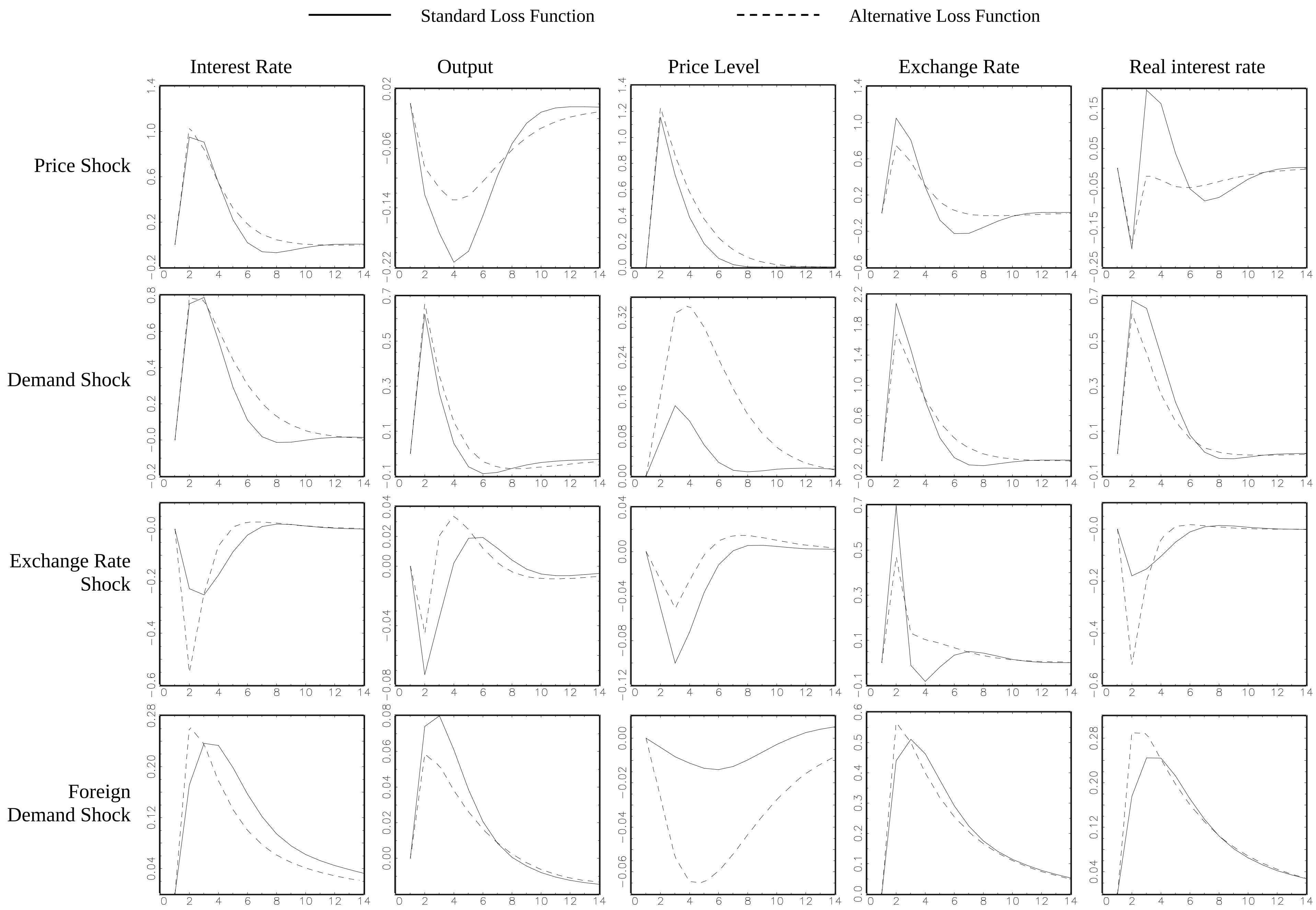
3.3.1 The effect of targeting the exchange rate on inflation expectations

Careful consideration of the demand shock in figure 5 illuminates an interesting property of the model. The alternative central bank holds nominal interest rates higher than the standard central bank, yet inflation and the output gap are both higher. The output gap part of this puzzle can be solved by observing the real interest rate in the fifth column. In real terms, the alternative central bank is in fact more gradualist than the standard central bank.

The difference in inflation rates is due to *inflation* expectations. Agents know that the alternative central bank is concerned about its effect on the exchange rate. Tthey understand that the alternative central bank will react more gradually to demand shocks, and will devote less attention to controlling inflation. They therefore expect more inflation. Since inflation expectations are less well anchored at target, expectations expert less favourable influence on inflation, leaving the alternative central bank with more work to do to return inflation to target.

This illustrates a very important point: the cost of including the exchange rate within the goals of monetary policy is that not must allow inflation and output to vary a bit more, but also that *expectations start to work against you*.

Figure 5: **Slow Pass-through model -** Impulse responses



3.4 Persistent deviations model results

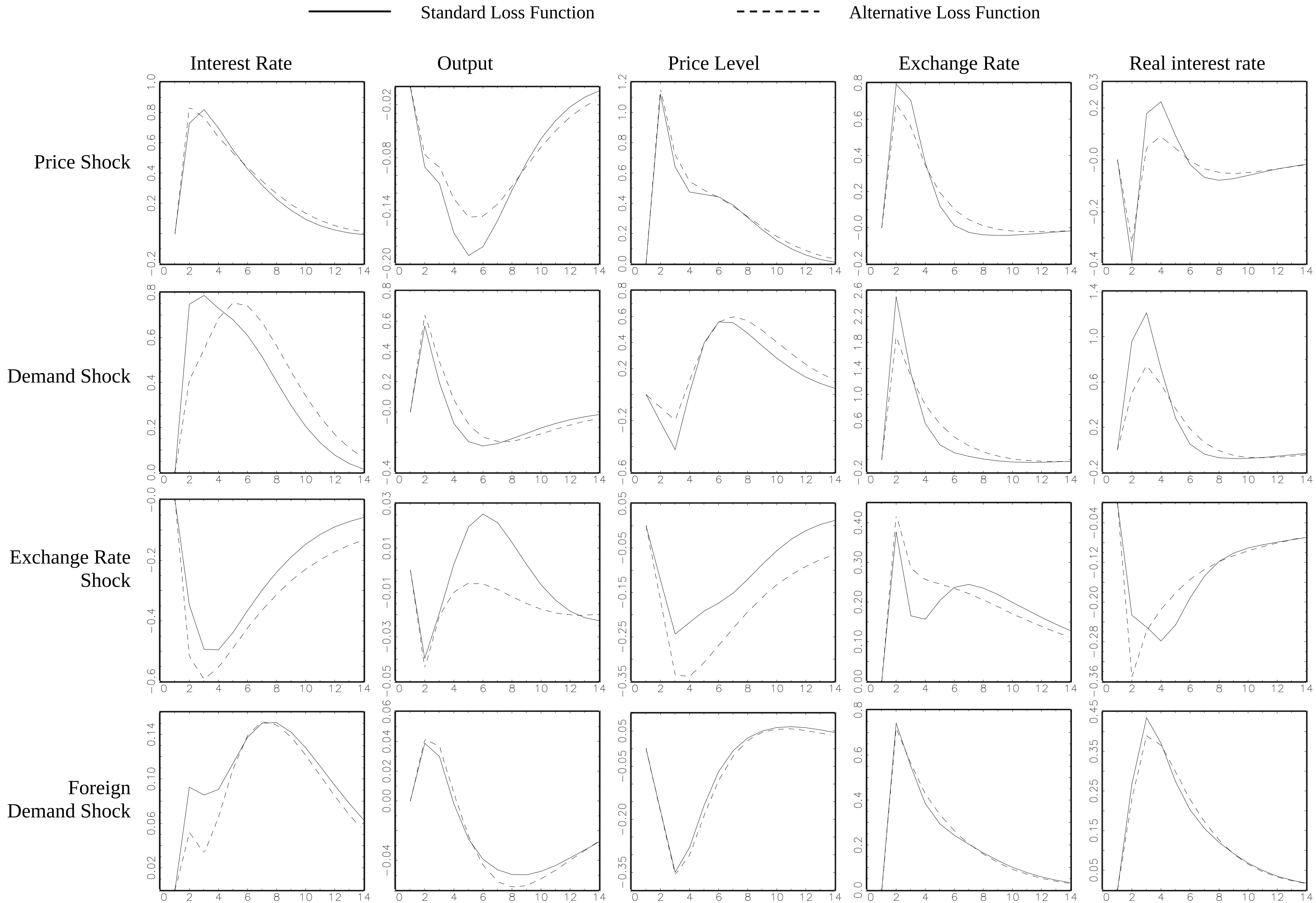
Table 8: Optimal reaction functions, persistent deviations model.

	Output shock	Inflation Shock	Exchange Rate Shock	Output (lagged)	Inflation (lagged)	Exchange Rate (lagged)	Imported Inflation (lagged)	Interest Rate (lagged)	Foreign Output	Foreign Inflation
	ε_{yt}	$\varepsilon_{\pi t}$	ε_{qt}	y_{t-1}	π_{t-1}	q_{t-1}	π^m_{t-1}	i_{t-1}	y^f_t	π^f_t
Standard loss function	0.94	0.91	-1.10	0.93	0.57	0.45	0.77	0.28	0.19	0.57
Alternative loss Function	0.51	1.05	-1.64	0.62	0.59	0.55	0.92	0.08	0.10	0.91

The impulse responses when deviations from UIP are more persistent are exactly the same as the baseline model in all cases except for an exchange rate shock, as shown in figure 6.

The effect on inflation and output of an exchange rate shock is longer lasting in the persistent deviations model. Consequently, both central banks are able to use interest rates to offset the inflation and output gap effects. Note that the two central banks behave in a similar fashion, indicating that concern for inflation and output is the primary reason to cut interest rates. In this model, there is very little that the central bank can do to affect the exchange rate.

Figure 6: **Persistent deviations model -** Impulse responses



3.5 Commodity prices model results

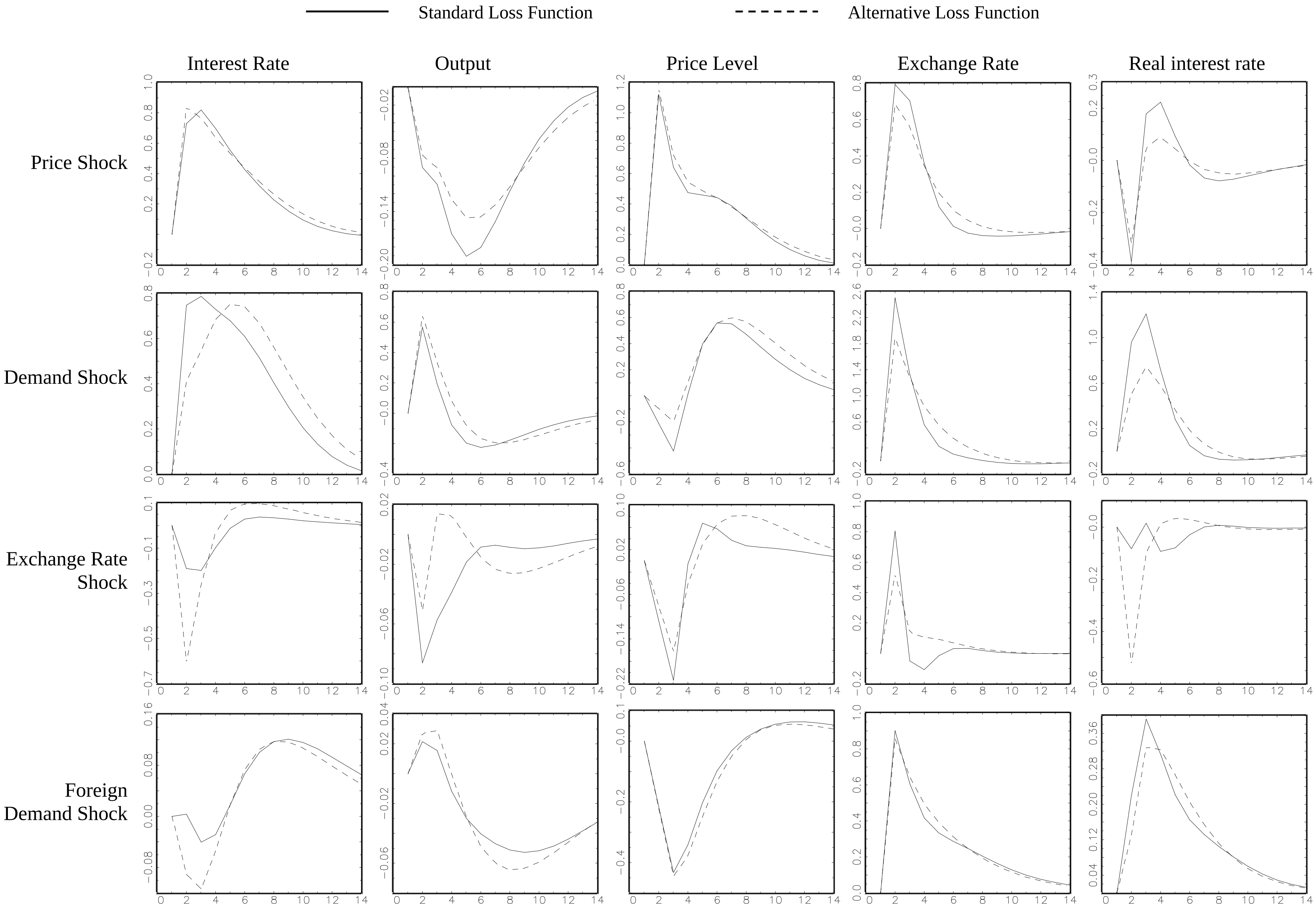
In the commodity prices model, the exchange rate is correlated with foreign demand. Table 9 shows that the optimal reaction functions are the same as in the baseline model, except for the reaction to foreign demand disturbances. The impulse responses for to a foreign demand shock in this model are shown in figure 7. The standard central bank no longer reacts much to foreign demand shocks – it prefers to allow the exchange rate to work as a shock absorber. The alternative central bank behaves in broadly the same manner, although it reduces interest rates slightly in response to the foreign demand shock.

Table 9: Optimal reaction functions, commodity prices model.

	Output shock	Inflation Shock	Exchange Rate Shock	Output (lagged)	Inflation (lagged)	Exchange Rate (lagged)	Imported Inflation (lagged)	Interest Rate (lagged)	Foreign Output	Foreign Inflation
	ε_{yt}	$\varepsilon_{\pi t}$	ε_{qt}	y_{t-1}	π_{t-1}	q_{t-1}	π^m_{t-1}	i_{t-1}	y^f_t	π^f_t
Standard loss function	0.94	0.91	-0.23	0.93	0.57	0.45	0.77	0.28	0.01	0.57
Alternative loss Function	0.51	1.05	-0.73	0.62	0.59	0.55	0.92	0.08	-0.18	0.91

The commodity prices model draws out another interesting conclusion: even if the central bank is concerned about exchange rate volatility, it should allow the exchange rate to undergo “positive volatility” when acting as a buffer against foreign demand shocks.

Figure 7: **Commodity prices model -** Impulse responses



3.6 Adaptive expectations model results

Table 10: Optimal reaction functions in adaptive expectations model

	Output shock	Inflation Shock	Exchange Rate Shock	Output (lagged)	Inflation (lagged)	Exchange Rate (lagged)	Imported Inflation (lagged)	Interest Rate (lagged)	Foreign Output	Foreign Inflation
	ε_{yt}	$\varepsilon_{\pi t}$	ε_{qt}	y_{t-1}	π_{t-1}	q_{t-1}	π_{t-1}^{m}	i_{t-1}	y_t^f	π_t^f
Standard loss function	-0.16	0.70	-1.09	0.01	0.33	0.40	0.65	0.02	0.13	0.96
Alternative loss Function	0.40	0.97	-1.01	0.52	0.54	0.49	0.83	-0.04	0.39	0.85

Modelling exchange rate expectations as adaptive significantly alters the properties of the model. The central bank can have a significant, immediate effect on the exchange rate. This means that in the case of an exchange rate shock, both central banks find it well worth while reacting directly.

Again, it is interesting to note that reacting to the exchange rate partly “unhinges” inflation expectations. The alternative central bank has to do far more work to return inflation to target. In nominal terms, the alternative central bank is far more aggressive than the standard central bank. However, figure 8 shows that in real terms, it is actually more gradualist. The adaptive expectations model is an example of a model whereby a more gradualist monetary policy would actually exacerbate the exchange rate cycle.

The adaptive expectations model contradicts the baseline result in three ways:

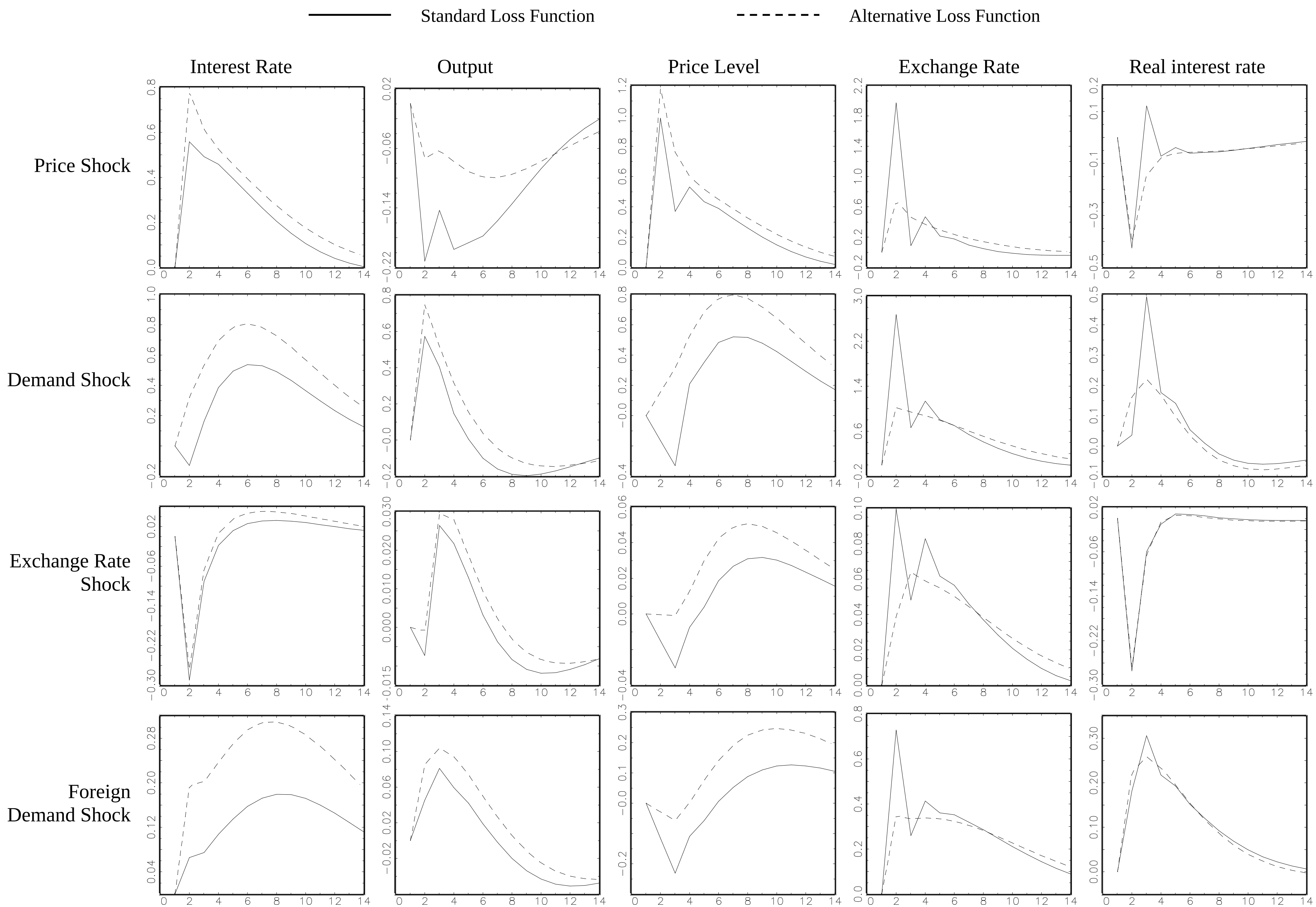
i) It says that the central bank really can affect the exchange rate

ii) It says that if the central bank cares about the exchange rate, it should behave more aggressively in nominal terms.

iii) The central bank should react to pure exchange rate shocks even if the exchange rate is not in the loss function.

However, the adaptive expectations model illustrates very clearly the biggest cost of including the exchange rate within the goals of monetary policy – that of unhinging inflation expectations.

Figure 5: **Adaptive expectations model -** Impulse responses



Section 4: Conclusion

We draw four main conclusions from this paper. Each is discussed in turn

1. *For models of the exchange rate that feature rational expectations, we cannot overturn the previous result that the costs of reacting to the exchange rate do not justify the benefits.*
   We found that a central bank operating optimal monetary policy under a loss function that includes the exchange rate behaves very similarly to an optimal central bank that is not directly concerned with the exchange rate. This implies that the alternative central bank finds that the costs of attempting to affect the exchange rate do not justify the benefits. This result holds under various models of exchange rate determination, so long as those models featured rational expectations.

   In the baseline model, we did find that a central bank that is concerned with the exchange rate should react more gradually to aggregate demand shocks. However, we found that this result depended crucially on the model of the exchange rate that is assumed. In some models, the difference in behaviour was negligible, and in others the result was reversed – the alternative central bank was more aggressive in nominal terms. We therefore concluded that the additional gradualism of the baseline model was not a robust result.

2. *A central bank that is concerned about the exchange rate should react strongly to pure exchange rate shocks if it can identify them, but should be careful not to counter the exchange rate's shock absorber effect.*
   We found that the optimal monetary policy for a central bank that is concerned with the exchange rate is to cut interest rates sharply to offset pure exchange rate shocks. However, the recommended interest rate reaction is concurrent with the exchange rate shock. The applicability of this result in the real world is limited by a central bank's ability to identify pure exchange rate shocks in a timely fashion. Furthermore, the commodity prices model showed the central bank should be very careful not to erode the exchange rate's positive, shock-absorber function.

3. *If exchange rate expectations are adaptive, then reacting to the exchange rate may be justified.*
   We specified a model that is consistent with the observed behaviour of the exchange rate, and featured adaptive exchange rate expectations. In such a model, the central bank has a powerful influence over the exchange rate, and therefore setting interest rates in a way that mitigates the exchange rate cycle may be justified. Interestingly, in this model a central bank that cares about the exchange rate should behave *more aggressive* in nominal terms, because inflation expectations don't help it as much. In real terms, it is more gradualist. Also, even a standard central bank should react very aggressively to pure exchange rate shocks in an adaptive expectations world.

4. *A major cost of targeting the exchange rate is that inflation expectations become less anchored to the inflation target.*

In a model with strongly forward looking dynamics and rational expectations, inflation expectations play a very important role. If the central bank chooses to include the exchange rate within its goals, then inflation expectations will be less strongly anchored to the inflation target. These less favourable inflation expectations will make the central bank's inflation control objective more difficult to achieve, and will result in more variable inflation. Loss of inflation targeting credibility is a very important risk for a central bank that is considering including exchange rate stabilisation within its goals.

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Appendix 1: Sensitivity analysis

Figure A1 shows the effect of increasing making the output gap more persistent and less self-stabilising, by increasing β_1 to 0.9. The alternative central bank finds that additional gradualism does not make such a great impact on the exchange rate, because investors know that more tightening will be required later. Therefore, the alternative central bank chooses to behave more like the standard central bank than in the baseline model.

Figure A2 shows the effect of increasing the forward looking dynamics in the aggregate demand equation by setting $\beta_2 = 0.5$, and $\beta_1 = 0.4$. Expectations now help the central bank to close the output gap more. The alternative central bank therefore finds that gradual monetary policy pays off.

Figure A3 shows the effect of the interest rate smoothing parameter in the loss function. Reducing it to a more standard 0.1 makes the standard central bank far more reactionary – in the case of an output shock, it raises interest rates by 130 basis points rather than 80. It would appear, therefore, that less interest rate smoothing is an unrealistic assumption, since the baseline model features a more realistic reaction to a typical output shock.

Figure A1: More persistent output gap - Impulse responses

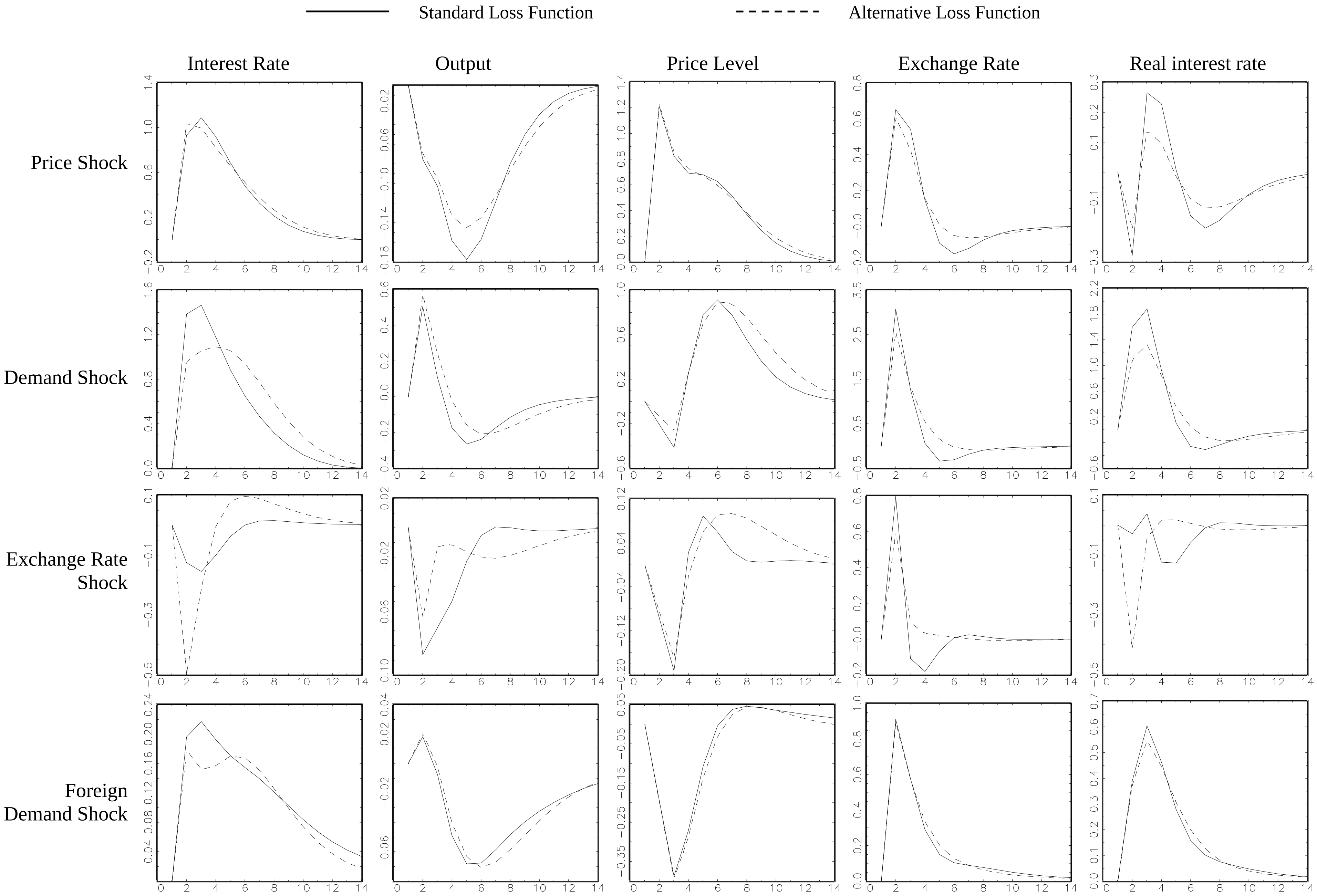

Figure A2: More forward looking dynamics - Impulse responses

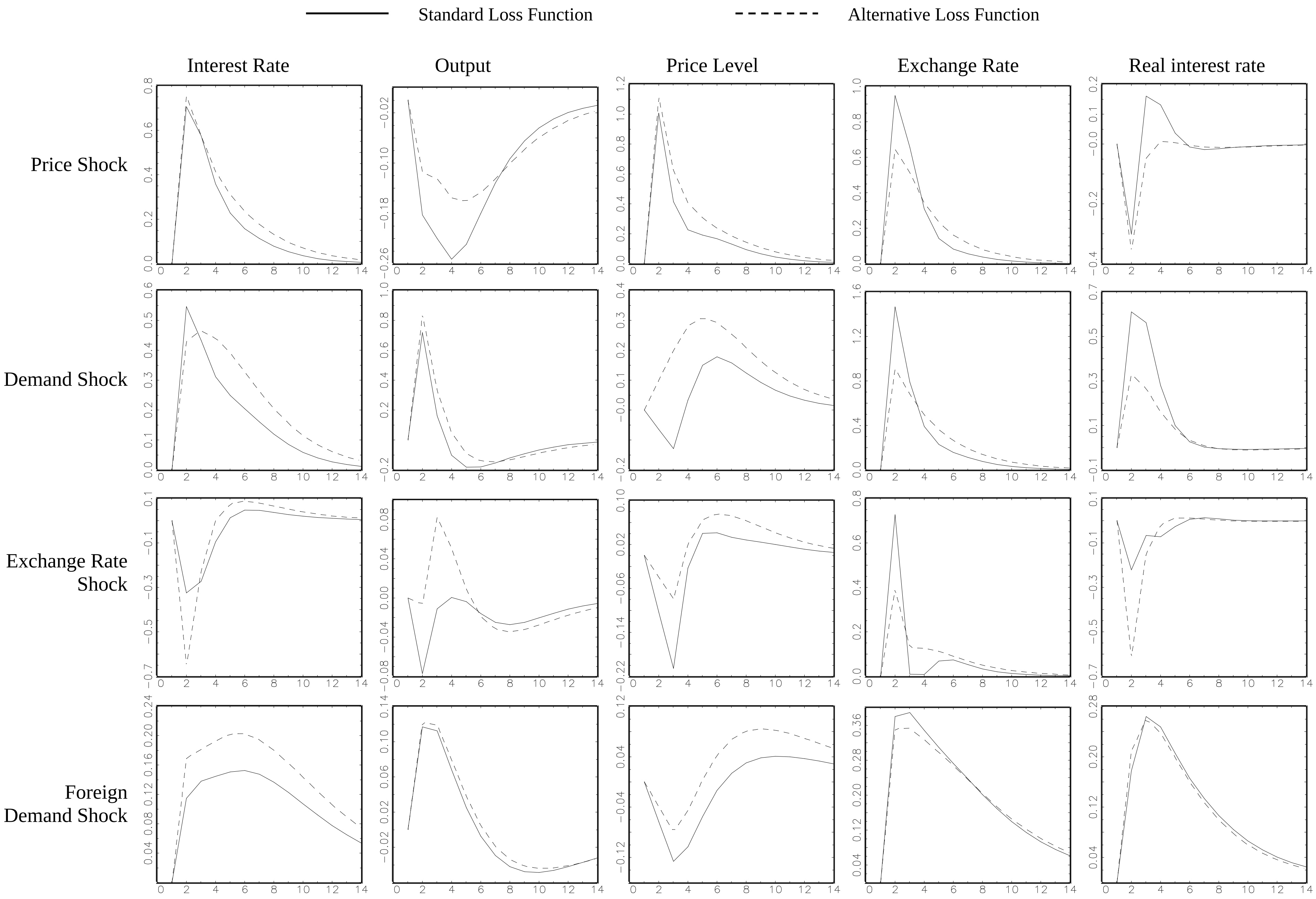

Figure A3: **Less interest rate smoothing -** Impulse responses