INFLATION TARGETING AND EXCHANGE RATE FLUCTUATIONS IN AUSTRALIA

Chris Ryan* and Christopher Thompson**

Research Discussion Paper
2000–06

September 2000

*Domestic Markets Department
**Economic Analysis Department
Reserve Bank of Australia

An earlier version of this paper was presented at the Sveriges Riksbank workshop on *Inflation Targeting and Exchange Rate Fluctuations*, held in Stockholm, 24–25 August 1999. We are grateful to participants at that workshop and colleagues at the Reserve Bank for their comments on the paper. We are particularly indebted to Luci Ellis for numerous comments and technical assistance with the use of *Mathematica*. The views expressed in this paper are our own and should not be attributed to the Reserve Bank of Australia.

Abstract

Several recent papers have explored the possibility that inflation-targeting central banks in small open economies pay too much attention to exchange rate fluctuations; changing short-term interest rates in response to fluctuations that have transient effects on inflation could be counterproductive. Accordingly, we investigate whether the Reserve Bank of Australia, while ultimately concerned with aggregate inflation and output, should set short-term interest rates on the basis of expected inflation in the non-tradeable sector or go even further and react directly to expected wage pressures in that sector's labour market. Our results indicate that there are no clear gains to be had from responding only to measures of inflation which abstract from temporary exchange rate fluctuations. The variability of inflation and output would be at least as great as under the current framework, while the shocks that have typically hit the Australian economy over the past couple of decades are such that interest rates would be no less variable than under the current inflation-targeting framework. We attribute these findings to the forward-looking nature of the current inflation-targeting framework, whereby exchange rate shocks are ignored in the setting of policy if they are expected to have only a temporary impact on inflation.

JEL Classification Numbers: E52, E58, E61, F41
Keywords: exchange rates, inflation targeting, macroeconomic model, monetary policy rules, open economy

Table of Contents

INFLATION TARGETING AND EXCHANGE RATE FLUCTUATIONS IN AUSTRALIA

Chris Ryan and Christopher Thompson

1. Introduction

In 1993, the Reserve Bank of Australia (RBA) introduced an inflation target of 2–3 per cent per annum, on average over the cycle. The available evidence suggests that, despite initial criticism from some quarters, this inflation-targeting framework has served the country quite well, possibly better than inflation targeting has served some other countries (Brooks 1998). We hasten to add that it may have been possible to do even better, and what has worked well for Australia may not work as well for some other countries, but the fact remains that it has worked well for Australia to date.

As for whether even better outcomes were possible, a number of recent papers have focused on the implications of exchange rate fluctuations for inflation targeting and have explored the possibility that inflation-targeting central banks in small open economies pay too much attention to these fluctuations.[1] The argument is that exchange rate fluctuations tend to have significant but transient effects on inflation and that monetary policy attempts to offset these effects could cause undue variability in output.

On first inspection, Australia would appear to be a good test case for this argument. The Australian dollar has ranged from around US$0.68 in 1993 to a high of around US$0.80 in mid 1996 and to its recent low of around US$0.55. Part of these movements reflect changes in Australia's commodity-driven terms of trade, which help dampen output variability, but there has also been considerable short-term volatility not related to such fundamentals, such as in mid 1998. Australia also fits the description of a small open economy: it exerts little or no influence on

---

[1] See, for example, Ball (1998), Svensson (1998), Bharucha and Kent (1998) and Conway *et al* (1998). For an earlier reference to targeting a measure of inflation that abstracts from exchange rate effects, see Pitchford (1993).

world prices and our exports and imports account for a large share, each around 20–25 per cent, of GDP.

On closer examination, it could be argued that Australia's monetary policy framework already deals with the problem adequately. The inflation target, for example, is not hard-edged: relatively small divergences from the 2–3 per cent target band are tolerated provided inflation is forecast to be back within 2–3 per cent in the medium term. The forward-looking nature of policy should also be sufficient to prevent the RBA from responding to exchange rate shocks which are only expected to have a temporary effect on inflation.

These counterarguments are clearly an empirical matter and should be assessed accordingly. Thus, while accepting that it is ultimately aggregate inflation (and output) that the central bank cares about, in this paper we compare the implications of allowing policy to respond to different measures of inflation: aggregate, non-tradeable and growth in unit labour costs in the non-tradeable sector. Such a comparison enables us to assess the validity of the argument that central banks, by reacting a lot to temporary exchange rate movements, can cause undue variability in output.

Figures 1 and 2 show four-quarter-ended and quarterly movements in underlying tradeable, non-tradeable and (for Figure 1) aggregate inflation. Non-tradeable inflation was particularly high in the early 1980s, when wages growth was high in some sectors of the economy. The large exchange rate depreciation in the mid 1980s pushed tradeable inflation higher than non-tradeable inflation. More recently, the Australian dollar price of imported items in the CPI fell in absolute terms, causing the prices of tradeables to be roughly flat.

Figure 1: Year-ended Underlying Inflation

Percentage change

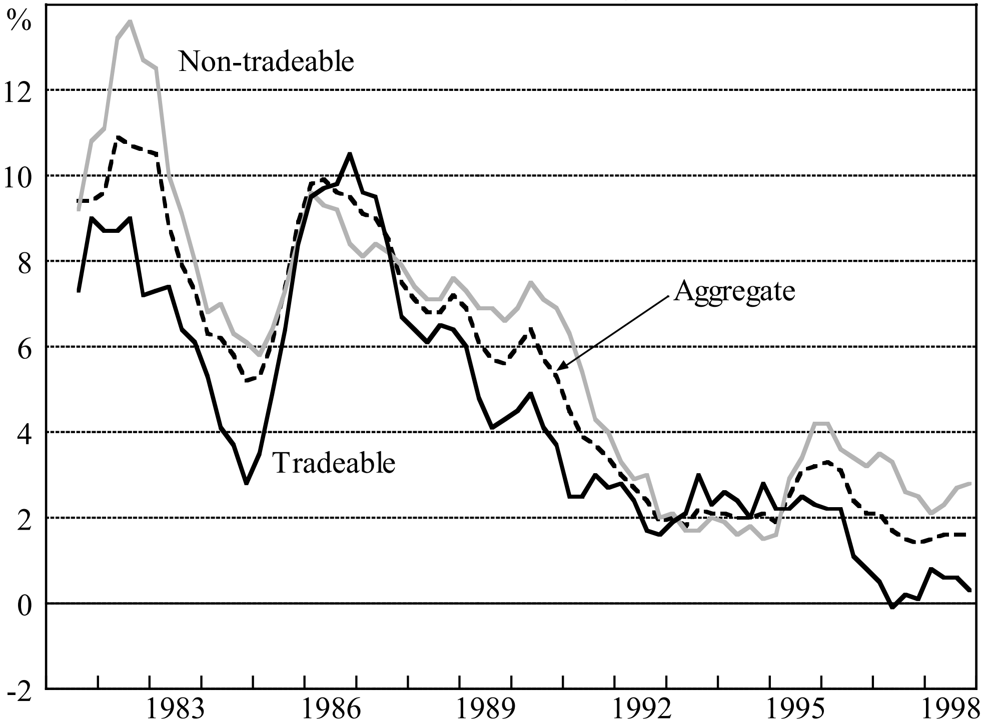
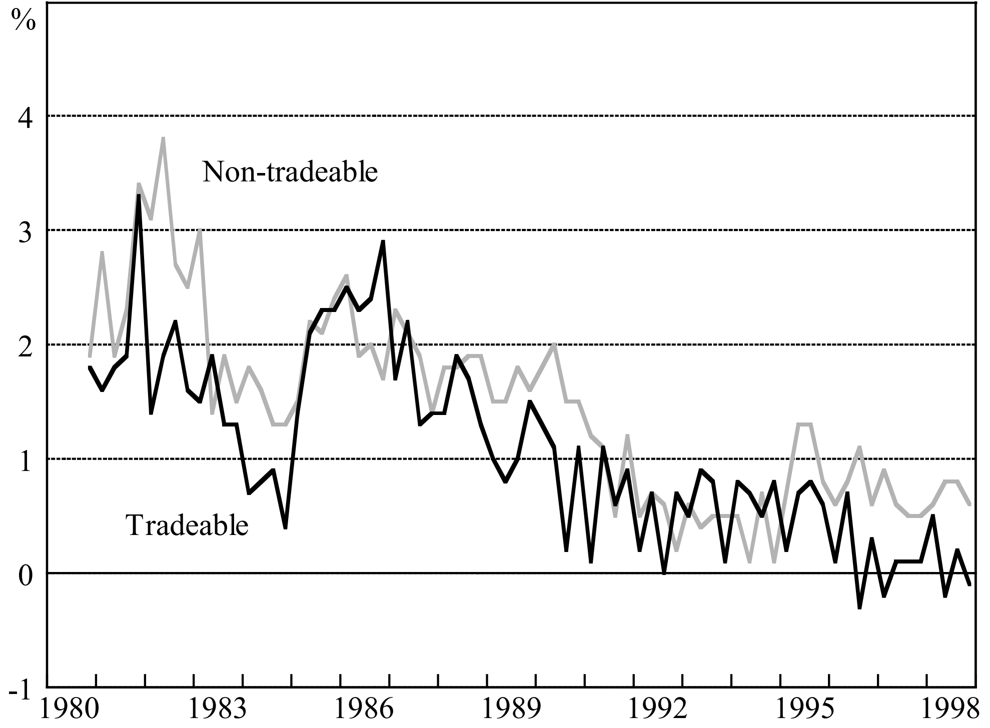


Figure 2: Quarterly Underlying Inflation

Percentage change



Figures 1 and 2 may suggest that non-tradeable inflation is at least as variable as tradeable inflation and that, at least occasionally, the two measures are negatively correlated such that aggregate inflation is less variable than non-tradeable inflation. If true, it would seem to be a foregone conclusion that one should target aggregate, rather than non-tradeable inflation. The issue is, however, more complicated than that. First, simple statistical analysis indicates that the two components generally move together and that aggregate inflation is almost as variable as non-tradeable inflation. More importantly, policy-makers are forward looking and non-tradeable inflation may be more predictable than tradeable inflation because it is less dependent on forecasts for the exchange rate, a variable which is notoriously difficult to predict.

The structure of the remainder of the paper is as follows. The next section reviews some previous research on open economy inflation targeting, motivates our distinction between aggregate and non-tradeable inflation and describes the simple monetary policy feedback rules which we use later in the paper. Section 3 describes the model that we use to investigate the properties of various monetary policy rules. The results of simulating the model under the different policy rules are discussed in Section 4. Section 5 concludes. As a preview, our findings suggest that there are no clear gains to be had from changing the nature of Australia’s inflation-targeting framework.

2. Open Economy Inflation Targeting

In an open economy, a depreciation of the exchange rate affects inflation directly by increasing the domestic-currency price of imports, and indirectly by increasing foreign demand for domestic output. This exchange rate effect works in conjunction with the aggregate demand channel of monetary policy whereby a decrease in interest rates stimulates aggregate demand and increases inflation. Because monetary policy generally affects inflation more quickly through the exchange rate channel than through the aggregate demand channel, an opportunity arises for activist policy to use the direct exchange rate channel to control inflation at a short horizon. Such a policy of frequent interest rate adjustments, however, could induce considerable variability in other key macroeconomic variables.

Recognising these considerations, several recent papers have examined the issue of what is the most appropriate measure of inflation to target in a small open economy. Building on the work of Ball (1998) and Svensson (1998), Bharucha and Kent (1998) compared the implications of targeting aggregate and non-tradeable inflation in a simple theoretical model of a small open economy with tradeable and non-tradeable sectors (roughly calibrated, where possible, to match the Australian economy). Importantly, the model assumed that aggregate inflation was more susceptible to exchange rate fluctuations than was non-tradeable inflation.

Bharucha and Kent showed that the implications of aggregate and non-tradeable inflation targeting depended on the relative size and source of shocks hitting the economy. For exchange rate shocks, optimal monetary policy was more activist under aggregate inflation targeting. This reduced the volatility of the exchange rate and aggregate inflation, but increased the volatility of the interest rate, output and non-tradeable inflation. In comparison, the less activist optimal policy response under non-tradeable inflation targeting generated less variability in output and non-tradeable inflation, but increased the variability of the exchange rate and aggregate inflation.

Compared with exchange rate shocks, the monetary policy implications of aggregate and non-tradeable inflation targeting under demand and supply shocks were reversed – optimal policy under aggregate inflation targeting was less activist than non-tradeable inflation targeting.

In a more realistic setting with all shocks operating at once, the unconditional variances of all variables (except non-tradeable inflation) were higher under non-tradeable inflation targeting. The authors acknowledge, however, that this result depends on the arbitrarily chosen size of exchange rate shocks relative to demand and supply shocks.

In concluding, Bharucha and Kent were ‘unable to provide an answer as to whether aggregate inflation targeting [was] strictly preferable to non-traded inflation targeting’. Instead, they suggested that policy should be conducted with a medium-term perspective so as to avoid the undesirable outcomes associated with either inflation-targeting regime.

In this paper we take up the issue of open economy inflation targeting once more. However, our approach differs from Bharucha and Kent (and earlier papers) in two important ways.

Whereas most previous papers have addressed the issue using small theoretical models (sometimes calibrated to match a small open economy), we examine the issue in the context of an econometrically estimated model of the Australian economy. In this way, we hope that the results will be more relevant than those contained in the earlier studies.

Another significant departure from previous papers is our use of simple monetary policy rules (reaction functions) to determine interest rates rather than the optimisation of an explicit policy objective function. A number of recent papers have examined the properties of simple monetary policy rules and shown that they provide a fairly accurate characterisation of actual policy in most industrialised countries. Characterising monetary policy as following an interest rate rule provides us with a convenient means of changing the measure of inflation which policy responds to and allows us to examine a number of related issues, such as the optimal length of the policy forecast horizon.

2.1 The Distinction Between Aggregate and Non-tradeable Inflation

In his work on open-economy inflation targeting, Svensson (1998) explored the distinction between CPI-inflation targeting and targeting inflation of domestically produced goods ('domestic-inflation targeting'). This distinction relies on the assumption that the country is small in the market for its imported goods, but large in the world market for its exportable output. The difference then between CPI-inflation and domestic-inflation reflects movements in the prices of imports which are determined by world prices and the exchange rate.

For Australia, we believe that the distinction between CPI-inflation and domestic-inflation is less appropriate for two reasons.

First, the prices of imported items in the Australian CPI are affected by more than just world prices and the exchange rate. Dwyer and Lam (1994), for example, found that the long run pass-through of exchange rate changes to the imported component of the Australian CPI was only about two-thirds. They argued that this reflected the costs, mainly incurred in the non-tradeable sector (for example, transportation, storage and wholesaling), of bringing imported goods to the retail market. A variable retail mark-up also contributes to the relative stability of imported goods prices in the face of exchange rate movements, and this too is a domestic consideration.

Second, the prices of import-competing and exportable goods in Australia are at least partly determined in world markets (Dwyer, Kent and Pease 1994). Australia's openness to international trade means that the prices of our import-competing goods are influenced by world markets. For example, the prices of domestically produced motor vehicles fell during 1998, at least partly in response to falls in the prices of imported motor vehicles. As for Australia's exportables, our small size and the homogeneity of many of our biggest exports means that we are more likely to be price takers on world markets. In any case, if we exclude imported and import-competing items (at a moderate level of aggregation in the CPI) from a definition of domestic inflation, we would also automatically exclude exportables.

Following Bharucha and Kent (1998), we argue that the appropriate distinction for a small open economy is between aggregate inflation and inflation in the non-tradeable sector.[2] We formalise this distinction as follows.

Assume that the aggregate consumer price level (p) is a composite index of the prices of tradeable (tp) and non-tradeable goods (ntp):

$$p = \alpha . ntp + (1-\alpha) . tp \tag{1}$$

where α represents the share of non-tradeable goods in the aggregate consumer price index.

---

[2] In any case, the Australian Bureau of Statistics has recently ceased recording the distinction, except for motor vehicles, between the domestic and imported components of the CPI, choosing instead to report only the distinction between tradeable and non-tradeable components. Moreover, the price deflators in the national accounts do not provide a good proxy for the domestic component of the CPI.

Next, assume that non-tradeable prices are determined as a mark-up over the costs of production – domestic and imported costs. Domestic costs are mainly for labour and are represented by unit labour costs in the non-tradeable sector ($ntulc$ – nominal wages adjusted for labour productivity in the non-tradeable sector). Imported costs reflect the prices of imported intermediate inputs, which we assume to follow the prices of final consumption imports (pm). Ignoring the mark-up, non-tradeable prices are given by:

$$ntp = \beta.ntulc + (1-\beta).pm \tag{2}$$

Tradeable prices include the prices of wholly imported and import-competing final consumption goods (importables) and exportable consumption goods. Assume that importable prices mainly comprise the prices of imported final goods and intermediate inputs (pm), but are also affected by the labour costs, incurred in the non-tradeable sector, of bringing those goods to the retail market ($ntulc$). Exportable prices are determined by world prices (proxied by pm), with some adjustment also for non-tradeable sector labour costs. Tradeable prices are then given by:

$$tp = \delta.ntulc + (1-\delta).pm \tag{3}$$

Substituting (2) and (3) into (1), we arrive at the following expression for aggregate prices:

$$\begin{aligned} p &= \alpha[\beta.ntulc + (1-\beta).pm] + (1-\alpha)[\delta.ntulc + (1-\delta).pm] \\ &= \varphi.ntulc + (1-\varphi).pm \end{aligned} \tag{4}$$

Furthermore, if $\beta > \delta$, then $\varphi < \beta$. This implies that a given movement in the price of imports (bought about by a change in the exchange rate, for example) will have a greater effect on aggregate prices than non-tradeable prices. Econometric estimates of aggregate and non-tradeable inflation equations for Australia (see Appendix A and the discussion in Section 3) confirm this pattern of long-run elasticities.

Aggregate inflation, which incorporates the prices of tradeable goods, will be more susceptible to movements in the exchange rate than non-tradeable inflation.

Because of this distinction, we later explore the implications of following policy rules which respond to each of these measures of inflation. Going a step further, we also examine rules in which the interest rate responds to movements in non-tradeable sector unit labour costs – a variable which is even less affected by exchange rate movements than non-tradeable inflation.

2.2 Monetary Policy Rules

In this paper we assume that monetary policy follows a linear interest-rate rule of the following general form:

$$i_t = \lambda i_{t-1} + (1-\lambda) i_t^* \qquad (5)$$

where

$$i_t^* = r^n + \pi_{t-1} + \psi_1 E_t(\Pi_{t+f} - \Pi^*) + \psi_2 E_t(y_{t+f} - y_{t+f}^p) \qquad (6)$$

This rule assumes the partial adjustment of the nominal interest rate (i) to a target rate (i^*), where the parameter λ ($0 \le \lambda \le 1$) represents the degree of interest rate smoothing. The target rate is a function of the deviation of year-ended inflation from target ($\Pi - \Pi^*$) and the output gap ($y - y^p$). When both of these feedback variables are zero then the target rate will be equal to the neutral real interest rate (r^n) plus expected inflation, proxied in our model by lagged *aggregate* inflation (π_{t-1}). Note that this represents the public – not the central bank – expectation for inflation.

The parameters ψ_1 and ψ_2 are reaction weights which measure the responsiveness of the target rate to each feedback variable, f is the forecast horizon (in quarters) at which the feedback variables enter the rule and E_t denotes the expectation of a variable formed at time t (conditional on the application of the policy rule through time).

Substituting (6) into (5) gives the following general rule:

$$i_t = \lambda i_{t-1} + (1-\lambda)\left[r^n + \pi_{t-1} + \psi_1 E_t(\Pi_{t+f} - \Pi^*) + \psi_2 E_t(y_{t+f} - y_{t+f}^p)\right] \qquad (7)$$

It is worth highlighting a number of characteristics of this policy rule.

The rule is an example of a 'simple' monetary policy rule in the sense that it includes only two feedback variables – the deviation of inflation from target and the output gap. In this paper we restrict ourselves to this class of simple rules rather than more complex 'optimal' rules which can be derived by optimising an explicit objective function subject to the constraints implied by the equations in a model. There are a number of reasons for this. First, simple rules, particularly when they include *forecasts* of the feedback variables ($f \geq 0$), can generally stabilise inflation and output almost as well as optimal rules while still satisfying their original purpose – to provide a simple and transparent guidepost for policy. Second, optimal rules, which are complex functions of all of the predetermined state variables in a model, are not as robust across model specifications as simple rules (Taylor 1999).[3] Finally, simple rules provide us with a relatively straightforward means of experimenting with different aspects of the monetary policy operating framework – such as changing the measure of inflation which policy responds to and gauging the optimal forecast horizon for policy.

The variable Π can refer to a variety of inflation measures, not just aggregate inflation. This enables us to compare the implications of following policy rules which respond to different measures of inflation. Irrespective of the inflation measure used, the steady state assumptions of our model (discussed in Section 3.2) imply the same numerical inflation target ($\Pi^* = 2½$ per cent per annum).

In this paper we consider rules in which f lies in the range -1 to 8. When $f = -1$, policy responds to the most recently observed data – we call these 'backward-looking' rules. These rules, of which the Taylor (1993) rule is a prominent example, are only able to stabilise the economy if inflation and the output gap are quite persistent, so that their past values help predict future inflation. While these rules tend to perform quite well in closed economies, recent research has made it clear that policy-makers in open economies can stabilise the economy further by reacting to forecasts of the feedback variables rather than their lagged values ($f \geq 0$ – which we call 'forward-looking' policy rules). In this way

---

[3] This argument may not be as relevant for simple rules which include forecasts of the feedback variables because these forecasts (model consistent or otherwise) are complex functions of the entire model.

policy uses all available information to forecast the feedback variables (rather than just lagged values) and is better able to control for lags in the monetary policy transmission process. Forward-looking policy rules also correspond more closely with actual 'pre-emptive' policy-making. In our forward-looking policy rules, forecasts of the feedback variables are fully model consistent – that is, they are generated assuming that the central bank actively uses the same policy rule in each future period.

Note that we generally restrict ourselves to rules in which $\lambda = 0$ (no interest rate smoothing). However, in the context of discussing possible remedies to excessive interest rate variability (in Section 4.1), we investigate rules in which $\lambda > 0$ and rules in which $\lambda = 0$ with constrained interest rate variability.[4]

3. The Model

The model we use in this paper comprises six econometrically estimated equations for aggregate output (real non-farm GDP), inflation (that is, equations for aggregate and non-tradeable inflation, non-tradeable unit labour costs and import prices) and the real exchange rate. There are also two identities; for the real interest rate and the nominal exchange rate. In the following section we provide a brief description of each equation. Empirical estimates of the equations are contained in Appendix A.

3.1 Summary of the Model's Equations

The demand side of the model is captured by an aggregate demand curve which models real non-farm output as depending on past real interest rates, real foreign output – proxied by US GDP – the real trade-weighted exchange rate and the terms of trade. The equation also allows for the dynamic impact of farm output on non-farm output. Estimates of the equation imply that a sustained one percentage point increase in the real interest rate eventually causes a 0.81 percentage point cumulative detraction from the level of output. When the real interest rate returns to its policy-neutral level – which we set at 3½ per cent – output eventually returns

---

[4] A more rigorous approach, beyond the scope of this paper, which addresses the various forms of uncertainty which face policy-makers in practice, is also discussed briefly in Section 4.1.

to its long-run path, implying that monetary policy has no permanent effect on the level of real output.

Following on from the discussion in Section 2.1, we model both aggregate and non-tradeable *underlying* inflation as mark-ups over costs, domestic and imported.[5] Domestic costs are represented by unit labour costs in the non-tradeable sector while imported costs are represented by import prices. As expected, the relative importance of import prices is found to be much lower in the non-tradeable inflation equation because in that equation import prices reflect only the costs of imported intermediate inputs. The presence of import prices in the aggregate inflation equation reflects the cost of both imported intermediate inputs and the direct effect of imported final consumption goods prices. In each case, the retail mark-up on costs is also affected in the short run by an output gap – the difference between actual and potential output – which captures the changing mark-up over the cycle.

Nominal unit labour costs in the non-tradeable sector are modelled as a Phillips curve relationship, being determined by expected inflation and the lagged level of excess labour demand, proxied by the output gap. The use of an *aggregate* output gap (rather than an output gap for the non-tradeable sector) reflects our assumption that labour flows freely between the two sectors. A 'speed-limit' term (the lagged *change* in the output gap) is also included, consistent with previous evidence for Australia.[6]

Expected inflation is proxied by average *past* aggregate inflation. Our appeal, as always, was to data consistency, which, for Australia, generally does not sit

---

[5] For the purposes of estimation, non-tradeable inflation was constructed by eliminating from the aggregate underlying CPI those sectoral components for which exports or import-competing production account for at least 10 per cent of total sectoral production. This disaggregation of the aggregate price series into tradeable and non-tradeable components follows the classification scheme originally used by Dwyer (1992). See Appendix A in Bharucha and Kent (1998) for further details on the measurement of non-tradeable inflation.

[6] The empirical fit of this unit labour cost equation is quite poor. Despite the importance of unit labour costs to inflation outcomes, the difficulty of modelling unit labour costs has, in the past, prompted attempts to develop models of inflation which exclude unit labour costs. One such empirically successful approach is to model price inflation directly in an expectations-augmented Phillips curve – ignoring unit labour costs completely. For example, see Gruen, Pagan and Thompson (1999).

favourably with rational (forward-looking) inflation expectations.[7] Note that backward-looking expectations also generate greater persistence in the response of inflation to shocks than does rational expectations, implying greater variability in output and inflation than otherwise for the results presented in Section 4.

The use of aggregate inflation for measuring inflation expectations assumes significant wage bargaining power on the part of employees who are concerned with maintaining their real consumption wage. We return to the assumptions regarding the role of *aggregate* inflation and output in the determination of unit labour costs in Section 4.

The sum of the coefficients on lagged inflation was restricted to equal one, implying that the unit labour cost Phillips curve is vertical in the long run and that all shocks to inflation are permanent since they feed through entirely to unit labour costs and, hence, back into prices (the coefficients on lagged inflation are also restricted to be equal to each other in order to avoid an implausibly volatile response of nominal unit labour costs to changes in prices).

Following Dwyer *et al* (1994), the domestic-currency ('over-the-docks') price of imports is determined by world prices converted to domestic currency using a nominal effective (G7 GNP-weighted) exchange rate. Dynamics are included to reflect the differing speeds of pass-through of changes in world prices and the exchange rate. Long-run pass-through is found to be complete.

The real effective (trade-weighted) exchange rate is modelled as having two 'fundamental' determinants: the terms of trade and the short-term real interest-rate differential between Australia and the rest of the world. A standard, forward-looking international interest-rate arbitrage condition is conspicuous in its absence but has repeatedly failed to replicate the observed behaviour of the Australian dollar. Instead, a lagged real interest-rate differential has consistently proved more successful (see, for example, Blundell-Wignall, Fahrer and Heath (1993) and Tarditi (1996)). Given that the link between the exchange rate

---

[7] We experimented with forward-looking inflation expectations – derived, for example, from the difference between nominal and indexed (real) bond yields – but were unable to find a significant influence for them. Gruen, Pagan and Thompson (1999) estimated a low weight – around 10 per cent or less – on forward-looking inflation expectations in their more fully specified Phillips curve equations.

and monetary policy is important to the central issue addressed by this paper, we later experiment with modifications to this relationship.

Although empirically the nominal *G7 GNP-weighted* exchange rate works best for estimating import prices in Australia, while the real *trade-weighted* exchange rate works best for estimating Australian output, we treat them as equivalent in the simulations. That is, we define changes in the nominal exchange rate as being equal to changes in the real exchange rate adjusted for the domestic–foreign inflation differential. This also facilitates a link between the real interest rate and domestic inflation via the nominal exchange rate.

The real interest rate is defined as being equal to the nominal interest rate less expected inflation, which we assume to be equal to lagged *aggregate* inflation.

For the purposes of the stochastic simulations, the exogenous variables in the model (foreign output, terms of trade, farm output, world prices and the world short-term real interest rate) were modelled using simple trend-correcting or autoregressive mechanisms. Appendix B contains the empirical estimates of each of these equations.

The final piece of the model concerns the determination of the nominal interest rate (the monetary policy instrument). As we discussed earlier, our approach is to model monetary policy as following an explicit monetary policy rule. Equation (7) showed the general form of the monetary policy rules which we use in this paper. In Section 4 we show the results of simulating the model under different specifications (and parameterisations) of this monetary-policy rule. Comparing the variability of the simulated outcomes for aggregate inflation and the output gap (and the other endogenous variables) then allows us to determine which rules are preferable.

3.2 Steady State of the Model

The steady state of the model relies upon our arbitrary prescription of a neutral (equilibrium) real interest rate of 3½ per cent. The difference between this and the long-term average of the world real interest rate can then be treated as a constant risk premium. Given steady farm output growth and a constant real interest rate and terms of trade (implying a constant real exchange rate), real equilibrium in this model is characterised by potential and actual output growing by around 3½ per cent per annum. See Appendices A and B for discussion on the measurement and simulation treatment of potential output.

The inflation target embedded in the monetary-policy rule acts as the nominal anchor and brings about nominal equilibrium in the model. This is characterised by domestic and foreign inflation and, because the output gap is closed in equilibrium, unit labour costs all growing at 2½ per cent per annum. The equilibrium nominal interest rate is 6 per cent.

If productivity in the tradeable sector is higher than productivity in the non-tradeable sector but wages growth is the same, non-tradeable price inflation will be higher than aggregate price inflation in equilibrium.[8] Import price inflation, in turn, will be lower than aggregate price inflation, reflecting the lower prices of higher-productivity tradeable goods that we import. However, for simplicity, we assume that all prices (domestic and foreign) and unit labour costs grow at the same rate in the steady state. While unrealistic, this assumption is likely to have only minor implications for the model's dynamic properties which are the focus of our attention.

3.3 Transmission Channels of Monetary Policy in the Model

Despite its simplicity, the model still captures the two usual channels of monetary-policy transmission in an open economy.

First, there is a conventional 'aggregate demand' channel, whereby real interest rates affect output – implicitly investment and other interest-sensitive components of output – with a lag. The output gap then affects price inflation *directly*, by changing the size of the mark-up in the two price equations, and *indirectly*, through the unit labour cost Phillips curve equation. Associated with this, there is an 'expectations' channel. With backward-looking inflation expectations, any change in monetary policy which influences actual inflation will also change inflation expectations which, in turn, affects wages and then prices. Second, monetary

---

[8] Consistent with this, regressions of aggregate prices on *aggregate* unit labour costs (and other variables) generally find a significant role for a time trend.

policy affects the exchange rate, which in turn affects inflation *directly*, by changing the domestic-currency price of imports, and *indirectly*, by changing the relative demand for foreign and domestic output.

The *relative* timing of the effect of monetary policy through each of these channels is consistent with most other open-economy models. An increase in interest rates takes two periods to reduce aggregate inflation through the exchange-rate channel – one period to affect the exchange rate and a further period for the exchange rate to affect prices. In contrast, an increase in the interest rate takes three periods to reduce inflation through the aggregate demand channel – two periods to reduce output and a further period for output to affect prices. Non-tradeable inflation, which excludes movements in the prices of imported final consumption goods, is less sensitive to the direct exchange rate channel.

3.4 Summarising the Model's Dynamic Properties

In order to preview the model's dynamic properties, we generated the dynamic impulse response of each of the endogenous variables to a once-off depreciation in the level of the real exchange rate of 10 per cent. All other shocks, including subsequent shocks to the exchange rate, were set to zero for the entire simulation period.

For the purposes of this experiment, we also assumed that the parameters of the monetary-policy rule (Equation (7)) were $f = 3$, ψ_1 and $\psi_2 = 3$, $\lambda = 0$ and $\Pi = aggregate$ inflation. This particular choice of reaction coefficients yields outcomes that, though not on the efficient frontier of output and inflation variability derived from stochastic simulations of the model with the three-period-ahead forecast monetary-policy rule, generate fairly plausible variability in the nominal interest rate.

Figure 3 summarises the model's dynamic properties by tracing out the impulse response of each of the endogenous variables to the temporary exchange rate shock. The responses are measured as per cent deviations from baseline (steady-state) values. Inflation and growth in unit labour costs and import prices are measured as deviations from baseline in year-ended percentage change terms.

The real exchange rate shock coincides with an equal sized depreciation of the nominal exchange rate, which, via import prices, begins to drive up aggregate inflation almost immediately. The favourable relative price shift also encourages demand for net exports (assuming the terms of trade remains constant) which translates into higher output. Consistent with the policy rule, the nominal (and real) interest rate rises immediately, driven by higher inflation and output gap forecasts. This monetary policy tightening helps reverse the initial depreciation. Given the lags of monetary policy, though, the policy response does not start to have any significant impact on output and inflation until around three quarters into the simulation.

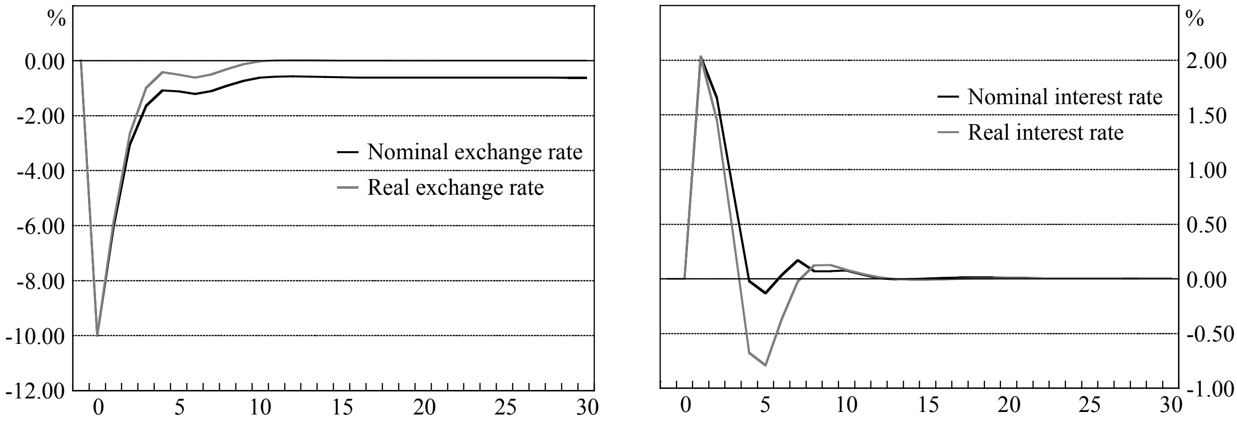
Panel (c) shows the different response of aggregate and non-tradeable inflation to the exchange rate shock. The exchange rate depreciation feeds into aggregate inflation much sooner. This reflects the impact of the exchange rate on the prices of imported final consumption goods and services, an effect excluded from non-tradeable inflation. The exchange rate depreciation does eventually show up in non-tradeable inflation, but the peak is lower than for aggregate inflation. Ultimately, the policy response brings both measures of inflation back to target. Aggregate inflation returns somewhat quicker owing to its higher long-run speed of adjustment coefficient.

Repeating this experiment with a monetary-policy rule that responds to the deviation of non-tradeable (rather than aggregate) inflation from target invokes a smaller initial policy response. This is seen in Figure 4, which compares impulse responses under the two different specifications of the monetary-policy rule. The response of non-tradeable inflation to the exchange rate shock was lower than the response of aggregate inflation, so the initial policy move under the non-tradeable inflation rule is smaller (Panel (b)). In this case, because policy does less to offset the stimulatory effect of the exchange rate depreciation on output (Panel (d)), the peak of the aggregate and non-tradeable inflation cycles is actually slightly higher under the non-tradeable inflation rule (Panel (c)). While the initial response is lower, policy under the non-tradeable inflation rule later remains tighter, for longer, in order to offset the higher inflation and output gap.

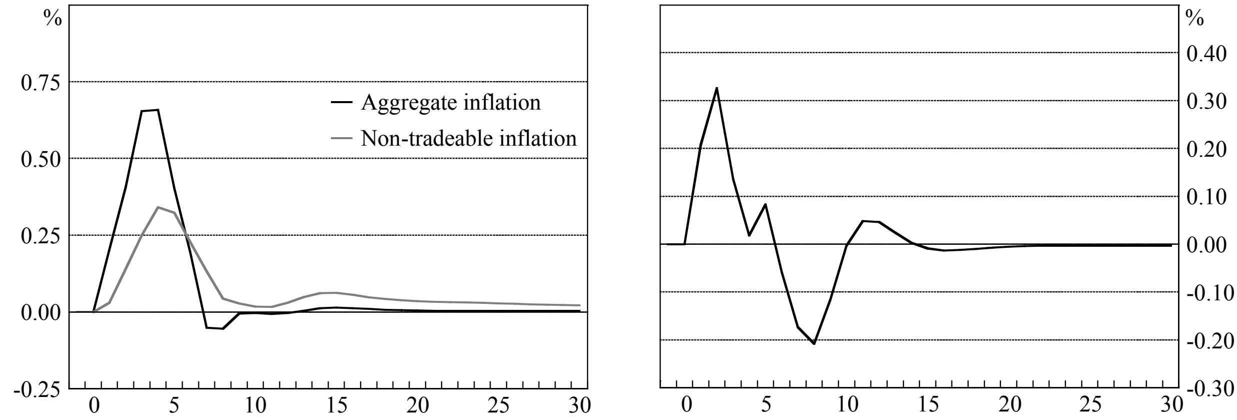
Figure 3: Impulse Responses to Exchange Rate Shock (Aggregate Inflation Rule)

Deviations from equilibrium, per cent

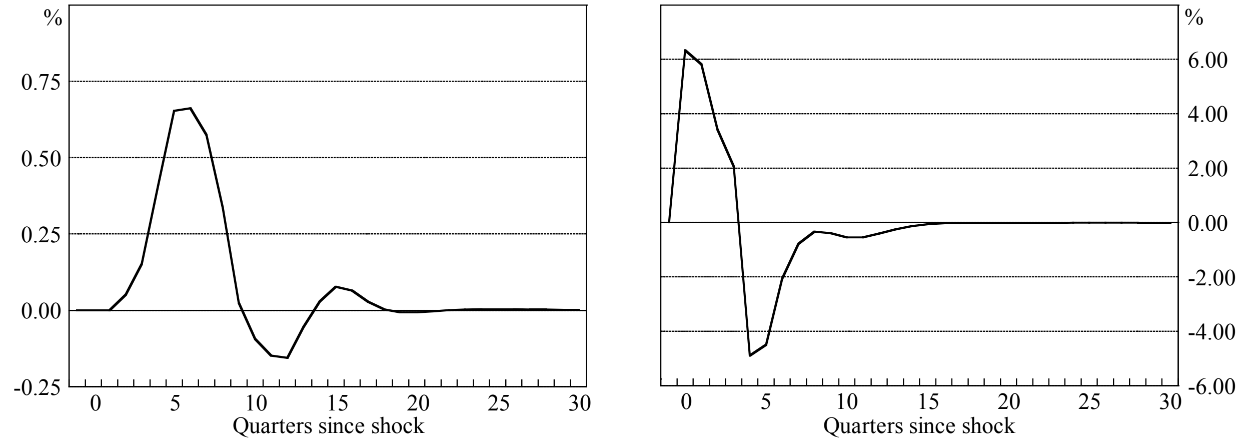
(a) Exchange rates (b) Interest rates



(c) Inflation (d) Output



(e) Unit labour cost growth (f) Import price growth



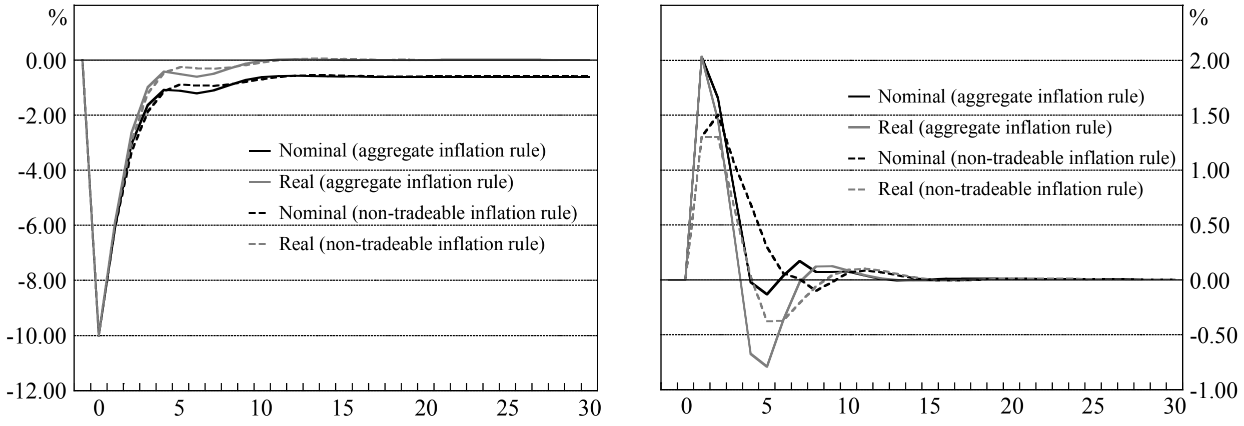
For a temporary exchange rate shock, the results in Figure 4 show that a monetary-policy rule in which the interest rate responds to non-tradeable inflation (rather than aggregate inflation) can actually induce greater conditional variability in output. Whether such a rule would reduce the unconditional variability of output in a stochastic simulation (where all shocks are operating) is the empirical issue addressed in the next section.

Figure 4: Impulse Responses Under Different Policy Rules

Deviations from equilibrium, per cent

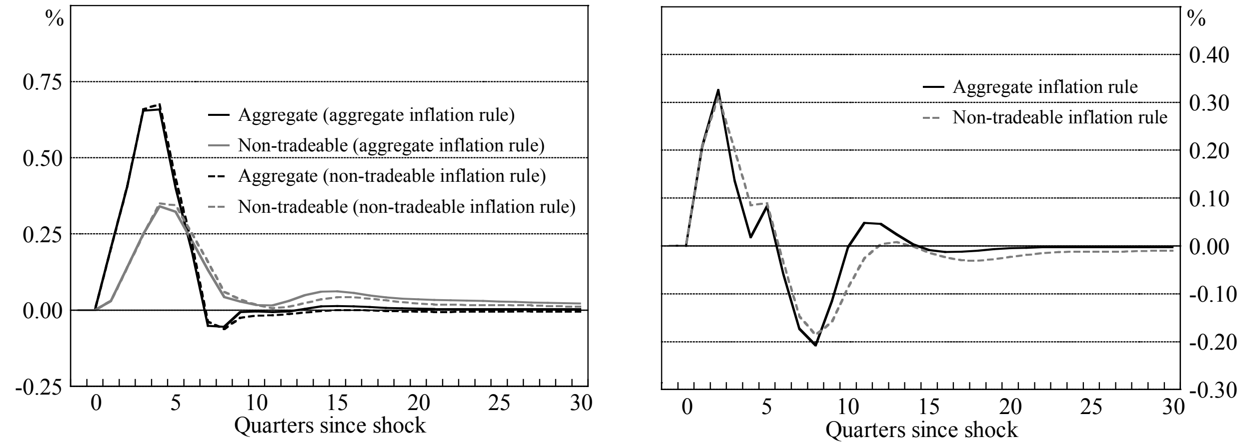
(a) Exchange rates

(b) Interest rates



(c) Inflation

(d) Output



4. Empirical Results of Stochastic Simulations

In this section we compare the stabilising properties of various specifications of a monetary-policy rule in stochastic simulations of the model described in Section 3.[9] Alternative specifications of the monetary-policy rule are compared according to their ability to minimise the variability (standard deviation) of selected macroeconomic variables, typically inflation and the output gap. In what follows, we define an 'efficient' policy rule as one that minimises the variability of four-quarter-ended *aggregate* inflation – the measure of inflation that the central bank ultimately aims to control – for given variability of the output gap, and vice versa. A 'constrained-efficient' or 'feasible' policy rule is defined as one which is efficient for given interest rate variability.

Before addressing the main question of the paper, we first examine (in Section 4.1) some properties of the typical monetary-policy rule based on aggregate inflation. In line with recent literature, we explore the possibility that rules which respond to forecasts of the feedback variables perform better than those which respond only to their lagged values. From this we determine the 'optimal' forecast horizon and then address the issue of excessive interest rate variability which tends to be generated by most policy rules.

In Sections 4.2 and 4.3 we take these results a step further by examining whether or not monetary-policy rules which respond to forecasts of non-tradeable inflation or growth in non-tradeable unit labour costs are better able to stabilise the economy than rules which respond to forecasts of aggregate inflation. Section 4.4 discusses these results.

---

[9] For each specification of the policy rule, the model is solved over 100 periods, with a new random draw of shocks imposed on the economy each period. The distribution of these shocks was based on the distribution of the residuals from the estimated equations in the model. In this way, our stochastic simulations embody the actual historical correlations of shocks that buffeted the economy over the period from 1985 to 1998. The properties of the shocks and the procedure for generating the stochastic simulations is described in more detail in Appendix C.

4.1 Properties of Efficient Rules Based on Aggregate Inflation

As in previous Australian studies, we allow for the possibility that forecasts of the output gap, in addition to inflation forecasts, could help improve the stabilising properties of these monetary-policy rules.[10] Including forecasts of the output gap ($\psi_2 > 0$), and restricting ourselves to the same forecast horizons for both output and inflation, means that we are implicitly allowing policy to respond to information about future inflation *beyond* the horizon of the inflation forecast (that is, beyond f quarters). This is because forecasts of the output gap contain information regarding future inflation.

For Australia, de Brouwer and O’Regan (1997) found that, relative to a (non-forward-looking) Taylor rule, output and inflation variability could be improved by policy rules that included forecasts of the target variables up to two quarters ahead. When the forecast horizon was extended much beyond this, however, forward-looking rules tended to deliver worse outcomes. As noted by the paper’s discussant (Macklem 1997), the forecasts which enter de Brouwer and O’Regan’s forward-looking policy rules were conditional on the assumption of a constant nominal cash rate (which they called ‘no-policy-change forecasts’). This assumption is less appropriate the longer the forecast horizon, partly explaining why the optimal forecast horizon was only two quarters.

de Brouwer and Ellis (1998) investigated forward-looking rules for Australia in which forecasts of the target variables were conditional on the assumption that the policy-maker actively applies the same policy rule (as opposed to the same nominal interest rate) over the forecast horizon. Using this approach, they found that the optimal forecast horizon was around one year. de Brouwer and Ellis’ use of model consistent forecasts provides a more realistic characterisation of actual policy because they allow for the effect of the appropriate future policy on forecast values. It is not consistent for a policy-maker to knowingly set interest rates today with a rule that uses forecasts based on inappropriate future policy. The

---

[10] The usual practice in evaluating forward-looking rules is to test whether the addition of *current* output to an inflation forecast rule improves outcomes (see, for example, Batini and Haldane (1999) and Black, Macklem and Rose (1997)). Typically, the improvement is slight. Batini and Haldane argue that inflation-forecast-only rules are already able to smooth output because they recognise the importance of output to future inflation – that is, they are already ‘output encompassing’.

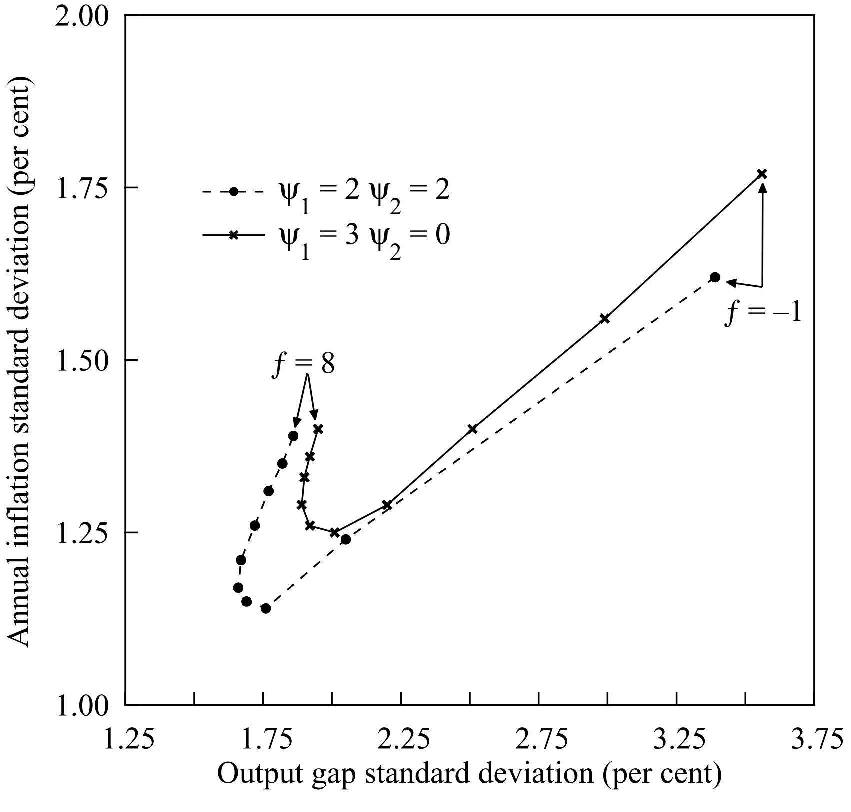
forward-looking policy rules in this paper use forecasts of the feedback variables which are fully model consistent.

Figure 5 shows the variability of output and inflation calculated from simulations of our model where the forecast horizon (f) in Equation (7) was increased from -1 to 8 (assuming $\lambda = 0$).

As Figure 5 shows, backward-looking rules ($f = -1$) are clearly inferior. For $\psi_1 = \psi_2 = 2$, the 'best' forecast horizon is around 2 to 3 quarters, depending on the (unspecified) preferences of the policy-maker. This accords with the control lag of policy in this model – it takes two quarters before a policy tightening begins to reduce inflation through the 'exchange rate' channel and three quarters through the 'aggregate demand' channel. Consistent with existing evidence on forward-looking rules, there is also a limit to how forward-looking the policy rule can be before it begins to generate worse outcomes. At longer horizons, unforeseen shocks can drive actual outcomes a long way from the forecasts, so that in the current period, policy is responding to relatively poor forecasts.

Figure 5: Inflation-Output Variability for Different Forecast Horizons

$\psi_1 = \psi_2 = 2$, $\psi_1 = 3$ and $\psi_2 = 0$



For $\psi_1 = 3$ and $\psi_2 = 0$, corresponding to an inflation-forecast only rule, the optimal length for the forecast horizon is between 3 and 5 quarters. The position of this frontier relative to the $\psi_1 = \psi_2 = 2$ frontier also indicates that excluding the output gap from the rule results in inferior outcomes.

Experiments with a range of different reaction weights revealed that the optimal forecast horizon was generally longer the lower the ratio of ψ_2 to ψ_1. A lower relative weight on output means that the policy-maker gets less 'headstart' in controlling inflation (given that the output gap helps forecast inflation at least two periods further ahead) and consequently, the optimal forecast horizon is longer to compensate for this.

We take up the question of interest rate variability shortly, but it is worth noting here that for *given reaction weights*, interest rate variability is decreasing in f. The policy rule delivers a path for the nominal interest rate that returns the economy to equilibrium in the assumed absence of future shocks. With model consistent forecasts, applying the policy rule with a longer forecast horizon implies the economy is expected to be closer to equilibrium. Accordingly, as f increases, the interest rate moves by less for given reaction coefficients.

Figure 6 shows the efficient policy frontiers corresponding to different forecast horizons (still with no smoothing) in the benchmark policy rule.[11] For each forecast horizon, the efficient frontier was derived by simulating the model for a range of reaction weights in the benchmark policy rule and selecting only those rules which minimised the variability of inflation for given variability in the output gap (or vice versa). The efficient frontiers for $f = 3$ and $f = 4$ generally dominate each of the other forecast horizons – increasing the forecast horizon in the benchmark policy rule beyond four periods results in worse outcomes.

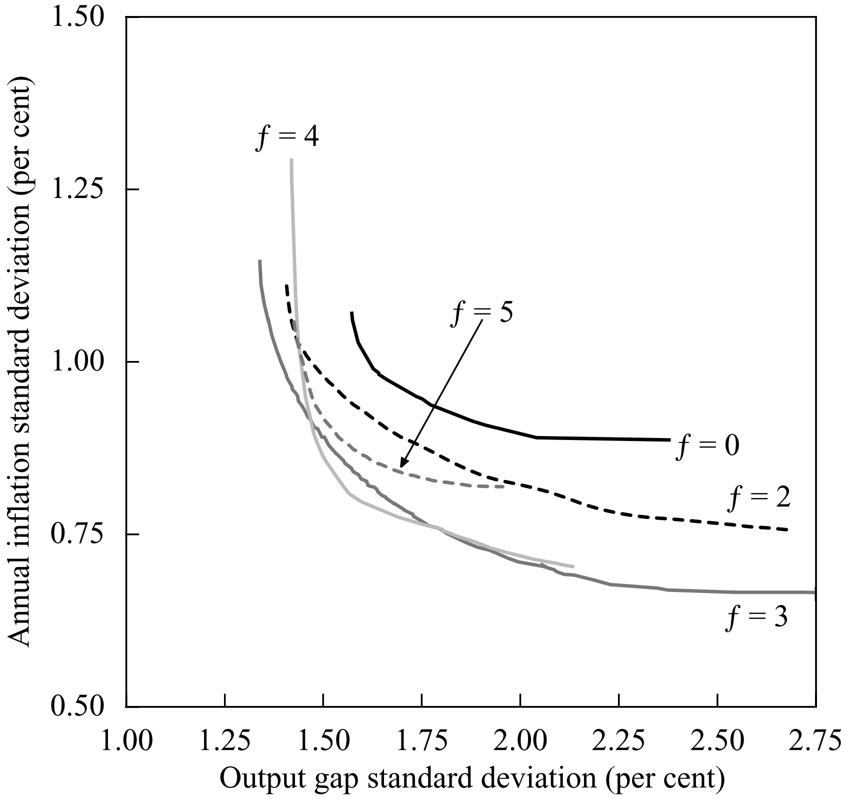
The results so far indicate that most forward-looking policy rules produce better outcomes than backward-looking rules. However, the apparent 'efficiency' of such rules belies a serious problem.

---

[11] The 'bumps' in the efficient frontiers reflect the fact that we have not searched over a sufficiently fine grid of reaction weights to generate the typically smooth convex curves.

Figure 6: Efficient Frontiers for Rules with Different Forecast Horizons

$\lambda = 0$



The solid line in Figure 7 corresponds to the $f = 3$ efficient frontier in Figure 6. Along this frontier we have isolated a representative sample of efficient rules labelled ‘A’ to ‘G’. The reaction weights and performance of the (model) economy under each of these rules are summarised in Table 1.

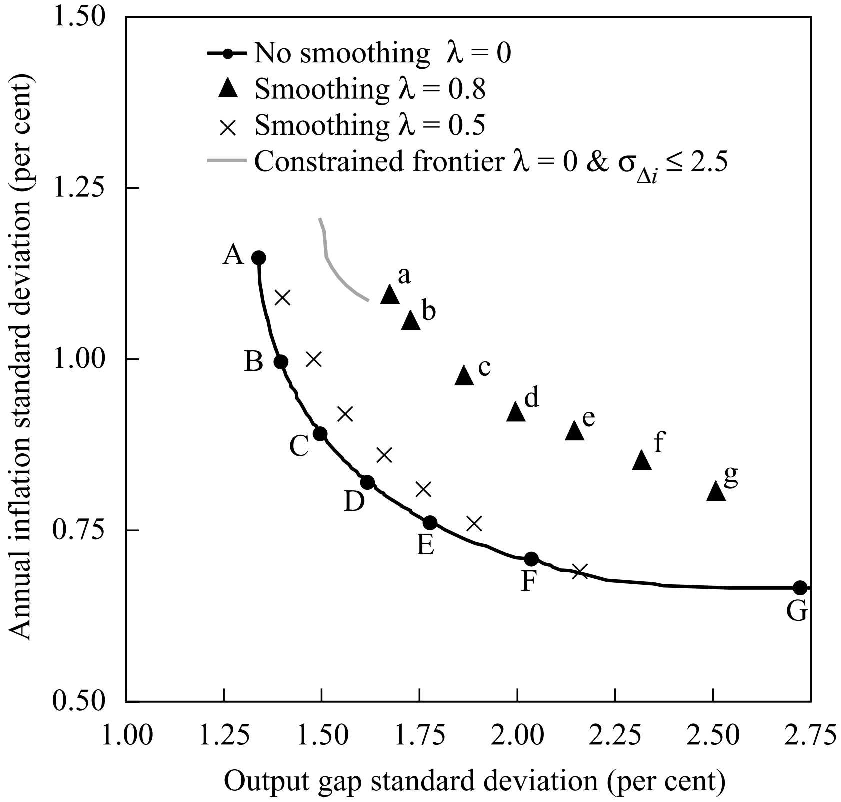
Moving along the efficient frontier from ‘A’ to ‘G’ in Figure 7, the weight on inflation (ψ_1) relative to output (ψ_2) in each of the rules increases and the variability of inflation is gradually decreased. These efficient weights, however, are much larger than the weights typically associated with policy rules.[12] Consistent with this, all of the efficient rules (especially those at either end of the frontier) generate extremely high variability of quarterly changes in the nominal interest rate. This variability is such that the nominal interest rate is negative

---

[12] The original Taylor (1993) rule, for example, had weights of 0.5 on lagged inflation and 0.5 on the lagged output gap. In their forward-looking Taylor rule, Clarida, Galí and Gertler (2000) estimated reaction weights for the US of a similar order of magnitude to Taylor’s original weights.

almost as often as it is positive. (The simulations allow nominal interest rates to be negative, even though this cannot occur in practice.)

Figure 7: Efficient and Feasible Frontiers for 3-period-ahead Forecast Rules



A number of recent studies have attempted to reconcile the finding of high interest rate variability implied by most economic models with the much lower interest rate variability typically seen in practice. One explanation is that economic models ignore various forms of uncertainty which might, in practice, make monetary policy less activist following most types of shocks. The growing literature on the implications of uncertainty for monetary policy is summarised by Batini, Martin and Salmon (1999), Armour and Côté (2000) and Apel *et al* (1999). Shuetrim and Thompson (1999) and Debelle and Cagliarini (2000) examine the implications of uncertainty for monetary policy in an Australian context.

Table 1: Properties of Efficient 3-period-ahead Forecast Rules with No Smoothing

$\lambda = 0$

	ψ_1	ψ_2	Unconditional standard deviation Per cent π^A	π^{NT}	$y - y^P$	Δi	rer	ρ
A	8	20	1.15	1.01	1.34	12.64	10.09	0.54
B	12	12	1.00	0.93	1.40	7.75	8.03	0.43
C	22	10	0.89	0.85	1.50	9.06	7.84	0.33
D	30	8	0.82	0.82	1.62	10.20	7.68	0.19
E	38	6	0.76	0.81	1.78	11.98	7.63	0.00
F	50	4	0.71	0.81	2.04	16.22	7.78	–0.28
G	80	0	0.67	0.83	2.72	33.54	9.02	–0.70

Note: ρ is the first autocorrelation coefficient of Δi.

While we do not deal with these issues here, we acknowledge that our model ignores a number of sources of uncertainty which the policy-maker faces in practice. This encouraged us to explore various ways of resolving the issue of excessive interest rate variability.

As a first attempt to redress the problem, we investigated specifications of the policy rule with a positive smoothing parameter ($\lambda > 0$). There are a number of practical issues associated with imposing a value for λ greater than zero in Equation (7). From the point of view of trying to reduce variability in the nominal interest rate, searching over a range of reaction weights for the efficient frontier with positive smoothing is futile. This is because the new efficient weights will be higher than the no-smoothing case in order to offset the effect of the smoothing.

Alternatively, it is possible to map out a new frontier using a set of reaction weights equal to the no-smoothing efficient weights and then applying a smoothing parameter greater than zero. Conceptually, this is equivalent to multiplying the no-smoothing efficient reaction weights by the smoothing parameter.

Figure 7 shows the result of applying a smoothing factor of $\lambda = 0.5$ and $\lambda = 0.8$ to the set of efficient reaction weights in Table 1.[13] The set of rules labelled (lowercase) 'a' to 'g', for example, use the same reaction weights as the corresponding (uppercase) rules 'A' to 'G' in Table 1, but with the smoothing parameter $\lambda = 0.8$. As must be the case when an additional constraint is placed on the model, the new policy frontier with positive smoothing is further from the origin. However, Table 2, which summarises the performance of the economy under each of these rules, shows that the reduction in interest rate variability is nowhere near enough, even with a smoothing factor of $\lambda = 0.8$. Relative to the equivalent no-smoothing rules in Table 1, the *serial correlation* of changes in the interest rate is higher for the rules in Table 2.

Table 2: Properties of Efficient 3-period-ahead Forecast Rules with Smoothing

$\lambda = 0.8$

	ψ_1	ψ_2	Unconditional standard deviation					ρ
			Per cent					
			π^A	π^{NT}	$y - y^P$	Δi	rer	
a	8	20	1.10	1.11	1.66	3.62	7.65	0.66
b	12	12	1.06	1.07	1.70	3.19	7.18	0.68
c	22	10	0.97	1.04	1.82	4.05	7.20	0.66
d	30	8	0.92	1.04	1.95	4.76	7.33	0.64
e	38	6	0.88	1.06	2.10	5.51	7.57	0.62
f	50	4	0.84	1.07	2.26	6.63	8.08	0.59
g	80	0	0.79	1.08	2.46	9.07	9.14	0.50

Note: ρ is the first autocorrelation coefficient of Δi.

While the serial correlation of quarterly changes in the interest rate is higher for the rules in Table 2 (compared with Table 1), the variability of interest rates is still too

---

[13] A smoothing parameter of $\lambda = 0.5$ is in line with what Batini and Haldane (1999) considered appropriate for the UK and a little lower than the smoothing parameter which Smets (1997) estimated for Australia.

high and consequently we abandoned further efforts with non-zero smoothing parameters.

Our alternative, and inevitably successful, way of limiting interest rate variability was to search over the entire grid of reaction weights – both on and off the efficient frontier – for the set of rules which deliver arbitrarily low variability of the interest rate. Specifically, we searched for the ‘feasible’ frontier of rules which generated a standard deviation of changes in the interest rate no greater than 2½ percentage points. Admittedly, this variability is still high by historical standards, but in simulations these rules rarely resulted in negative nominal interest rates.[14] Unreported results also indicated that the most efficient ‘feasible’ frontier still corresponded to $f = 3$.

The solid grey line in Figure 7 is the constrained efficient frontier for $f = 3$. The magnitude of the loss associated with these feasible rules (around one quarter of a percentage point increase in the standard deviation of either inflation or output) is quite small, given the significant reduction in interest rate variability. Consistent with this, the reaction weights are now much lower. This result echoes the finding of Lowe and Ellis (1997) for Australia that, in the context of optimal policy, moderate interest rate smoothing (and stabilisation) does not come at great cost in terms of output and inflation variability.

Compared with the unconstrained frontier, however, the feasible frontier is severely truncated. The range of efficient outcomes decreases as the constraint on interest rate variability is tightened. Moreover, unlike the unconstrained frontier, the feasible frontier is less convex. The truncation also applies more to inflation variability than to output variability because low inflation variability requires

---

[14] The variance of the *change* in a variable is roughly equal to $2(1-\rho)$ multiplied by the variance in the level, where ρ is defined as the first autocorrelation coefficient of the levels. In simulations the first autocorrelation coefficient of the level of the nominal interest rate was around 0.7 – lower than the actual historical value of around 0.9. A standard deviation of 2½ percentage points on the change in the nominal interest rate therefore translates into a standard deviation of just over 3 percentage points in the level of the nominal interest rate. This is still a bit high but in a representative simulation (with an inflation target of 2½ and neutral real interest rate of 3½) the nominal interest rate was negative only 4 per cent of the time.

strong reactions to movements in the exchange rate. Output, on the other hand, is a lot less sensitive to the exchange rate. Put another way, a bigger increase in interest rate variability is needed to 'buy' a given decrease in inflation variability than the same decrease in output variability.

The results so far have indicated that policy rules which include forecasts of the feedback variables tend to produce better outcomes than those that respond only to lagged values. These rules, however, tend to generate an inordinate amount of interest rate volatility. One solution to this problem is to constrain the rules to a feasible level of interest rate variability. Such a constraint tends to worsen outcomes in terms of inflation and output variability. We build on these foundations to explore further modifications to the benchmark policy rule in the next section. In particular, we investigate whether or not the constraint on interest rate variability is less deleterious when the monetary-policy rule uses a measure of inflation which is less sensitive to exchange rate fluctuations.

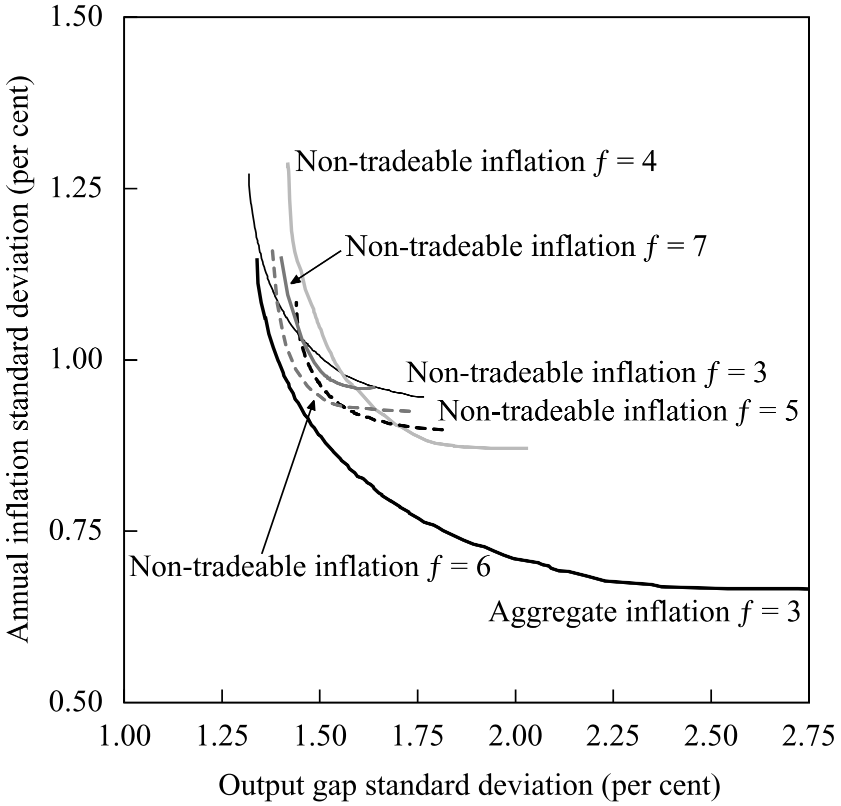
4.2 Different Measures of Inflation in the Policy Rule

We first substitute *non-tradeable* inflation for aggregate inflation in the benchmark policy rule. Notwithstanding the fact that these rules can still include the output gap, we refer to them as 'non-tradeable inflation rules'. As we showed earlier, such a measure of inflation is less susceptible to the direct effect of temporary exchange rate shocks because it excludes the prices of imported final consumption goods and services. But the exchange rate still affects non-tradeable inflation through the prices of imported intermediate imports. Recall also that our specification of the unit labour cost Phillips curve with inflation expectations proxied by past *aggregate* inflation means that exchange rate shocks can feed into inflation expectations and hence, into wages and inflation in the non-tradeable sector.

Figure 8 compares the efficient frontier for three-period-ahead aggregate inflation rules (from before) with those generated from policy rules that respond to forecasts of non-tradeable inflation (and the output gap) at various horizons. At this point, we compare frontiers without any restriction on interest rate variability. Note also that, which ever measure of inflation the central bank responds to, it is aggregate inflation and output gap variability that it is assumed to care about.

Depending on the (unspecified) preferences of the policy-maker, the optimal forecast horizon for the unconstrained non-tradeable inflation rules can be between three and six quarters. A central bank which cared a lot about aggregate inflation variability, for example, would be better served by following a non-tradeable inflation rule with a four-quarter forecast horizon ($f = 4$). In this case, because the central bank cares more about aggregate inflation variability than output gap variability, but responds to non-tradeable inflation (which policy takes longer to affect through the exchange rate channel) then it makes sense to adopt a longer forecast horizon. This contrasts with Figure 6, where under an aggregate inflation rule, the optimal forecast horizon for a central bank which cared most about aggregate inflation variability was three periods.

Figure 8: Efficient Frontiers for Forecast Rules which Respond to Aggregate and Non-tradeable Inflation

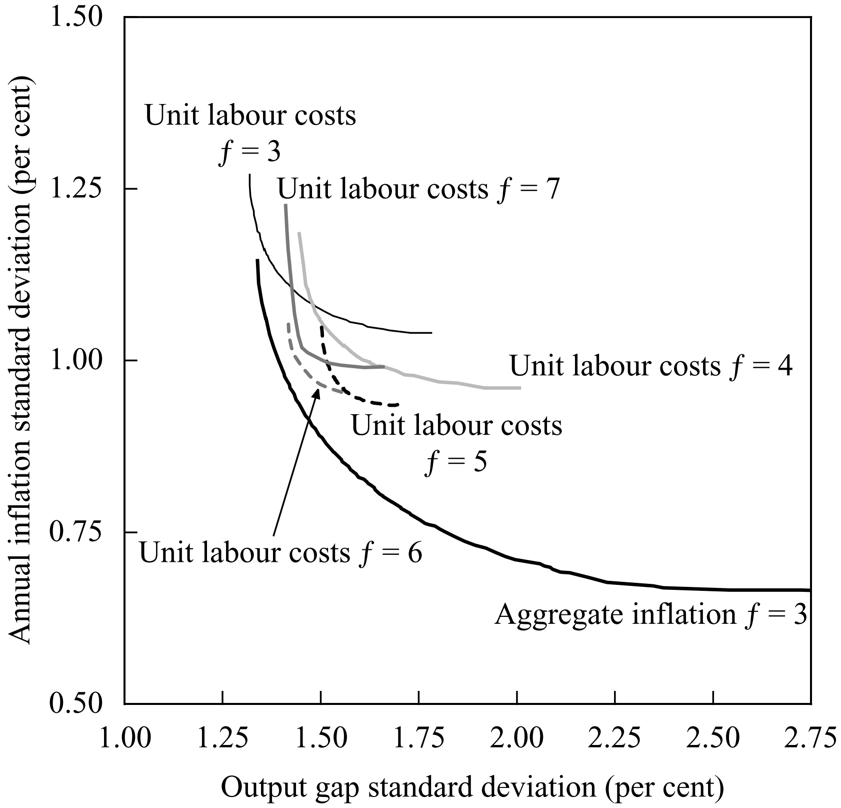


Despite all this, Figure 8 shows that none of the efficient frontiers for non-tradeable inflation rules (regardless of forecast horizon) dominates the efficient frontier for the benchmark aggregate inflation rule with $f = 3$. Responding to a measure of inflation that abstracts from temporary exchange rate movements appears to buy little in terms of output and aggregate inflation variability, at least given our model and the shocks that have typically hit the Australian economy.

According to Equation (A3), non-tradeable inflation is almost entirely determined by domestic labour costs – the estimated long-run elasticity of non-tradeable prices with respect to unit labour costs is 0.915 (compared with an elasticity of 0.568 for aggregate prices). This motivates our next modification to the benchmark policy rule – changing the measure of inflation to growth of unit labour costs in the non-tradeable sector. In these rules, which we refer to as 'unit labour cost growth rules', the interest rate responds to the forecast deviation of unit labour cost growth from target (also assumed to be 2½ per cent per annum – see Section 3.2) and forecasts of the output gap.

Figure 9 compares the efficient frontier for three-period-ahead aggregate inflation rules (our benchmark) with those generated from unit labour cost growth rules of various forecast horizons (still with no constraint on interest rate variability).

Figure 9: Efficient Frontiers for Forecast Rules which Respond to Aggregate Inflation and Growth in Unit Labour Costs

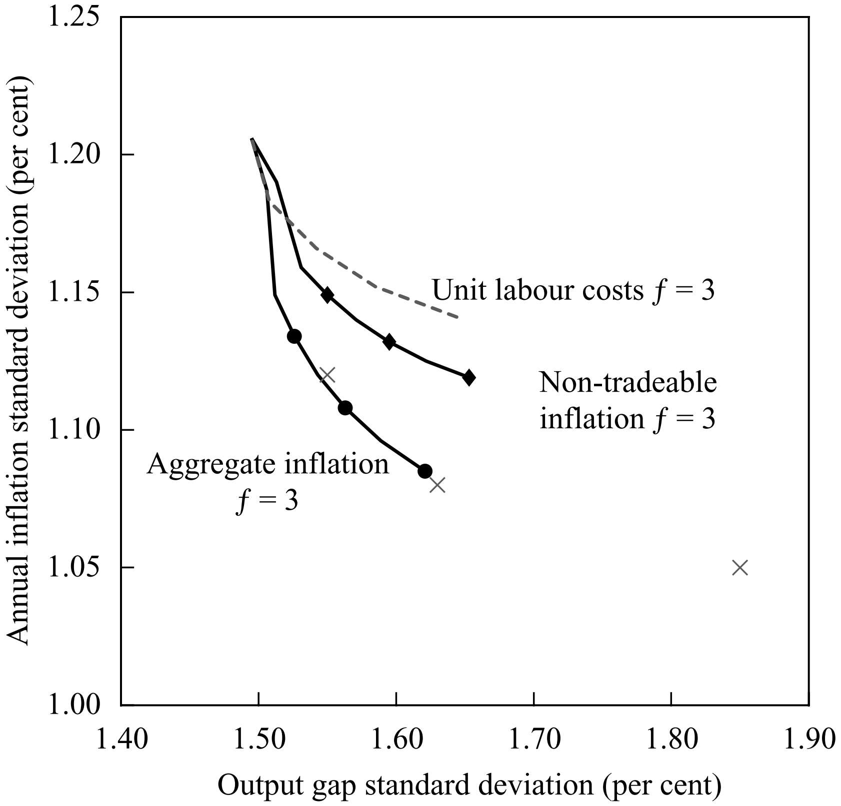


The optimal forecast horizon for the unconstrained unit labour cost growth rules is around five to six quarters. More importantly, there still do not appear to be any gains from making policy respond to the growth of non-tradeable sector unit labour costs rather than aggregate inflation – the benchmark $f = 3$ efficient frontier for aggregate inflation rules dominates the efficient frontiers for unit labour cost growth rules at all forecast horizons.

4.3 Comparing Feasible Frontiers for Policy Rules

The efficient frontiers for non-tradeable inflation and unit labour cost growth rules shown in Figures 8 and 9 suffer from somewhat less interest rate variability than those implied by the aggregate inflation rule, but this variability is still extremely high. As in Section 4.1, our solution to this problem was to constrain the rules to those which generated a standard deviation no greater than 2½ percentage points in changes in the nominal interest rate. Figure 10 shows the set of constrained frontiers for each of the three-period-ahead forecast rules that we have considered.

Figure 10: Feasible Frontiers for 3-period-ahead Forecast Rules



The efficient rule at the north-west extreme of each constrained frontier corresponds to a rule which only has reaction weight on output ($\psi_1 = 0$ and $\psi_2 > 0$). This explains why the efficient frontiers converge at this point irrespective of the inflation measure used in the rule.[15] The reaction weights corresponding to rules along the feasible frontiers are a lot smaller than those which characterise the efficient frontier when there is no constraint on interest rate variability. In order to generate lower interest rate variability, these rules specify that the interest rate responds by less for a given deviation of inflation from target (or output gap) than would be the case on the unconstrained efficient frontier.

Table 3 summarises the stochastic behaviour of the economy using three different sets of reaction weights. These reaction weights correspond to constrained efficient rules in the class of three-period-ahead forecast aggregate inflation rules (they are marked by black dots along the constrained efficient frontier for aggregate inflation rules in Figure 10). The same reaction weights also correspond to efficient rules in the class of three-period-ahead non-tradeable inflation rules (marked by triangles along the constrained efficient frontier for non-tradeable inflation rules) but they generate too much variability in changes in the nominal interest rate to also make it into the set of feasible three-period-ahead unit labour cost growth rules. That is, the crosses do not lie on the feasible frontier represented by the dotted line. In that sense, the results in Table 3 for the unit labour cost growth rules understate the variability in inflation and output but overstate interest rate variability.

For given reaction weights, the results in Table 3 show that non-tradeable inflation rules generate less stability in all variables except changes in the interest rate. Moreover, the unit labour cost growth rules generate less variability in inflation, but more variability in output and changes in the interest rate. It is worth noting here that all of the rules in Table 3 produce inflation variability that would probably be tolerated under the flexible inflation-targeting framework in place in Australia.

---

[15] Strictly speaking, they all asymptote to infinite inflation variability because there is no control over inflation if the nominal interest rate does not respond directly to price shocks.

Table 3: Properties of Selected 3-period-ahead Forecast Rules

Rule specification ($(f=3)$)	Unconditional standard deviation Per cent				
	π^{A}	π^{NT}	$y-y^{P}$	Δi	rer
$\psi_1=2$ $\psi_2=4$					
Aggregate inflation	1.13	1.08	1.53	2.46	7.14
Non-tradeable inflation	1.15	1.09	1.55	2.45	7.25
Unit labour cost growth (a)	1.12	1.07	1.55	3.05	7.22
$\psi_1=3$ $\psi_2=3$					
Aggregate inflation	1.11	1.05	1.56	2.44	6.96
Non-tradeable inflation	1.13	1.07	1.59	2.42	7.12
Unit labour cost growth (a)	1.08	1.04	1.63	3.62	7.18
$\psi_1=4$ $\psi_2=2$					
Aggregate inflation	1.09	1.03	1.62	2.49	6.74
Non-tradeable inflation	1.12	1.06	1.65	2.46	6.97
Unit labour cost growth (a)	1.05	1.05	1.85	4.81	7.48

Note: (a) These rules are not on the feasible frontier for unit labour cost growth rules – the standard deviation of quarterly changes in the nominal interest rate generated by these rules is greater than 2.5 per cent. They correspond to the crosses in Figure 10.

The results presented in Table 3 are consistent with the evidence presented earlier in this section – even when a constraint is placed on interest rate variability, policy rules which respond to forecasts of non-tradeable inflation or even unit labour cost growth do not, so far as we have seen here, perform any better than rules which respond to forecasts of aggregate inflation.

Note that the results in Table 3 related only to three-period-ahead forecast rules. However, similar to the results in Figures 8 and 9, the most efficient outcomes in the class of constrained non-tradeable inflation and unit labour cost growth rules actually occur with forecast horizons greater than three periods. Despite this, the most efficient constrained frontiers for these rules still lie further from the origin than the $f=3$ constrained frontier for the aggregate inflation rule. Regardless of the forecast horizon then, constrained aggregate inflation rules do not appear to generate worse outcomes than the most efficient constrained non-tradeable inflation and unit labour cost growth rules.

4.4 Discussion of Results

For a once-off shock to the exchange rate, the impulse responses in Figure 4 showed that a non-tradeable inflation rule generated modestly higher variability in the output gap than an aggregate inflation rule. For policy, this result is not terribly informative because it is based on the effect of just a single shock. Stochastic simulations provide a more realistic setting in which to assess alternate policy rules because they allow for the possibility that a number of shocks can affect the economy at any one time. As we have seen in the previous two sections, the results from the stochastic simulations also indicate that non-tradeable inflation (and unit labour cost growth) rules perform no better at stabilising the economy than aggregate inflation rules.

As with any paper which generates results using a model, our results are model dependent. Consequently, conclusions based on these results will only be relevant to the extent that our model is an accurate reflection of the actual economy. In this section we explore a number of simple modifications to the model in order to test the robustness of the results.

In order to explore the possibility that exchange rate shocks have been less relevant for Australia than domestically sourced shocks (and hence, that alternative interest rate rules are not as appropriate for Australia as they might be for some other countries), we first conducted simulations of the model in which the variance of real exchange rate shocks was scaled to be five times greater than that implied by the empirical estimates of the real exchange rate equation. The resulting feasible frontiers for each policy rule (aggregate inflation, non-tradeable inflation and unit labour cost growth) were further from the origin (as one would expect) but the ranking of the rules was not changed.

A second issue concerns our empirical finding that interest rates affect the exchange rate with a one period lag. Because this is likely to be at odds with what many think to be the case, and because any superiority of a rule based on non-tradeable inflation should stem from (temporary) exchange rate effects being particularly quick, we also performed simulations of the model in which the interest rate had a contemporaneous effect on the exchange rate. Again, the ranking of the frontiers was unchanged.

A third issue relates to our treatment of inflation expectations. In the unit labour cost Phillips curve (Equation (A4)) we assumed that workers in the non-tradeable sector bargain for their wages on the basis of expected aggregate inflation which, as we have already seen, is more susceptible to exchange rate shocks, than non-tradeable inflation. This means that exchange rate shocks which show up in aggregate inflation will eventually feed into unit labour costs, and hence, inflation in the non-tradeable sector. An alternate assumption – that wages are determined by expected non-tradeable inflation – was less readily accepted by the data and, in any case, did not result in a different ordering of the three rules.

A fourth issue relates to how well we have captured the distinction between aggregate and non-tradeable inflation. In Bharucha and Kent's theoretical model the distinction between tradeable and non-tradeable inflation was imposed by assuming that there was no non-tradeable component in the final price of tradeable goods – tradeable inflation was entirely determined by changes in the exchange rate (assuming that the world price of tradeable goods was constant). By implication, the distinction between aggregate inflation (weighted sum of tradeable and non-tradeable inflation) and non-tradeable inflation in the model must also benefit from this assumption governing tradeable prices.

In contrast, the distinction between aggregate and non-tradeable inflation in our estimated model depends entirely on actual data, for which Bharucha and Kent's assumption regarding tradeable prices is not borne out. Tradeable prices – implied by the difference between aggregate and non-tradeable prices – include a significant non-tradeable component associated with bringing those goods to the retail market. Because of this, our distinction between the determinants of aggregate and non-tradeable inflation will be less clear than the distinction assumed in Bharucha and Kent's theoretical model. Even though our econometric estimates of the long-run determinants of aggregate and non-tradeable inflation (in Equations (A2) and (A3)) are quite distinct, it is the short-run dynamics of each of these equations which are likely to matter most when ranking rules according to their impact on inflation and output variability in stochastic simulations of the model. In this respect, it is possible that the short-run dynamics are not very distinct and on this basis we would expect to see less difference between the behaviour of the economy under aggregate and non-tradeable inflation rules than that presented in Bharucha and Kent.

In an attempt to further distinguish the two inflation processes, however, we dropped the direct influence of aggregate inflation on inflation in the non-tradeable sector (the Δp_{t-1} term in Equation (A3)). In simulations of this modified version of the model the ranking of the rules was again unchanged.

It may also be the case that one should distinguish between output in the two sectors in order to more fully capture price determination in the respective sectors. We did not attempt this in this paper, but we acknowledge that the distinction between an aggregate and non-tradeable output gap is likely to be more important for the unit labour cost Phillips curve than for the inflation equations. This is because the output gap is only meant to capture the effect of the mark-up in each of the inflation equations, but acts as a demand pressure variable in the Phillips curve equation.

Finally, we note that the persistence of exchange rate shocks could be an important consideration in the context of comparing aggregate and non-tradeable inflation rules. For example, exchange rate shocks may be more persistent, or at least expected to be more persistent, than we modelled here. While we did not experiment with the persistence of exchange rate shocks, we note that increased persistence of exchange rate shocks would actually argue more for the use of an aggregate inflation rule and there appears to be no need to provide further evidence in support of such a rule than we have already presented.

5. Conclusion

Inflation targeting in a small open economy is complicated by the exchange rate channel of monetary policy. In this paper we have used a small econometrically estimated model of the Australian economy to examine a number of issues relevant to the pursuit of inflation targeting in an open economy.

Our results, some of which are already well established, are summarised here.

Policy rules in which the interest rate responds to model-consistent forecasts of inflation and the output gap are preferable to those which respond only to lagged outcomes. This will be particularly relevant for an open economy where inflation is likely to be influenced by more than just past inflation and output. Forward-looking policy takes account of all available information to forecast future inflation and is better able to account for lags in the monetary policy transmission mechanism. This result lends support to the current central bank practice of 'pre-emptive' monetary policy.

While forward-looking policy can certainly improve outcomes, our results indicate that there is a limit on how forward-looking policy can be before it begins to generate worse outcomes. This finding merely reflects the fact that forecasting future inflation is an imperfect science – the further the forecast horizon, the less chance that the forecast will eventually prove correct because there is more time for unforeseen circumstances to occur.

Many of the forward-looking policy rules which we consider are 'efficient' in the sense that they stabilise the economy better than most other rules, but they typically imply interest rate variability which is much larger than that seen in practice. One explanation is that our model ignores a number of sources of uncertainty which the policy-maker actually faces in practice. The implication of uncertainty for monetary policy is an issue which is the focus of a lot of ongoing research so we did not attempt to address the issue in this paper. Instead, we investigated a number of ways of trying to solve the problem. Smoothing the response of the interest rate by means of a partial adjustment mechanism in the policy rule, for example, did not sufficiently reduce interest rate variability. The approach which we ultimately took was to ignore those policy rules which generated excessive interest rate variability. For the remaining feasible rules, the results of the paper were unchanged.

In this paper we also examined the implications of following policy rules in which the interest rate responded to a measure of inflation which was less susceptible to temporary exchange rate shocks. We also noted whether these alternative rules helped alleviate the problem of excessive interest rate variability.

Our results suggest that in the highly simplified world of a one-off shock to the exchange rate – the sort of world that one might think would most favour an alternative interest rate rule – an aggregate inflation rule actually seemed preferable.

Accepting that one cannot draw firm conclusions based on these results, we proceeded to stochastic simulations of the model. Non-tradeable inflation (and unit labour cost growth) rules appeared to generate at least as much variability in output and aggregate inflation – it is aggregate inflation that we care about – without any significant reduction in interest rate variability.

Our results appear to be robust to a number of simple modifications to the model. For example, we considered a more theoretically consistent version of the model in which policy had an immediate (rather than lagged) impact on the exchange rate. Another version allowed for inflation expectations in the non-tradeable sector to be determined by past non-tradeable rather than aggregate inflation. Neither of these variations, nor the other modifications which we tried, altered the main result of the paper.

Notwithstanding this, we do not rule out the possibility that our results are model dependent. However, to the extent that we have adhered to data-consistency wherever possible, we believe that our findings should be relevant to Australia.

Appendix A: Estimates of the Model

The model which we use is a modification of a small data-consistent set of equations developed in the course of previous research at the Reserve Bank of Australia. These equations were generally developed in isolation and first treated as a single macroeconomic model by de Brouwer and O'Regan (1997) for the purposes of stochastic simulations. A detailed description of a more recent version of the model is provided by Beechey *et al* (2000).

Most of the equations are expressed in error-correction form in order to distinguish the long-run relationships between the variables from their short-run dynamics. In each case, we began with general specifications (containing many lags of the dynamics) and arrived at a parsimonious specification using an informal general-to-specific model reduction approach. Various parameter restrictions were tested and imposed – in accordance with our theoretical priors – in an effort to include as much theoretical content as possible while still adhering to the overriding principle of data consistency.

Interest rates are expressed in per cent per annum divided by 100, and all other variables are expressed in logs. All data are quarterly and Δk denotes the quarterly log difference in variable k, $\overline{R}^2$ is the adjusted squared multiple correlation coefficient, $\hat{\sigma}$ is the estimated standard error of the regression. Where appropriate, in the specification of the equations below, error-correction terms are contained within square brackets. The definition, measurement and source for each of the variables is contained in Appendix D.

Equations (A1) to (A6) list the specification and coefficient estimates (with associated absolute values of *t*-statistics in parentheses below) for each of the behavioural equations in the model. The two identities in the model are given by Equations (A7) and (A8). Section 3 of the main text contains a more general description of each of the equations.

Note, for the purposes of estimation, potential non-farm output (y^p) is equal to the linear trend of actual non-farm output (y) generated over the sample period: 1980:Q1–1998:Q4.

Non-farm output equation

$$\begin{aligned}\Delta y_t = \alpha_y &- \underset{(4.77)}{0.207}\left(y_{t-1} + 0.1 rer_{t-1} - 0.05 tot_{t-1} - \underset{(40.06)}{1.212}\, wy_{t-1} \right) \\ &+ \underset{(2.77)}{0.371}\Delta wy_t + \underset{(3.05)}{0.022}\Delta fy_{t-1} + \underset{(0.29)}{0.020} r_{t-1} - \underset{(1.09)}{0.101} r_{t-2} \\ &+ \underset{(0.16)}{0.014} r_{t-3} + \underset{(0.09)}{0.045} r_{t-4} - \underset{(1.40)}{0.128} r_{t-5} - \underset{(0.25)}{0.017} r_{t-6} + \varepsilon_t^y \end{aligned} \tag{A1}$$

$$\text{Sample: } 1982:\text{Q}1 - 1998:\text{Q}4 \quad \overline{R}^2 = 0.498 \quad \hat{\sigma} = 0.638\% \quad DW = 2.116$$

When freely estimated, the coefficients on the real exchange rate (rer) and the terms of trade (tot) in the error-correction term, while of the correct sign, were insignificantly different from zero. Nevertheless, we have reason to believe that these variables have a significant, albeit small, effect on output. In order to account for this, the long-run elasticities on these two variables were calibrated to accord more closely with our priors while still being accepted by the data ($\chi^2(2) = 1.694$ [0.43]). According to this calibration, the direct effect of a terms of trade shock on output is small. Moreover, the resulting exchange rate movement's effect on output more than offsets the terms of trade effect, so a positive terms of trade shock eventually has a negative effect on output.

The six lags of the real interest rate are jointly significant ($\chi^2(6) = 18.000$ [0.01]) and their sum implies that a sustained one percentage point increase in the real cash rate eventually reduces the level of output by 0.81 per cent.

Aggregate price inflation equation

$$\begin{aligned}\Delta p_t = \alpha_p &- \underset{(6.30)}{0.064}\left(p_{t-1} - \underset{(5.76)}{0.568}\, ntulc_{t-1} - (1-0.568)\, pm_{t-1} \right) + \underset{(0.44)}{0.004}\,\Delta pm_{t-1} \\ &+ \underset{(0.53)}{0.005}\,\Delta pm_{t-2} + \underset{(2.46)}{0.024}\,\Delta pm_{t-3} + \underset{(7.18)}{0.111}(y_{t-1} - y^p_{t-1}) + \varepsilon^p_t \end{aligned} \qquad \text{(A2)}$$

Sample: $1984{:}\text{Q1} - 1998{:}\text{Q4} \quad \overline{R}^2 = 0.884 \quad \hat{\sigma} = 0.230\% \quad DW = 1.669$

The restriction of static homogeneity was accepted by the data ($\chi^2(1) = 0.908\ [0.34]$) and imposed.

Non-tradeable price inflation equation

$$\begin{aligned}\Delta ntp_t = \alpha_{ntp} &- \underset{(4.92)}{0.056}\left(ntp_{t-1} - \underset{(10.53)}{0.915}\, ntulc_{t-1} - (1-0.915)\, pm_{t-1} \right) + \underset{(2.29)}{0.291}\,\Delta p_{t-1} \\ &+ \underset{(5.82)}{0.118}(y_{t-1} - y^p_{t-1}) + \varepsilon^{ntp}_t \end{aligned} \qquad \text{(A3)}$$

Sample: $1984{:}\text{Q1} - 1998{:}\text{Q4} \quad \overline{R}^2 = 0.855 \quad \hat{\sigma} = 0.244\% \quad DW = 2.308$

The restriction of static homogeneity was accepted by the data ($\chi^2(1) = 0.185\ [0.67]$) and imposed.

Non-tradeable unit labour cost equation

$$\Delta ntulc_t = 0.25\sum_{j=1}^{4}\Delta p_{t-j} + \underset{(2.53)}{0.134}(y_{t-3} - y^p_{t-3} - 0.012) + \underset{(1.90)}{0.313}\,\Delta(y_{t-3} - y^p_{t-3}) + \varepsilon^{ulc}_t \qquad \text{(A4)}$$

Sample: $1984{:}\text{Q1} - 1998{:}\text{Q4} \quad \overline{R}^2 = 0.238 \quad \hat{\sigma} = 1.066\% \quad DW = 1.919$

The restriction that the coefficients on lagged inflation sum to one (the property which underlies a vertical long-run Phillips curve) was accepted by the data ($\chi^2(1) = 2.265\ [0.13]$) and imposed. The restriction that each of the coefficients on lagged inflation is equal to 0.25 was not accepted by the data, but was imposed in order to avoid an implausible dynamic response of non-tradeable unit labour costs to a change in aggregate prices.

In estimating the unit labour cost equation, the level of the output gap was adjusted downwards by 1.2 per cent in order to roughly capture the observed disinflation which actually occurred over the estimation sample period.

Import price equation

$$\begin{aligned}\Delta pm_t = \alpha_{pm} - \underset{(2.04)}{0.170}\left(pm_{t-1} - wp_{t-1} + ner_{t-1}\right) - \underset{(17.69)}{0.633}\Delta ner_t - \underset{(2.97)}{0.135}\Delta ner_{t-1} \\ + \underset{(3.60)}{0.646}\Delta wp_t - \underset{(2.56)}{0.001}t + \varepsilon_t^{pm}\end{aligned} \tag{A5}$$

Sample: $1982{:}\text{Q1} - 1998{:}\text{Q4}$ $\quad \overline{R}^2 = 0.860 \quad \hat{\sigma} = 1.196\% \quad DW = 2.189$

The restriction of static homogeneity (purchasing power parity in the long-run) was accepted by the data ($\chi^2(2) = 1.175\ [0.56]$) and imposed.

The time trend (t) in this equation reflects a gradual shift in the source of Australia's imports towards lower priced trading partners in the Asian region, suggesting that our measure of world prices (wp) does not fully capture the foreign-currency price of all of our imports. In simulations of the model, the coefficient on this time trend is set equal to zero.

Real exchange rate equation

$$\Delta rer_t = \alpha_{rer} - \underset{(4.15)}{0.413}rer_{t-1} + \underset{(2.93)}{0.411}tot_{t-1} + \underset{(7.20)}{1.263}\Delta tot_{t-1} + \underset{(1.76)}{0.392}(r_{t-1} - wr_{t-1}) + \varepsilon_t^{rer} \tag{A6}$$

Sample: $1985{:}\text{Q1} - 1998{:}\text{Q4}$ $\quad \overline{R}^2 = 0.598 \quad \hat{\sigma} = 2.896\% \quad DW = 1.743$

Real interest rate identity

$$r_t \equiv i_t - \pi_t^e = i_t - (p_{t-1} - p_{t-5}) \tag{A7}$$

Nominal exchange rate identity

$$ner_t \equiv rer_t + (wp_t - p_t) \qquad \text{(A8)}$$

For the simulations, the constant term in each equation was calibrated to place the model in equilibrium in the initial period ($\alpha_y = -3.354$, $\alpha_p = 0.006$, $\alpha_{ntp} = 0.004$, $\alpha_{pm} = 16.998$ and $\alpha_{rer} = 0.144$) for initial values for each variable (other than interest rates) of 100.

Appendix B: Equations for the Exogenous Variables in the Model

This Appendix sets out the estimated equations for each of the exogenous variables in the model. The specification of these equations is based on de Brouwer and O'Regan (1997).

The same general definitions apply as before (see Appendix A). Further details on the measurement and sources for each of these exogenous variables is contained in Appendix D.

All of the equations were estimated by OLS using quarterly data over the sample period: 1982:Q1–1998:Q4. Where necessary, linear trends in the exogenous variables were estimated over the slightly longer sample period: 1980:Q1–1998:Q4. Absolute values for *t*-statistics are contained in parentheses below the coefficient estimates.

Foreign output equation

$$\begin{aligned}\Delta wy_t = \alpha_{wy} &- \underset{(3.07)}{0.094}\left(wy_{t-1} - wy_{t-1}^{trend}\right) + \underset{(3.90)}{0.425}\Delta wy_{t-1} + \underset{(1.12)}{0.125}\Delta wy_{t-2} \\ &+ \underset{(1.85)}{0.200}\Delta wy_{t-3} + \varepsilon_t^{wy}\end{aligned} \tag{B1}$$

$$\overline{R}^2 = 0.374 \quad \hat{\sigma} = 0.520\%$$

Terms of trade equation

$$\Delta tot_t = \alpha_{tot} - \underset{(3.35)}{0.146} tot_{t-1} + \underset{(1.24)}{0.139}\Delta tot_{t-1} + \underset{(2.37)}{0.266}\Delta tot_{t-2} + \underset{(2.80)}{0.328}\Delta tot_{t-3} + \varepsilon_t^{tot} \tag{B2}$$

$$\overline{R}^2 = 0.225 \quad \hat{\sigma} = 1.914\%$$

Farm output equation

$$\Delta fy_t = \alpha_{fy} - \underset{(4.48)}{0.466}\left(fy_{t-1} - fy_{t-1}^{trend}\right) + \varepsilon_t^{fy} \tag{B3}$$

$$\bar{R}^2 = 0.222 \quad \hat{\sigma} = 9.929\%$$

Foreign short-term real interest rate equation

$$wr_t = \alpha_{wr} + \underset{(21.50)}{0.939}\, wr_{t-1} + \varepsilon_t^{wr} \tag{B4}$$

$$\bar{R}^2 = 0.873 \quad \hat{\sigma} = 0.315\%$$

World price inflation equation

$$\begin{aligned} \Delta wp_t = \alpha_{wp} - \underset{(2.44)}{0.125}\left(wp_{t-1} - wp_{t-1}^{trend}\right) + \underset{(2.64)}{0.336}\Delta wp_{t-1} + \underset{(0.10)}{0.012}\Delta wp_{t-2} \\ + \underset{(2.83)}{0.355}\Delta wp_{t-3} + \varepsilon_t^{wp} \end{aligned} \tag{B5}$$

$$\bar{R}^2 = 0.180 \quad \hat{\sigma} = 0.825\%$$

As with the endogenous variables, the constants in the equations for the exogenous variables were calibrated to place the model in equilibrium in the initial period ($\alpha_{wy} = 0.0017$, $\alpha_{tot} = 14.5806$, $\alpha_{fy} = 0.0063$, $\alpha_{wr} = 0.0012$ and $\alpha_{wp} = 0.0019$). These calibrated coefficients also ensure that the exogenous variables, except the world real interest rate, are equal to 100 in the initial period. The equilibrium world real interest rate is set equal to its historical long-run average of 1.97 per cent.

For the purposes of the simulations, potential output (y^p) was treated as exogenous and non-stochastic, growing at a constant rate consistent with the notion of potential output implicit in the error-correction term of Equation (A1), that is, 1.212 times the long-run trend real output growth rate in the US (which was estimated to be 2.7 per cent per annum over the sample 1980:Q1–1998:Q4).

Appendix C: Design of the Stochastic Simulations

The stochastic simulations involve solving the model (described in Appendix A) over 100 periods allowing for the effect of a new draw of random shocks in each period. Here we describe the properties of the shocks and the procedure which we used to generate the simulations of the model for each specification of the policy rule.

For an estimated model, the distribution of the shocks is usually based on the estimated distribution of the residuals from each of the equations. The advantage of this approach is that the shocks used to simulate the model embody the actual historical correlations of the shocks – making the results of such simulations more quantitatively significant. The approach which we used to generate the shocks is based on Bryant, Hooper and Mann (1993, pp 240–241) and was also used by de Brouwer and O'Regan (1997).

The approach involves calibrating each vector of shocks to the estimated variance-covariance matrix of the equation residuals. The matrix was calculated over the common sample 1985:Q1–1998:Q4. Residuals from the import price equation were excluded because, for the purposes of the simulations, we assume that all foreign nominal shocks are captured in shocks to the world price Equation (B5). In each period, shocks to the remaining 10 variables in the model were obtained by passing a 10×1 vector of realisations from the standard normal distribution through a Cholesky decomposition of the 10×10 residual variance-covariance matrix.[16] The seed of the random number generator was kept constant in order to generate the same set of shocks for each simulation. In this way, differences in the stochastic behaviour of the economy under each simulation can only be attributed to differences in the specification of the policy rule.

Armed with a set of shocks, the process for generating the stochastic simulations starts with the assumption that the policy-maker sets the policy instrument at the beginning of each period, before the current period's shocks have arrived. Then, at

---

[16] While we did not perform the same experiment ourselves, de Brouwer and O'Regan (1997, footnote 17) – using a similar model to ours – reported that their efficient policy frontiers did not change significantly when the covariances between the shocks were set to zero, so that only the variances of the shocks mattered.

each point in time, we simultaneously solve for each of the endogenous variables in the model, including the policy instrument, over a 25-period horizon, assuming there are no future shocks and the exogenous variables follow the data-generating processes reported in Appendix B. Beyond 25 periods, we close the model by assuming that aggregate and non-tradeable inflation have returned to target and actual output is at potential. Our experiments indicated that a 25-period horizon was sufficiently far in the future that imposing these end conditions did not affect current outcomes.

The forward solution at each point in time involves a path for each of the endogenous variables over the next 25 periods, conditional on the specification of the policy rule and the assumption of no further shocks. The first realisation from the path for the policy instrument is then taken to be the actual setting for the policy instrument in the current period. The actual outcomes for the remaining endogenous variables are then determined by applying a set of shocks to the exogenous variables and the solutions for the endogenous variables in the current period. We then move forward one period in time, and repeat the whole process, using the actual outcomes just derived as part of the historical starting values for the next 25-period solution to the model. We repeat this process for 100 periods, revealing a different set of shocks each period.

By repeating the entire process, we are able to generate stochastic simulations of the model for each specification of the policy rule. From the simulated outcomes for each policy rule, we can then summarise various aspects of the stochastic behaviour of the model by calculating unconditional moments of the endogenous variables. In order to construct the efficient policy frontier in inflation and output variability space, we calculate the standard deviation of annual inflation and the output gap (both expressed in percentage points). These standard deviations are calculated around the population means (2½ per cent for inflation, and zero for the output gap) in order to account for small-sample biases that can cause the sample means to deviate from population means. Each specification of the policy rule therefore provides us with a single point in inflation and output variability space. The efficient policy frontier is mapped out by joining the set of outcomes that minimise the variability in either inflation or the output gap for given variability of the other.

The simulations were performed entirely in *Mathematica* (version 4.0) based on code used to generate the stochastic simulations in de Brouwer and Ellis (1998). The computational burden involved in generating these simulations was heavy – *each* 100 period simulation (for a given specification of the policy rule) took just over 2 minutes to generate. In order to obtain our results within a reasonable period of time, we relied on the earlier results of de Brouwer and Ellis (1998) to reduce the dimensions of the grid search over possible feedback coefficients in the benchmark policy rule. Nevertheless, we still searched at least 300 sets of weights in order to produce a reliable estimate of each efficient frontier.

Appendix D: Data Definitions and Sources

The estimations used quarterly data up to 1998:Q4 which were available as at May 1999.

y **Real non-farm output**

Definition:	Real non-farm gross domestic product.
Units:	Chain volume, 1996/97 reference prices, (sa).
Source:	ABS Cat No 5206.0

ner **Nominal exchange rate**

Definition:	Australian dollar against a GNP-weighted basket of G7 currencies.
Units:	Indexed to March 1985 = 100.
Source:	Reserve Bank of Australia, unpublished data

rer **Real exchange rate**

Definition:	Australian dollar against a trade-weighted basket of major-trading-partner currencies, adjusted by domestic and foreign consumer prices.
Units:	Indexed to March 1985 = 100.
Source:	Reserve Bank of Australia, unpublished data

tot **Terms of trade**

Definition: Terms of trade for goods and services.

Units: Indexed to 1996/97 = 100, (sa).

Source: ABS Cat No 5206.0

wy **Foreign output**

Definition: Real US gross domestic product.

Units: Chain volume, US$ 1992 reference prices, (sa).

Source: Datastream, USGDP…D

i **Nominal cash rate**

Definition: Australian official cash rate.

Source: Reserve Bank of Australia *Bulletin*, Table F.11

wr **Foreign real short-term interest rate**

Definition: GNP-weighted average of the nominal policy interest rate less four-quarter-ended core inflation for the US, Japan, Germany and the UK.

Sources: Nominal policy interest rates for the US, Japan and the UK –
Reserve Bank of Australia *Bulletin*, Table F.11
Datastream, BDSU0110 for the German policy rate.

Core consumer price indices sourced from Datastream,
USCPXFDEE for the US,
JPCPXFFDF for Japan,
UKRPAXMIF for the UK,
WGUS0057E for Germany.

Weights are based on US dollar GNP data for each country contained in annual issues of the World Bank *World Atlas*.

p **Aggregate consumer prices**

Definition: Treasury underlying consumer price index.

Units: Indexed to 1989/90 = 100.

Source: ABS Cat No 6401.0. Note that the ABS discontinued publishing this measure of underlying consumer prices from the September quarter 1999 onwards.

ntp **Non-tradeable sector consumer prices**

Definition: Laspeyres index of non-tradeable sector components of the Treasury underlying consumer price index. Further details on the construction of this series are contained in Bharucha and Kent (1998, Appendix A).

Units: Indexed to 1989/90 = 100.

Source: Components of the Treasury underlying consumer price index contained in ABS Cat No 6401.0

ntulc Non-tradeable sector unit labour costs

Definition: Non-tradeable sector wages per person divided by non-tradeable sector output per person.

Non-tradeable sector wages per person were calculated as an industry full-time employment-weighted average of average weekly ordinary-time earnings (AWOTE) per employee in the non-tradeable industries.

Non-tradeable sector output per person was calculated as total gross value added in the non-tradeable industries divided by total employment in the non-tradeable industries.

For the purposes of this calculation, non-tradeable industries consists of all industries excluding mining and manufacturing.

Units: Indexed to 1989/90 = 100.

Source: AWOTE by industry: ABS Cat No 6302.0 (seasonally adjusted in Eviews using multiplicative X-11).

Full-time adult employment by industry: unpublished data provided by the ABS (seasonally adjusted by the ABS).

Total employment by industry: ABS Cat No 6203.0 (seasonally adjusted by the ABS).

Gross value added by industry: ABS Cat No 5206.0 (seasonally adjusted by the ABS).

pm **Import prices**

Definition: Implicit price deflator for merchandise imports, excluding fuels and lubricants, civil aircraft and Reserve Bank of Australia imports of gold.

Units: Indexed to 1989/90 = 100.

Sources: ABS Cat No 5206.0. Data on Reserve Bank of Australia imports of gold are unpublished.

wp **Foreign export (and consumer) prices**

Definition: GNP-weighted average of domestic currency export prices in each of the G7 economies.

Units: Indexed to 1989/90 = 100.

Sources: Export price data is sourced from Datastream,
USIPDEXPE for the US,
JPEP1975F for Japan,
CNEXPPRCE for Canada,
BDEXPPRCF for Germany,
UKEP1975F for the UK,
ITEP1975F for Italy,
FREP1975F for France.

Weights are based on US dollar GNP data for each country contained in annual issues of the World Bank *World Atlas*.

References

Apel M, M Nessén, U Söderström and A Vredin (1999), ‘Different Ways of Conducting Inflation Targeting: Theory and Practice’, *Sveriges Riksbank Quarterly Review*, 4, pp 13–42.

Armour J and A Côté (2000), ‘Feedback Rules for Inflation Control: An Overview of Recent Literature’, *Bank of Canada Review*, Winter 1999–2000, pp 43–54.

Ball LM (1998), ‘Policy Rules for Open Economies’, Reserve Bank of Australia Research Discussion Paper No 9806.

Batini N and AG Haldane (1999), ‘Forward-looking Rules for Monetary Policy’, Bank of England Working Paper No 91.

Batini N, B Martin and CK Salmon (1999), ‘Monetary Policy and Uncertainty’, *Bank of England Quarterly Bulletin*, 39(2), pp 183–189.

Beechey M, N Bharucha, A Cagliarini, DWR Gruen and C Thompson (2000), ‘A Small Model of the Australian Macroeconomy’, Reserve Bank of Australia Research Discussion Paper No 2000–05.

Bharucha N and C Kent (1998), ‘Inflation Targeting in a Small Open Economy’, Reserve Bank of Australia Research Discussion Paper No 9807.

Black R, T Macklem and D Rose (1997), ‘On Policy Rules for Price Stability’, in T Macklem (ed), *Price Stability, Inflation Targets and Monetary Policy*, Proceedings of a Conference, Bank of Canada, Ottawa, pp 411–461.

Blundell-Wignall A, JG Fahrer and A Heath (1993), ‘Major Influences on the Australian Dollar Exchange Rate’, in A Blundell-Wignall (ed), *The Exchange Rate, International Trade and the Balance of Payments*, Proceedings of a Conference, Reserve Bank of Australia, Sydney, pp 30–78.

Brooks R (1998), 'Inflation and Monetary Policy Reform', in J Hayden (ed), *Australia: Benefiting from Economic Reform*, IMF, Washington DC, pp 63–94.

Bryant RC, P Hooper and CL Mann (1993), 'Design and Implementation of the Empirical Simulations', in Bryant RC, P Hooper and CL Mann (eds), *Evaluating Policy Regimes: New Research in Empirical Macroeconomics*, Brookings Institution, Washington DC, pp 219–260.

Clarida R, J Galí and M Gertler (2000), 'Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory', *Quarterly Journal of Economics*, 115(1), pp 147–180.

Conway P, A Drew, BF Hunt and A Scott (1998), 'Exchange-rate Effects and Inflation Targeting in a Small Open Economy: A Stochastic Analysis Using FPS', *Topics in Monetary Policy Modelling*, August, pp 191–211.

de Brouwer G and L Ellis (1998), 'Forward-looking Behaviour and Credibility: Some Evidence and Implications for Policy', Reserve Bank of Australia Research Discussion Paper No 9803.

de Brouwer G and J O'Regan (1997), 'Evaluating Simple Monetary-policy Rules for Australia', in PW Lowe (ed), *Monetary Policy and Inflation Targeting*, Proceedings of a Conference, Reserve Bank of Australia, Sydney, pp 244–276.

Debelle G and A Cagliarini (2000), 'The Effect of Uncertainty on Monetary Policy: How Good are the Brakes?', Reserve Bank of Australia Research Discussion Paper, (forthcoming).

Dwyer JA (1992), 'The Tradeable Non-tradeable Dichotomy: A Practical Approach', *Australian Economic Papers*, 31(59), pp 443–458.

Dwyer JA, C Kent and A Pease (1994), 'Exchange Rate Pass-through: Testing the Small Country Assumption for Australia', *Economic Record*, 70, pp 408–423.

Dwyer JA and R Lam (1994), 'Explaining Import Price Inflation: A Recent History of Second Stage Pass-through', Reserve Bank of Australia Research Discussion Paper No 9407.

Gruen DWR, AR Pagan and C Thompson (1999), 'The Phillips Curve in Australia', Reserve Bank of Australia Research Discussion Paper No 1999–01.

Lowe PW and L Ellis (1997), 'The Smoothing of Official Interest Rates', in PW Lowe (ed), *Monetary Policy and Inflation Targeting*, Proceedings of a Conference, Reserve Bank of Australia, Sydney, pp 286–312.

Macklem T (1997), Discussion of 'Evaluating Simple Monetary-policy Rules for Australia', in PW Lowe (ed), *Monetary Policy and Inflation Targeting*, Proceedings of a Conference, Reserve Bank of Australia, Sydney, pp 277–285.

Pitchford JD (1993), 'The Exchange Rate and Macroeconomic Policy in Australia', in A Blundell-Wignall (ed), *The Exchange Rate, International Trade and the Balance of Payments*, Proceedings of a Conference, Reserve Bank of Australia, Sydney, pp 147–201.

Shuetrim GC and C Thompson (1999), 'The Implications of Uncertainty for Monetary Policy', Reserve Bank of Australia Research Discussion Paper No 1999–10.

Smets F (1997), 'Financial Asset Prices and Monetary Policy: Theory and Evidence', in PW Lowe (ed), *Monetary Policy and Inflation Targeting*, Proceedings of a Conference, Reserve Bank of Australia, Sydney, pp 212–237.

Svensson LEO (1998), 'Open-economy Inflation Targeting', NBER Working Paper No 6545.

Tarditi A (1996), 'Modelling the Australian Exchange Rate, Long Bond Yield and Inflationary Expectations', Reserve Bank of Australia Research Discussion Paper No 9608.

Taylor JB (1993), 'Discretion Versus Policy Rules in Practice', *Carnegie- Rochester Conference Series on Public Policy*, 39, pp 195–214.

Taylor JB (1999), 'The Robustness and Efficiency of Monetary Policy Rules as Guidelines for Interest Rate Setting by the European Central Bank', *Journal of Monetary Economics*, 43(3), pp 655–679.