FORWARD-LOOKING BEHAVIOUR AND CREDIBILITY: SOME EVIDENCE AND IMPLICATIONS FOR POLICY

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Abstract

Whether people form their expectations of the future in a model-consistent or extrapolative manner, has implications for the way the economy and monetary policy are modelled. The first half of this paper provides three pieces of information about inflation expectations – that survey measures of expectations are inconsistent with rational expectations, but less so for financial markets than households; that actual and expected inflation interact with each other; and that the foreign exchange market anticipates tighter monetary policy when inflation is higher than expected. The second half of the paper explores some policy implications. First, the variability of inflation and output is lower when policy-makers respond to model-based forecasts, rather than just current values, of inflation and output. Second, model-consistent behaviour elsewhere in the economy stabilises inflation and output, given that the model includes a central bank reaction function which the public believes the bank will adhere to. When inflation expectations differ between groups, the *ex ante* real interest rates that affect output and the exchange rate differ from each other, and this can induce oscillations or overshooting in the exchange rate, with consequences for the variability of inflation and output. Third, 'optimal' policy cannot fully compensate for the greater variability in inflation and output associated with extrapolative expectations.

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FORWARD-LOOKING BEHAVIOUR AND CREDIBILITY: SOME EVIDENCE AND IMPLICATIONS FOR POLICY

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1. Introduction

It is universally accepted that expectations play a crucial role in the way the economy works, but there is considerable dispute about how expectations are formed. In particular, there is debate about whether people anticipate future changes in policy when they form their expectations, or whether they simply extrapolate what has happened in the recent past into the future. This paper analyses some issues related to the way expectations are formed and examines a number of policy implications. The first half of the paper examines inflation forecast errors and the information people use to form their expectations of the future. The second half explores some implications for monetary policy.

In Section 2, we assess three pieces of information about expectations processes. We start by examining the 'rationality' of inflation expectations as measured by surveys of financial market economists and households. These survey measures are found to be inconsistent with rational expectations, although the inconsistency is smaller for financial market participants than for households. We also examine the relationship between actual inflation and households' expectations, and show that they interact with each other, such that expectations help predict actual inflation and *vice versa*. Current beliefs about future inflation have an effect on future inflation, but these expectations are also affected by past inflation.

The characterisation of expectations probably differs across sectors in the economy, with the financial markets, for example, typically regarded as more explicitly forward looking. We look, therefore, at how perceptions in the foreign exchange market of future monetary policy have evolved over time. If inflation is higher than expected, financial markets will expect higher future *real* interest rates and an appreciation of the exchange rate (all else given) if they believe that the central bank will not accommodate higher inflation. We show that in recent years inflation surprises have on average induced a movement of the Australian dollar in the same direction as the inflation surprise, whereas the response was more ambiguous during the 1980s. This is consistent with participants in the foreign exchange market forming their expectations on the basis of a model of the economy in which the Reserve Bank will not accommodate inflation shocks.

In Section 3, we use the simple data-consistent model of the Australian economy set out in de Brouwer and O'Regan (1997) to examine some implications of forward-looking behaviour and credibility. We look, first, at forward-looking monetary policy. Forward-looking policy reduces the variability of inflation around target and output around potential considerably more than when policy reacts only to current inflation and output statistics. We find that a rule based on four-quarter ahead forecasts of inflation and the output gap outperforms rules based on other forecast horizons, given that policy-makers use forecasts which are consistent with the policy rule (rather than assuming, for example, that the nominal interest rate is constant over the forecast horizon).

The effect of shocks also depends on the way in which expectations are formed. To illustrate this, we set out a model which embodies two extremes of how price, wage and exchange rate expectations can be formed. One case is that people form their expectations of the future based on the structure of the model, including how the central bank sets monetary policy. The other case is that their expectations of the future are simply extrapolations from the recent past. A more realistic model is probably some combination of these two cases. Consistent with earlier work, our results show that shocks are less destabilising when people know the structure of the economy and the central bank's reaction function, rather than when they rely only on data from the recent past. Moreover, when groups of people in the economy form their expectations about inflation in different ways, the *ex ante* real interest rates that influence activity and the real exchange rate can differ from each other. This can induce oscillations or overshooting in the exchange rate, depending on the particular mix of expectations, with implications for the variability of inflation and output.

Given that expectations which are formed only on the basis of past data tend to increase the variability of inflation and output in response to shocks, we examine whether policy-makers can compensate for this if they set interest rates 'optimally'. For a given set of shocks and using a common basic economic structure, we find that optimal policy cannot fully compensate for the greater variability produced when people take insufficient account of the structure of the economy and future monetary policy in forming their expectations. In this sense, policy-makers have to work with the economic structure around them.

2. Evidence on the Formation of Inflation Expectations

This section examines some aspects of inflation expectations. We start by analysing the inflation forecast errors of financial market economists and households. In Section 2.2, we examine whether there are interactions between actual and expected inflation, testing whether expectations influence actual inflation. Most economists draw a distinction between financial markets and other groups in the economy in terms of forward-looking behaviour. Accordingly, in Section 2.3, we look at how the foreign exchange market responds to expected future monetary policy. A summary of the results is presented in Section 2.4.

2.1 Inflation Expectations

If expectations are ‘rational’, in the sense that they use all currently available information, then they are unbiased predictors of the actual inflation rate. We test this for two very different measures of inflation expectations. The first is the median response to the Money Market Services (MMS) survey of financial market economists’ expectations of the next release of *quarterly* headline inflation. The second is the median response to the Melbourne Institute survey of what households expect inflation to be over the coming *year*.[1] Given that financial markets are thought to be relatively efficient, their inflation expectations would be expected to exhibit a smaller bias.

The top panel of Figure 1 plots the inflation-expectation error of financial market economists. Financial market economists thought headline inflation would be lower

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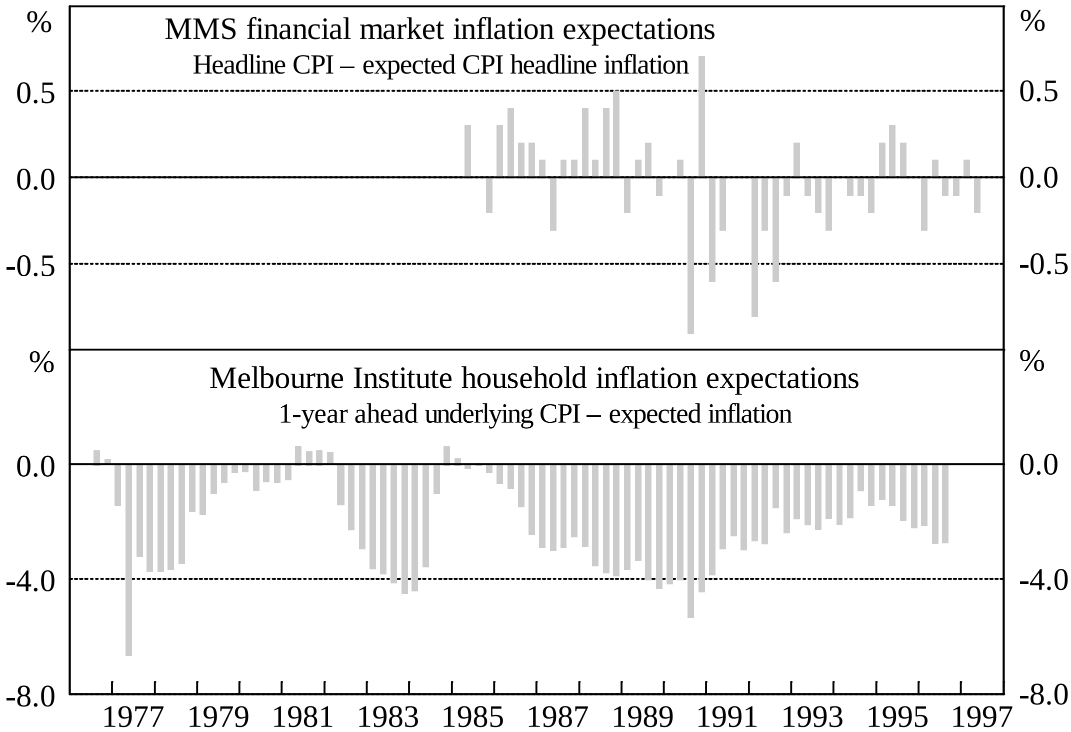
[1] Households are asked ‘By this time next year, do you think the prices of the things you buy will go up or down? If up, by how much? If down, by how much?’ We compare household expected inflation with underlying inflation since the questions refer to broad inflationary pressures in the economy, of which underlying inflation is a better indicator. (The results are not substantively different when headline inflation is used in place of the underlying rate.) We compare financial market economists’ inflation expectations with headline inflation since they are asked specifically about the headline rate.

than it was during the second half of the 1980s, and they then failed to predict the disinflation that occurred from 1990 to 1992, with inflation repeatedly coming in well below the market expectation. Errors have been smaller and more evenly balanced between under and over predictions in the past few years. While Figure 1 suggests that financial market economists generally underestimate inflation when it is rising and overestimate it when it is falling, the average forecast error over the past 13 years is indistinguishable from zero.

Figure 1: Actual Less Expected Inflation



The bottom panel of Figure 1 plots the inflation-expectation error of households, as measured by the difference between underlying inflation (one-year ahead) and the Melbourne Institute's measure of household expected inflation for the coming year. In contrast to financial market economists, households have systematically expected inflation to be higher than it turned out to be, with this bias not falling substantially with the mean shift in inflation in the 1990s. Appendix A presents the results of a formal test of rational expectations, indicating that neither of these expectations series conform with the predictions of the rational expectations hypothesis, although the rejection is much stronger for households than for financial market economists.

2.2 Interactions Between Actual and Expected Price Inflation

We next examine the interaction of actual inflation and measured inflation expectations. The question we have in mind is whether movements in actual inflation occur before changes in expected inflation, or the other way around. Before we answer this question, there are a few preliminary data issues to resolve.

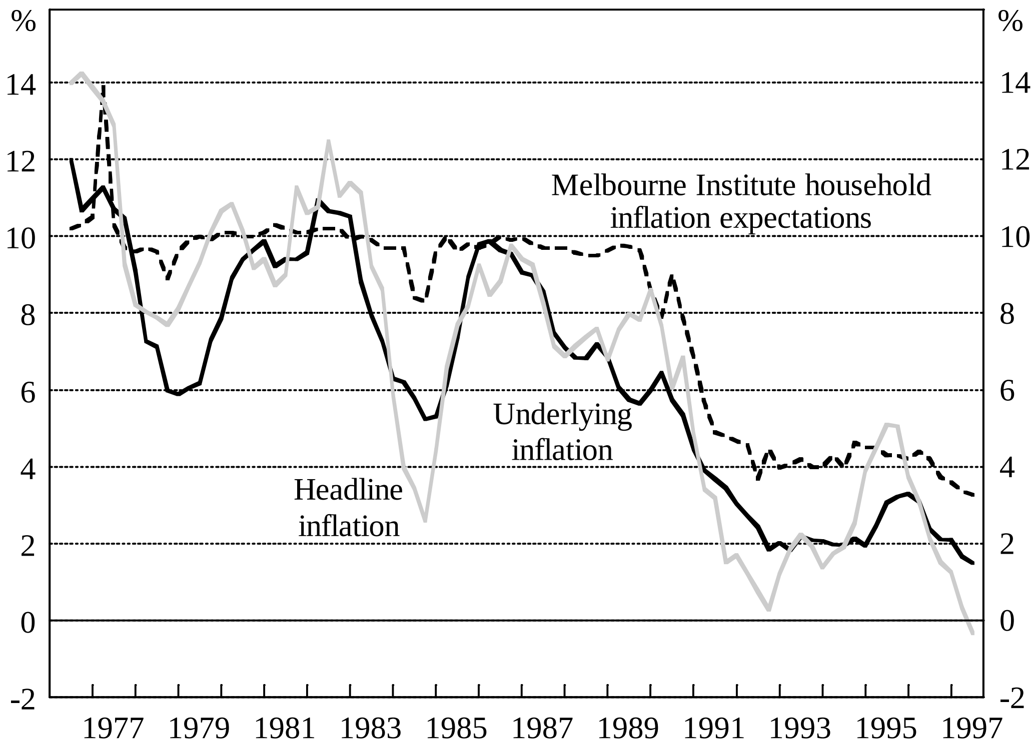
The first is to decide which inflation series is relevant. There are (at least) two candidates. On the one hand, monetary policy is made with reference to underlying CPI inflation, since this removes anomalous and volatile items, providing a more accurate representation of 'true' price pressures in the economy. On the other hand, the published 'headline' figure typically has more coverage in the non-specialist media, and so is more likely to influence popular opinion. Moreover, underlying inflation only gained prominence in the 1990s. The upshot is that it is unclear which series is relevant, and so both are examined. The second issue is the selection of the inflation expectations measure. A broad measure is preferred, and so the median response from the Melbourne Institute survey of households' inflation expectations is used.

Figure 2 plots headline and underlying CPI inflation with the quarterly reading of the Melbourne Institute survey measure of what households expect inflation to be one year ahead (hereafter called 'inflation expectations').[2] Eyeballing these data, it is difficult to draw a clear inference about whether actual or expected inflation 'leads' the other. Expected inflation hardly responded to the substantial changes in actual inflation through the late 1970s and 1980s, although this was not a bad call in the sense that two of the three reductions in inflation over this period proved to be transitory. (There is a 'chicken and egg' dimension to this, since the falls in actual inflation were bound to be transitory if expectations did not change.) The fall in inflation expectations over 1989 to 1991 to about 4½ per cent occurred on the back of a steady reduction in underlying inflation. Expected inflation ticked up slightly in late 1994, ahead of the rise in underlying inflation, but fell in 1996, to close to 3 per cent, following lower underlying and headline inflation. On this measure,

2 The CPI data are released about six weeks after the end of the quarter under consideration. The Melbourne Institute expectations data were collected on a quarterly basis until December 1986, after which they were collected on a monthly basis (with the survey conducted at the start of the month and released in the middle of the month). Quarterly expectations from March 1987 are calculated as the average of the monthly responses.

expected inflation was around 3 per cent at the end of 1997, which was still well above actual inflation.[3]

Figure 2: Actual and Expected Inflation



Granger-causality tests provide a simple statistical tool to assess whether changes in actual inflation precede expected inflation or *vice versa*. Table 1 lists the Chi-square statistics for excluding lags of the relevant variables in a two-variable four-lag VAR (similar results apply to estimation in a two-lag VAR and in first differences of inflation). There are two points of interest. First, the results indicate that there is *feedback* between actual and expected inflation, such that it cannot be said that one systematically precedes the other. The statistical importance of expected inflation to

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[3] It is worth observing that while this measure of inflation expectations is currently around 2 to 3 per cent, the Australian inflation target is expressed in terms of a medium-term mean, and does not specify a range or band within which inflation necessarily must lie in the short term for policy to be judged 'successful'. This means that the sort of credibility test proposed by Amano *et al.* (1996) – whether inflation expectations over all periods lie within the band – is not necessarily an appropriate test of credibility. Given that the inflation target is a medium-term mean, *short-term* inflation expectations can lie away from the target rate at times even if the target is fully credible. The better test of credibility is that medium-term inflation expectations be consistent with the target (although short-term inflation expectations should also exhibit a tendency to revert to the target rate if the target is credible).

actual inflation has increased in the 1990s, suggesting that expectations may have become more important to the inflationary process in recent years. Second, while actual inflation has consistently been a predictor of expected inflation, the headline rate seems to have been supplanted by the underlying rate of inflation as the driving force behind expected inflation.

Table 1: Granger-Causality Tests for Actual and Expected Inflation

	Dependent variable								
	1977:Q3–1997:Q3			1980:Q1–1989:Q4			1990:Q1–1997:Q3		
	Headline inflation	Underlying inflation	Expected inflation	Headline inflation	Underlying inflation	Expected inflation	Headline inflation	Underlying inflation	Expected inflation
Excluding lags of headline inflation	498** [0.00]	n.a.	13.4** [0.01]	62.8** [0.00]	n.a.	16.8** [0.00]	211** [0.00]	n.a.	6.0 [0.20]
Excluding lags of underlying inflation	n.a.	823** [0.00]	15.9** [0.00]	n.a.	491** [0.00]	6.8 [0.15]	n.a.	60.5** [0.00]	13.1** [0.01]
Excluding lags of expected inflation	147** [0.00]	17.4** [0.00]	176** [0.00]	78.1** [0.00]	20.1** [0.00]	277** [0.00]	144** [0.00]	30.6** [0.00]	63.3** [0.00]

Note: The table reports $\chi^2(4)$ statistics; figures in brackets are marginal significance values; ** and * indicate 1 and 5 per cent significance; all statistics are Newey-West adjusted for serial correlation induced by overlapping observations.

2.3 Inflation Surprises and the Exchange Rate

Economists generally believe that financial markets are more explicitly forward looking and less likely to be systematically biased in forming their expectations than other groups. This is consistent with the analysis of inflation forecast errors in Section 2.1. We look here at how the foreign exchange market anticipates monetary policy will respond when actual inflation differs from the expected outcome.

In a floating exchange rate regime, when inflation is higher than expected, the nominal exchange rate depreciates in order to maintain the real exchange rate if no policy response is anticipated. If monetary policy is focused on inflation, however, policy would generally be tightened in response to the higher inflation forecast. In a rational market, foreign exchange market participants anticipate the higher real interest rates, and the exchange rate may appreciate in response to the positive inflation surprise. This is a testable proposition (Kim 1994; Amano *et al.* 1996). It provides an insight into the anti-inflation credibility of a central bank as assessed by the financial market, since it indicates whether or not the market believes that the monetary authority will accommodate inflation shocks.

Following Kim (1994), we estimate the equation:

$$Der_t = a + bp_t^e + gsurprise_t \tag{1}$$

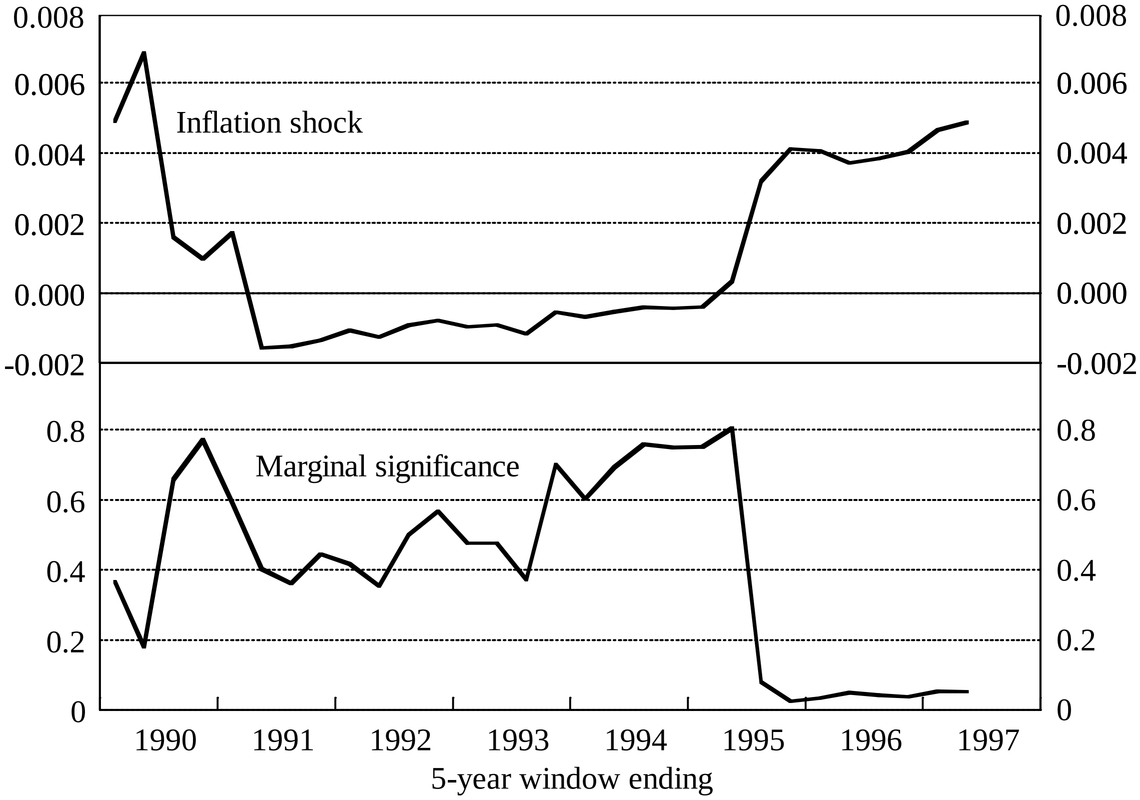
where *er* is the US dollar per Australian dollar exchange rate (so a rise is an appreciation of the Australian dollar), p^e is the expected inflation rate and *surprise* is actual inflation less the expected inflation for that quarter. If the foreign exchange market is efficient, so available information is already incorporated into the exchange rate, then $a = b = 0$ and $g \neq 0$. If the inflation surprise indicates higher future inflation, then $g < 0$ if a policy response is not anticipated, but $g > 0$ if a policy response is. Kim (1994) used quarterly data for Australia from 1985 to 1992, split the sample into two periods of about a dozen observations each, and found that the exchange rate tended to depreciate when published headline inflation was above expected inflation from 1985 to 1988 inclusive, but tended to appreciate after 1988.

The measure of expected inflation that we use is the MMS survey of financial market economists' expected headline annual CPI inflation the week before the ABS releases the CPI data. The data are available from March 1985 to June 1997. The inflation surprise is headline inflation less the MMS measure of expected inflation. The ABS released CPI data at 9.00 am until the December 1988 release, and at 11.30 am from the March 1989 release. The exchange rate change is the log difference between the opening rate (before 9.00 am rate) and the 11.00 am rate from March 1985 to December 1988, and the log difference between the 9.00 am rate and the midday rate from March 1989.

The top panel in Figure 3 plots the γ coefficient from Equation (1) estimated by rolling a regression forward from March 1985 to June 1997 with a fixed window of 20 observations (5 years). The bottom panel shows its marginal significance. The inference drawn from this exercise is that during most of this period, inflation surprises have tended to have no clear impact on the exchange rate, but this has changed – and significantly so – in recent years. The exchange rate now systematically moves in the same direction as the inflation surprise, so that, for example, the exchange rate depreciates if inflation comes in lower than expected.[4] This suggests that the market believes that the Reserve Bank of Australia will not accommodate inflation shocks.

Figure 3: Inflation Surprises and the Exchange Rate

20-quarter rolling-window estimation of γ in Equation (1)



2.4 An Assessment

The evidence on the information that people use to form their expectations is mixed. In the first place, survey measures of inflation expectations for households and financial market economists are not consistent with the predictions of rational expectations, which is a common result in the international literature (Maddala 1989; Roberts 1997). The degree of inconsistency, however, differs between these groups. The median financial market economist missed changes in

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4 Equation (1) also contains a test of whether the foreign exchange market is efficient, in the sense of whether it has used all available information (particularly about inflation) such that changes in the exchange rate are unpredictable. While the coefficients are not reported, the null hypothesis of financial market efficiency, $a = b = 0$, is not rejected for the 20-quarter rolling window regressions.

the inflation regime, but basically has ‘got it right’ once the mean shift in inflation took place. The median household is yet to get this far, with the size of the bias only falling moderately despite the substantial fall in inflation in the 1990s relative to the 1980s.

Moreover, financial market participants also exhibit explicit forward-looking behaviour which takes account of a policy reaction when inflation outcomes differ to what was expected. The exchange rate now systematically moves in the same direction as the inflation surprise, suggesting that the market anticipates that real interest rates will be changed in response.

Inflation expectations also seem to matter to the inflation outturn, as shown by the interaction between actual and expected inflation over the 1990s. Actual inflation is explained by its own past values and by past inflation expectations, which indicates that inflation expectations contain separate information about future inflation. Inflation expectations, in turn, however, also depend on past inflation, suggesting that inflation expectations are based on a mix of different sets of information.

3. Policy Implications

Expectations play a key role in most economic models, and models of the macroeconomy are no exception. For example, one of the main determinants of economic growth in the short to medium term is the real interest rate, which is defined as the nominal interest rate less the *expected* rate of inflation. Similarly, models of price and wage adjustment typically include the expected inflation rate, and models of the exchange rate can include not just current values of the driving variables but also their expected future values. In many cases, specifying how these expectations are formed has profound implications for the outcomes and predictions of the model.

Perhaps the simplest approach to modelling expectations is to assume that the expected value of a variable is a weighted combination of its current and recent values. In the case of the real interest rate, for example, expected inflation would be equal to current annual inflation, so that the real interest rate is the nominal interest rate less the current rate of inflation. This characterisation is often referred to as ‘backward looking’ expectations, which is somewhat paradoxical since the fact that expectations are being formed at all indicates that people are thinking about the future. However, the basic idea in this formulation is that people form their expectations of the future by looking at recent history, or, in other words, looking backwards. The terms 'extrapolative' or 'adaptive' expectations convey a similar meaning, and in this paper, we use 'backward looking', 'extrapolative' and 'adaptive' interchangeably.

An alternative approach is to assume that people form their expectations of the future with reference to the structure of the economy, including how the central bank responds to various pieces of information. Expectations formed in this way are usually called 'model consistent' or 'forward looking' expectations, although the latter term is clearly tautological. When expectations are model-consistent, an announced change in the way the central bank operates, for example, can change people's expectations of the future and thus the way the economy evolves. Of course, the policy response has to be seen to be credible for this to happen; if it is not credible, the public will not change the way they view the future. Thus in any modelling exercise in which it is assumed that people know the structure of the economy, it is also necessary to make an assumption about the credibility of policy responses. In this paper, when we use model-consistent expectations we assume that the public knows the way the central bank operates and that the central bank does not deviate from this expected behaviour.

In this section, we consider models of the economy that are based on both backward-looking and model-consistent expectations, and we include a hybrid version in which expectations are a mix of these two approaches. In Section 3.1, we use a model in which people have backward-looking expectations to examine how forward-looking behaviour on the part of the central bank can affect the variability of inflation and the output gap. In Section 3.2, we focus on the way expectations of people other than policy-makers can affect the way shocks influence economic outcomes. Model-consistent expectations reduce the variability in inflation and output, although when sectors in the economy have different inflation expectations, the *ex ante* real interest rates that affect output and the exchange rate differ, which we show can generate either oscillations or overshooting in the exchange rate. In Section 3.3, we assess different expectations processes in this model from the perspective of *optimal* monetary policy, to see whether policy-makers can compensate for the greater variability in inflation and output that occurs when people form their expectations of the future by extrapolating from the past.

3.1 The Benefits of Forward-looking Policy

One characterisation of monetary policy is that policy-makers follow a feedback rule, by which they raise the short-term real interest rate above its ‘neutral’ rate when current inflation is above target or when current output is above potential, and *vice versa*, which we call a Taylor-type rule for short (Taylor 1993; Bryant, Hooper and Mann 1993). For example, if policy-makers react to current data in setting interest rates, one possible rule is:

$$i_t = \bar{r} + p_t^e + y_1(p_{t-1} - p_{t-5} - 2.5) + y_2 gap_{t-1} \tag{2a}$$

where $\bar{r}$ is the neutral real cash rate, p^e is expected annual inflation,[5] p is the price level, 2.5 is the annual inflation target, *gap* is the output gap (actual less potential output) and the information variables are dated at *t*-1 since, in general, only statistics for the previous quarter are available in the current quarter. But if policy-makers set the instrument with respect to model-based forecasts of inflation and the output gap,[6] the rule becomes:

$$i_t = \bar{r} + p_t^e + y_1(E_t[p_{t+f} - p_{t+f-4}] - 2.5) + y_2 E_t[gap_{t+f}] \tag{2b}$$

where E_t indicates an expectation at time t and f is the forecast horizon. Such Taylor-type rules are not an exact representation of policy, since the economy, shocks and central bank reaction functions are considerably more complex than suggested by simple rules, although the focus on deviations of inflation from target and output from potential is generally considered to be a good first approximation.

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5 Since output and inflation are influenced by the *real* interest rate, we assume that policy-makers set the nominal interest rate to achieve the desired real interest rate. Accordingly, in Equations (2a) and (2b), the expected annual inflation rate used to define the real interest rate can be different from the inflation rate to which policy-makers respond. This also allows us to show the impact that heterogeneous private-sector inflation expectations can have on economic outcomes in the next section of the paper.

6 Policy-makers use structural, model-based forecasts of inflation, and so the system is not subject to the indeterminacy problem that arises when policy-makers use inflation forecasts which are set equal to the inflation target (Bernanke and Woodford 1997).

Using stochastic simulation of a simple data-consistent model of the Australian economy with adaptive expectations processes (reproduced in Appendix B), de Brouwer and O'Regan (1997) showed that policy-makers following a Taylor-type rule can more successfully reduce the variability of inflation around target, and of output around potential, when they set interest rates based on forecasts of inflation and output, instead of relying on the most recent available data on these variables. Interest rates affect economic activity and inflation with a lag, and so policy-makers can reduce variability if they change rates now in anticipation of future developments in activity and inflation. This is the well known rationale for pre-emptive monetary policy.

Assuming that policy-makers forecast on the basis of unchanged future policy, defined as a constant nominal interest rate, de Brouwer and O'Regan (1997) reported that simple forward-looking policy rules based on two-period ahead forecasts do better than simple rules based on other forecast horizons. While the unchanged-policy assumption is fairly standard in policy analysis, it is undesirable in model-based exercises since fixing the nominal or real interest rate over the forecast horizon implies that policy accommodates inflation shocks, in turn increasing the variability of inflation and output. Moreover, the supposition that sometimes policy-makers set interest rates based on a particular reaction function but then at other times keep rates constant, is inconsistent with both the model and the argument that the reaction weights in such a rule are efficient.

The constant-rate assumption also implies greater variability in interest rates (and inflation and output) since it rules out policy-makers planning a path for interest rates. When interest rates are assumed to be constant over the forecast horizon, policy-makers are unable to allow for the effect of their own future reaction on the forecast variables, and hence they overestimate the variability of inflation and output. In modeling exercises such as this, policy-makers therefore over-react to shocks in the current period, only to partially reverse the response in subsequent periods (see Appendix C for more details). Accordingly, in this paper we examine which forecast horizon most reduces variability in inflation and output assuming that policy-makers make their forecasts conditional on the application of the given policy rule over the forecast horizon.

We also search for reaction weights across all possible values in a rule, and do not restrict these coefficients to take a value of two or less, as was the case in earlier work. This is important because we use model-consistent policy rules in the forecast period. Since policy is assumed to be responding in each of the forecast periods, the expected deviation of inflation from target following an inflation shock, for example, is likely to be smaller the further out is the forecast period. To achieve a given change in the interest rate, the reaction weight has to be larger since the end-point deviation is smaller.

We turn now to the results of the stochastic simulation.[7] Figure 4 shows the trade-off between the variability of inflation and the output gap when three alternative sets of data – the latest data release, four-quarter ahead forecasts and six-quarter ahead forecasts of inflation and the output gap – are used in the Taylor-type rule. Each curve shows the efficient set of outcomes for different reaction weights for each rule, where a set of reaction weights is said to be 'efficient' if it minimises the variability in inflation or the output gap, given the variability in the other. The curves are convex, with each further reduction in the variability of inflation or output coming at the cost of an ever-larger increase in the variability of the other.

While there is an irreducible variability in inflation and output, these variabilities fall substantially when policy-makers set interest rates with reference to their conditional forecasts, rather than the most recently available statistics. For example, the 'best' that policy-makers who react to actual inflation and the output gap can do is to reduce the standard deviation of inflation to about 1.1 per cent. But if they use their four-period ahead forecasts, the 'best' standard deviation is about 0.8 per cent. For this model and draw of shocks, the best horizon in terms of minimising the

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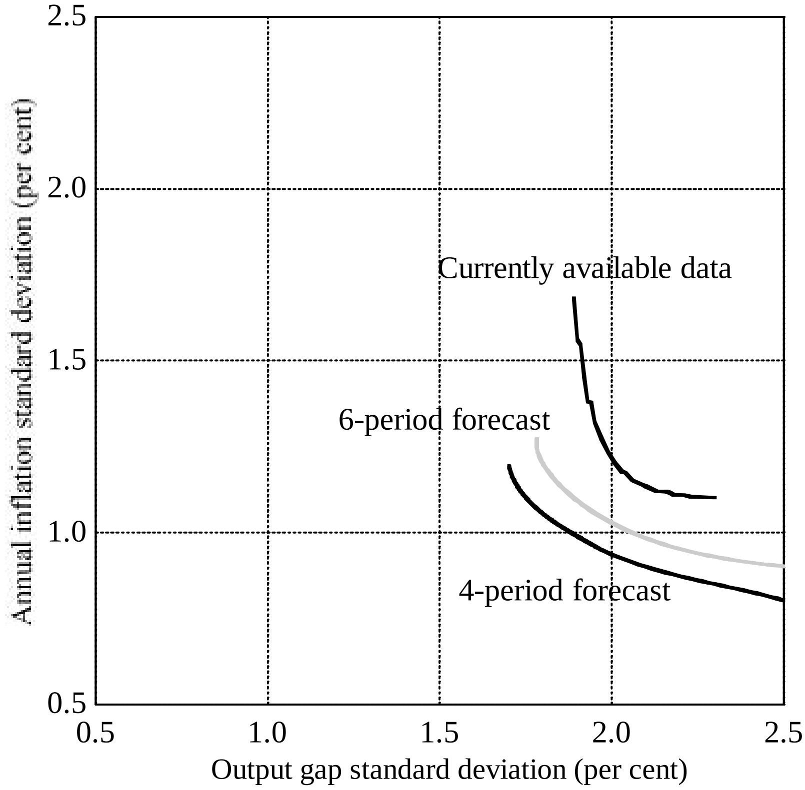
7 We use the first 200 of the 1 000 shocks in de Brouwer and O'Regan (1997). The properties of the shocks are outlined in Appendix B. Since we use a smaller number of shocks, our sample means are more likely to deviate from the population means, and so we evaluate variabilities around the population mean, rather than the sample mean. For example, variability of the output gap is assessed around zero, while variability of annual inflation is assessed around 2.5. The simulations were constructed by solving simultaneously for the endogenous variables over a 25-period horizon. At each point in time, the system is solved assuming exogenous and endogenous variables take their expected values, based on the known data-generating processes. To close the model, annual inflation is assumed to be 2.5 per cent and output is assumed to be at potential beyond the 25-period horizon (which is sufficiently far in the future in an adaptive model to not affect current outcomes). The realisations for the current period are determined by applying the current set of shocks to these solutions. These realisations become part of the historical starting values for the forecast horizon beginning in the following period.

variability in inflation and the output gap using a simple rule is four quarters. Given that data for the current quarter are not yet observable, this implies that the rule explicitly uses forecasts for five periods.

Figure 4: Efficient Taylor-type Rules for Backward Inflation Expectations



This forecast horizon is well within the control lag of policy in this model, which Haldane (1997) has shown to be necessary if policy is to be stabilising. In this model, for example, there is a two-period lag from policy to inflation via the exchange rate. The control lag from policy to inflation via the output gap is at least three periods, since policy affects output with a lag of at least two periods (both directly and indirectly through the real exchange rate) and the output gap in turn affects wages, and hence, inflation, with a one period lag.

But Figure 4 also shows that policy-makers cannot rely on ever-longer forecast horizons in a simple rule. The forecast-error variance rises as the forecast horizon is extended further out. Even if everyone knows the 'true' model of the economy and forms forecasts based on this, the world is stochastic, and the realisations differ from the expected values. At some stage, the increase in forecast-error variance dominates the stabilising properties of pre-emptive policy.

In this model, the reduction in the variability of inflation and output is smaller when policy-makers use forecasts six quarters out, compared to when they use forecasts four quarters out. The four-quarter forecast horizon, however, is not as short as it might seem, since the four-quarter forecast of the output gap helps predict inflation a further one to two quarters out through the wages process and a further three quarters out directly through its effect on the mark-up. This essentially means that interest rates are responding to forecasts of inflation four to seven quarters out. It is worth noting that the rules we are considering here restrict policy-makers to set interest rates with respect to the forecasts of only one particular period in the future. A more efficient, but complex, rule would be for policy-makers to set the interest rate based on the full profile of inflation and output over time, with different weights on each period's forecasts.

Simple forward-looking policy rules can substantially reduce the variability in inflation and output. But as policy becomes more forward looking, it also becomes more activist, in the sense that interest rates are moved around considerably more than otherwise. Table 2 sets out some reaction weights and associated standard deviations on interest rate changes on some of the efficient frontiers shown above. As policy becomes more forward looking, the variability in interest rates increases.

Although this volatility seems implausibly high when compared to historical experience, some other combinations of reaction weights can generate much lower instrument volatility with only a small cost in increased variability in inflation and the output gap. For example, the inflation and output reaction weights (8, 4) shown in Table 2 generate a standard deviation of the quarterly change in nominal rates which is greater than 4 per cent to achieve standard deviations of inflation and the output gap of 0.95 per cent and 1.97 per cent respectively. The near-efficient weights of (2.8, 1), however, reduce the quarterly standard deviation of interest rate changes to 1.38 per cent, but only at the cost of an increase in the standard deviation of inflation of less than a quarter of one percentage point. This result is consistent with the finding in Lowe and Ellis (1997), in the context of optimal policy, that moderate smoothing of interest rates does not substantially affect the variability of inflation and output.

Table 2: Some Efficient Reaction Weights

Taylor-type rule	Inflation reaction coefficient	Output gap reaction coefficient	Inflation standard deviation	Output gap standard deviation	Δ interest rate standard deviation
Current data	0.1	1.0	1.55	1.91	0.98
	0.5	1.3	1.27	1.97	1.35
	1.4	1.4	1.10	2.30	1.82
4-period forecast	2.0	3.5	1.19	1.70	2.46
	5.0	4.0	1.03	1.82	3.36
	8.0	4.0	0.95	1.97	4.02

While the results are not reported, when the standard deviation of quarterly interest rate changes was constrained to be less than 1.5 percentage points, the four-period ahead forecast horizon still yielded the lowest combined inflation and output variability, although longer forecast horizons almost performed as well in some cases. Similarly, reducing the variability of interest rates by imposing a partial adjustment process onto an efficient Taylor rule also gave the best results when the rule involved a four-period ahead horizon.

Finally, the relative weight on inflation in the central bank's reaction function also increases as policy becomes more forward looking, since the information about future inflation embodied in the output gap has already been exploited to some degree (de Brouwer and O'Regan 1997). But in the model used here, this does not imply that the weights on the output gap go to zero as the forecast horizon is extended. As the forecast horizon moves out to, say, four periods, efficient policy still reacts to the output gap.

3.2 The Effect of Various Expectations Formations Processes

In the exercise above, we focused on central bank behaviour, assuming that people other than policy-makers did not have model-consistent expectations. In this section, we shift the focus to the private sector, and show how moving from backward-looking expectations to model-consistent expectations in goods/services, labour and foreign exchange markets can affect outcomes. We use the underlying structure of the model outlined in de Brouwer and O'Regan (1997), but adapt part of it – specifically, consumer prices, wages and the exchange rate – to allow for expectations to be based on different information sets (Appendix B). At one extreme, expectations are assumed to be fully model-consistent, (and hence, people know the reaction function of the central bank), while, at the other extreme, expectations of the future are formed only on the basis of lags of the particular variable. It is useful to spell this out in more detail.

Since the central bank has a low but non-zero target for consumer price inflation, the steady-state inflation rate is positive. Long-run inflation is modelled as a mark-up over unit labour costs and import prices in domestic currency:

$$Dp_t = -p_{t-1} + b_1 ulc_{t-1} + (1-b_1) ip_{t-1} \tag{3a}$$

where p is the price level, ulc is unit labour costs, ip is import prices in domestic currency, and b_1 is a parameter bounded between 0 and 1. As written, Equation (3a) states that adjustment to the long run is instantaneous, an assumption clearly rejected by the data (de Brouwer and Ericsson 1995). Accordingly, we modify Equation (3a) so that inflation adjusts gradually to its long-run mark-up:

$$\begin{aligned} Dp_t = {} & b_2\left[-p_{t-1} + b_1 ulc_{t-1} + (1-b_1) ip_{t-1}\right] + \\ & (1-b_2)0.25\left[b_3 \sum_{i=1}^{4} Dp^e_{t+i} + (1-b_3)\sum_{i=1}^{4} Dp_{t-i}\right] + b_4 gap_{t-1} \end{aligned} \tag{3b}$$

where *gap* is actual output less potential (estimated as a linear trend) and a superscript *e* indicates a model-consistent expected value at time *t*.[8] Inflation this quarter depends on the mark-up over unit labour costs and import prices (the 'inflation fundamentals'), but the transition path is also determined by expected inflation and the state of demand (Blake and Westaway 1996). Expected inflation is assumed to be model-consistent average expected inflation over the coming year when price and wage setters are explicitly forward looking, and is average quarterly inflation over the past year when they form their expectations solely on the basis of

8 The coefficients on the mark-up and leads and lags of inflation sum to unity in order to ensure that inflation equals the expression for inflation in Equation (3a) in the long run. The leads and lags of inflation are multiplied by 0.25 since inflation depends on the *average* lead or lag (and so if we used eight leads or lags, the second term would be multiplied by 0.125).

where inflation has been in the recent past. The response of the central bank to inflation and output is part of the model, and so when people have model-consistent inflation expectations they take this into account. If the central bank is not credible, in the sense that (some) people do not think the central bank will respond to inflation shocks, then we assume that those people's expectations of inflation are based on recent past inflation. If the central bank lacks credibility, people expect that shocks to inflation permanently affect inflation.

The mix of 'forward' and 'backward' price adjustment incorporated in Equation (3b) can be motivated by forward-looking optimising models which incorporate stickiness in price adjustment, due, for example, to staggered contracts (Taylor 1979, 1980) or non-continuous price setting (Calvo 1983); see Petursson (1995) and Cochrane (1995) for more recent applications. The mark-up increases when inflation expectations rise, because of convex costs of price adjustment.

The parameter b_3 is the weight on model-consistent expectations, taking a value of 1 when expectations are fully model-consistent. In this case, inflation is characterised as:

$$Dp_t = b_2\left[-p_{t-1} + b_1 ulc_{t-1} + (1-b_1) ip_{t-1}\right] + (1-b_2)0.25\sum_{i=1}^{4} Dp^e_{t+i} + b_4 gap_{t-1} \qquad (3c)$$

When expectations are extrapolative, however, inflation is:

$$Dp_t = b_2\left[-p_{t-1} + b_1 ulc_{t-1} + (1-b_1) ip_{t-1}\right] + (1-b_2)0.25\sum_{i=1}^{4} Dp_{t-i} + b_4 gap_{t-1} \qquad (3d)$$

The adjustment path also depends on the state of demand in the economy, with inflationary pressure falling when demand is relatively weak. In the long run, when there is no output gap and adjustment is complete, Equation (3b) collapses to Equation (3a).

We use estimates of parameters from earlier work to calibrate the inflation equation. On the basis of de Brouwer and O'Regan (1997), we assume that the coefficient on unit labour costs, b_1, is 0.7, and that the coefficient on the output gap, b_4, is 0.07.

The error-correction coefficient, b_2, is set to 0.25. Since we are interested in the properties of the economic system as people's expectations become more model-consistent, we set b_3 to 0 or 1 to model the extremes of extrapolative and model-consistent inflation expectations respectively.

Inflation is modelled as a mark-up on costs, and the first component of this is unit labour costs. We use the terms unit labour costs and wages interchangeably. De Brouwer and O'Regan (1997) assumed that wages growth depends on recent past inflation and the state of demand. When wages growth is a linearly homogeneous function of past inflation, real wages will tend to be maintained without explicitly including a real wage target: an inflation shock is passed onto wages since wages growth is simply a function of past inflation. When alternative expectations processes are used, however, the real wage has to be modelled explicitly.[9]

Accordingly, we assume that wages are set to preserve real purchasing power consistent with an equilibrium value:

$$ulc_t - p_t = (ulc - p)^{eqm} \tag{4a}$$

where the superscript *eqm* denotes the equilibrium real wage that is consistent with the inflation process and target. In the simple model used here, the equilibrium real wage is derived from the inflation equation. Assuming that import prices in domestic currency grow at the same rate as domestic prices in the long run, Equation (3a) can be rewritten in terms of the real wage, which implies an equilibrium real wage of Dp / b_1.

Equation (4a) can be rewritten as a dynamic process for real wage growth, with adjustment to the long run also depending on the state of demand in the economy:

$$Dulc_t = E(Dp_t) + g_1\left[(ulc - p)^{eqm} - (ulc_{t-1} - p_{t-1})\right] + g_2 gap_{t-1} \tag{4b}$$

9 If there is no explicit real wage targeting by wage setters, such that nominal wages depend only on future expected inflation, then real wages will fall when there is an unanticipated rise in inflation.

Wage setters do not know current inflation, so they set nominal wage growth for the current period with expected inflation in mind. If expectations are rational (that is, model-consistent), then $E(Dp_t)$ is given by the expected value of Equation (3c) at time t – Dp_t^e – which is simply the inflation equation at time t without the inflation surprise. Since the inflation equation contains future expected values of inflation, the wages process is also forward looking. If expectations are extrapolations from the past, then $E(Dp_t)$ is given by some average of past inflation rates, which we assume to be average quarterly inflation over the past year, $0.25\sum_{i=1}^{4} Dp_{t-i}$. When there is a mix of model-consistent and extrapolative expectations, Equation (4b) becomes:

$$Dulc_t = g_3 Dp_t^e + (1 - g_3)0.25\sum_{i=1}^{4} Dp_{t-i} + g_1\left[(ulc - p)^{eqm} - (ulc_{t-1} - p_{t-1})\right] + g_2 gap_{t-1} \qquad \text{(4c)}$$

where g_3 is 1 when wage-setters' expectations are model-consistent and zero when they are extrapolative.[10] In the long run, when adjustment is complete and output is at potential, real wages equal their equilibrium value, regardless of the way in which expectations are formed. Real wage adjustment in Australia is typically a slow process, and so we assume a low speed of adjustment coefficient, with g_1 set to 0.1. Following de Brouwer and O'Regan (1997), we set g_2 to 0.17 (and so the labour market is more sensitive to excess demand pressures than is the mark-up in consumer prices).

Consumer prices are also a mark-up over import prices, which are affected by movements in world prices and the nominal exchange rate, with gradual, but eventually complete, pass-through (see Appendix B for the pass-through equation). World prices are assumed to be exogenous, but the exchange rate is not. While the nominal exchange rate is unpredictable in the near term, over longer periods of, say,

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[10] This specification assumes that wage contracts are written only for the current quarter. If contracts are longer and if expectations are forward looking, then longer leads of inflation will enter the equation. While we do not report the results of extending wage contracts, the effect is to lengthen the adjustment process. The qualitative results of the analysis in Sections 3.2 and 3.3 are unaffected.

quarters and years, it can be explained by inflation differences between countries, the terms of trade and the real short-term interest differential (Tarditi 1996).

We assume that the real exchange rate comprises forward-looking and backward-looking elements, in the form:

$$\begin{aligned} rtwi_t = {} & d_1\left[\sum_{i=0}^{n}(\tilde{r}^e_{t+i} - r^{*e}_{t+i}) + \sum_{i=0}^{n}(tot^e_{t+i} - tot^{eqm}) + tot^{eqm}\right] + \\ & (1-d_1)\left[tot_{t-1} + 0.35(\tilde{r}_t - r^*_t) + 0.30(\tilde{r}_{t-1} - r^*_{t-1}) + 0.25(\tilde{r}_{t-2} - r^*_{t-2}) + 0.10(\tilde{r}_{t-3} - r^*_{t-3})\right] \end{aligned} \tag{5a}$$

where an asterisk denotes a foreign variable, *tot* is the terms of trade, *rtwi* is the real exchange rate in terms of domestic currency (so a rise is an appreciation), $\tilde{r}$ is the real interest rate less the risk premium, and *r* is the real interest rate.[11] If the foreign exchange market is forward looking, the real exchange rate is:

$$rtwi_t = \sum_{i=0}^{n}(\tilde{r}^e_{t+i} - r^{*e}_{t+i}) + \sum_{i=0}^{n}(tot^e_{t+i} - tot^{eqm}) + tot^{eqm} \tag{5b}$$

and appreciates when monetary policy is expected to be tighter or the terms of trade is expected to rise. This derivation is based on the uncovered interest parity condition (for example, see McKibbin and Sachs 1991). The more temporary is the expected movement in 'fundamentals', the smaller is the effect on the real exchange rate. If the equilibrium terms of trade rises, the real exchange rate moves immediately to its new equilibrium when expectations are fully forward looking, but temporary changes in the expected terms of trade have only temporary effects on the real exchange rate. In this formulation, the exchange rate is a jumping variable.

If the foreign exchange market uses only current and past information, then the real exchange rate is:

$$rtwi_t = tot_{t-1} + 0.35(\tilde{r}_t - r^*_t) + 0.30(\tilde{r}_{t-1} - r^*_{t-1}) + 0.25(\tilde{r}_{t-2} - r^*_{t-2}) + 0.10(\tilde{r}_{t-3} - r^*_{t-3}) \tag{5c}$$

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[11] For the purposes of this model, we assume that the neutral real rate for Australia is 3.5, which is higher than the average world real interest rate since 1980. We call the difference between 3.5 and the world average real rate the risk premium. Implicitly, a rise in the risk premium induces a depreciation of the Australian dollar.

and responds to the most recent terms of trade and to current and lagged interest differentials. This formulation captures the empirical regularity that the exchange rate is highly responsive to the terms of trade and tends to appreciate steadily over time in response to tighter monetary policy (Gruen and Wilkinson 1991; Blundell-Wignall, Fahrer and Heath 1993; Tarditi 1996; de Brouwer and O'Regan 1997). Even in this scenario, the real exchange rate adjusts quickly, as is typical of asset prices in general. In the long run, the real exchange rate is determined by the terms of trade. The effect of different forward and backward-looking behaviour can be identified by shifting d_1 in Equation (5a) between 1 and zero. Since the real exchange rate also enters the output equation, it provides a link between the real cash rate, output and inflation.

We use the same data generating process for Australian output as de Brouwer and O'Regan (1997):

$$\begin{aligned} Dy_t = {} & a_1 - a_2 y_{t-1} + a_3 y^*_{t-1} + a_4 tot_{t-1} - a_5 rtwi_{t-1} + a_6 Dfy_{t-1} + a_7 Dfy_{t-2} + a_8 Dy^*_t \\ & - a_9 r_{t-2} - a_{10} r_{t-3} - a_{11} r_{t-4} - a_{12} r_{t-5} - a_{13} r_{t-6} \end{aligned} \tag{6}$$

where y is non-farm output, y^* is OECD output and fy is farm output (Appendix B). In the long run, Australian output is determined by foreign output, the terms of trade and the real exchange rate. Output falls below its long-run path when the real interest rate lies above the policy-neutral rate, which is the real rate when output is at potential and inflation is stable at the desired rate. Monetary policy affects activity over a period of time, but has no impact in the notional long run. Growth in farm output also has short-run effects on non-farm growth.

The data generating processes for foreign output, foreign prices, foreign real interest rates, farm output and the terms of trade are set out in Appendix B. The Fisher equation for the interest rate is:

$$r_t = i_t - p^e_t \tag{7}$$

where $p^e_t = (p^e_{t+4} - p^e_t)$ when inflation expectations are forward looking, and $p^e_t = (p_{t-1} - p_{t-5})$ when they are adaptive. We are implicitly assuming that it is the *ex ante* real interest rate which matters to output and the exchange rate.

This stylised representation of the economy embodies a simple transmission process. The policy instrument is the nominal cash rate. Monetary policy reduces inflation by generating output gaps and an appreciation of the exchange rate. A rise in the nominal interest rate raises the real interest rate which affects output indirectly through the real exchange rate and directly through other mechanisms (Grenville 1995), generating downward pressure on wages and inflation. The appreciation of the nominal exchange rate, induced by higher local interest rates, also directly lowers inflation by reducing the Australian dollar price of imports. Given the lag structure of the model, the policy control lags for output are shorter than for inflation, and the initial effects of policy on inflation are through the exchange rate, with the output effects taking relatively longer.

To close the model we need to specify the way in which monetary policy is set. Since we are interested in assessing the properties of the system for different types of expectations formation, we characterise monetary policy as a four-period-ahead-forecast Taylor-type rule. We use arbitrary 0.5 weights on inflation deviations and the output gap in both cases.[12] While not shown here, the outcome that forward-looking policy does better than policy based only on currently available data follows when price setters are also explicitly forward looking.[13]

Figures 5 and 6 set out the effects on the nominal interest rate, the real interest rate (of price and wage setters), annual inflation, annual wages growth, the output gap and the real exchange rate of an unanticipated 1 per cent rise in wages at time t-1 when the foreign exchange market uses, respectively, current and past values or expected future values of fundamentals. Each figure shows the outcomes for model-consistent and extrapolative expectations in consumer price and wage inflation. The impulses are shown as deviations from baseline.

Consider the effect of a temporary rise in nominal wages growth when the foreign exchange market uses current and past, but not future expected, values of fundamentals (Figure 5). The real interest rate rises as soon as policy-makers are aware of the wages shock, since policy-makers increase the nominal rate. The effect

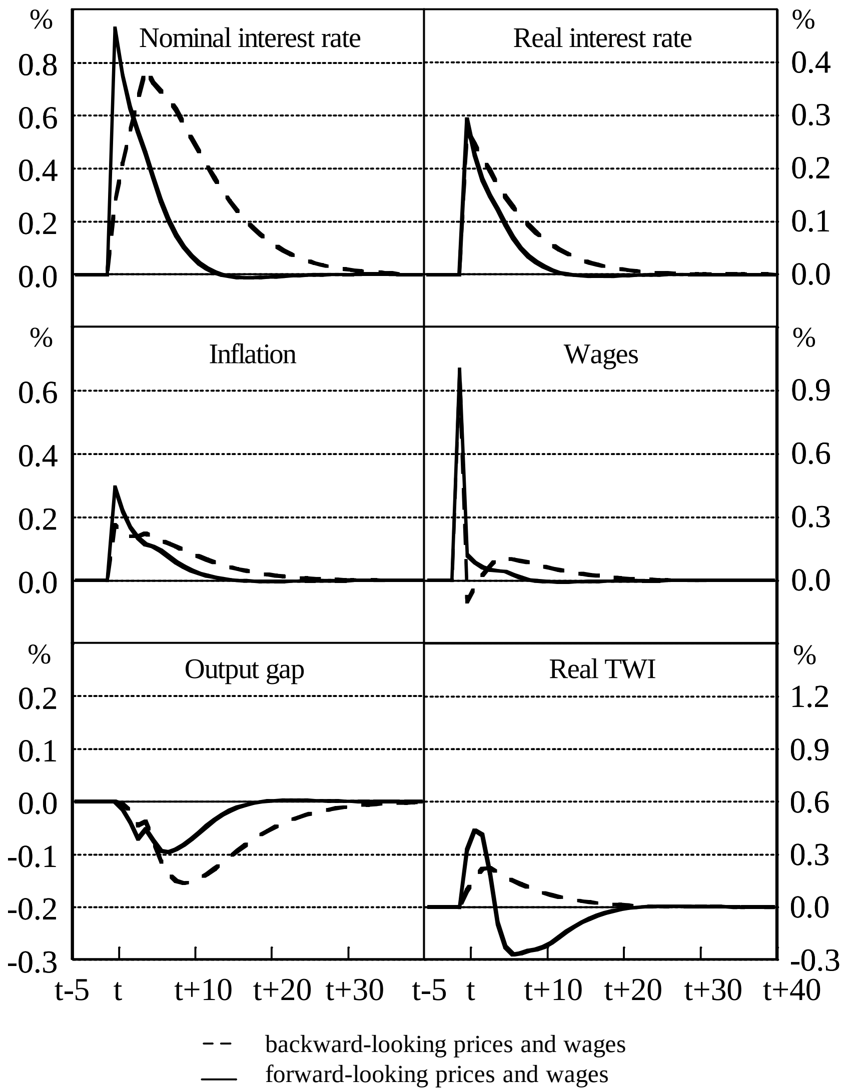
[12] While the 0.5 weights were used by Taylor, other work has shown that this weighting is probably neither efficient nor optimal (Bryant, Hooper and Mann 1993; Black, Macklem and Rose 1997; de Brouwer and O'Regan 1997).

[13] We assume that policy-makers use the inflation expectations of price and wage setters to set the nominal interest rate.

of the shock on inflation dissipates only gradually. But the more model-consistent are expectations of prices and wages, the faster is adjustment to equilibrium, and the smaller is the deviation of inflation from target and output from potential. Explicit forward-looking behaviour tends to reduce the variability in the economic system caused by shocks.

Figure 5: Wages Shock

Backward-looking foreign exchange market



The effect of the shock on the real exchange rate depends on the way expectations of consumer prices and wages are formed. If policy-makers use price and wage setters' inflation expectations in the Taylor-type rule, and if these inflation expectations differ to those of the foreign exchange market, then the real interest rates that affect output and the real exchange rate will be different from each other.

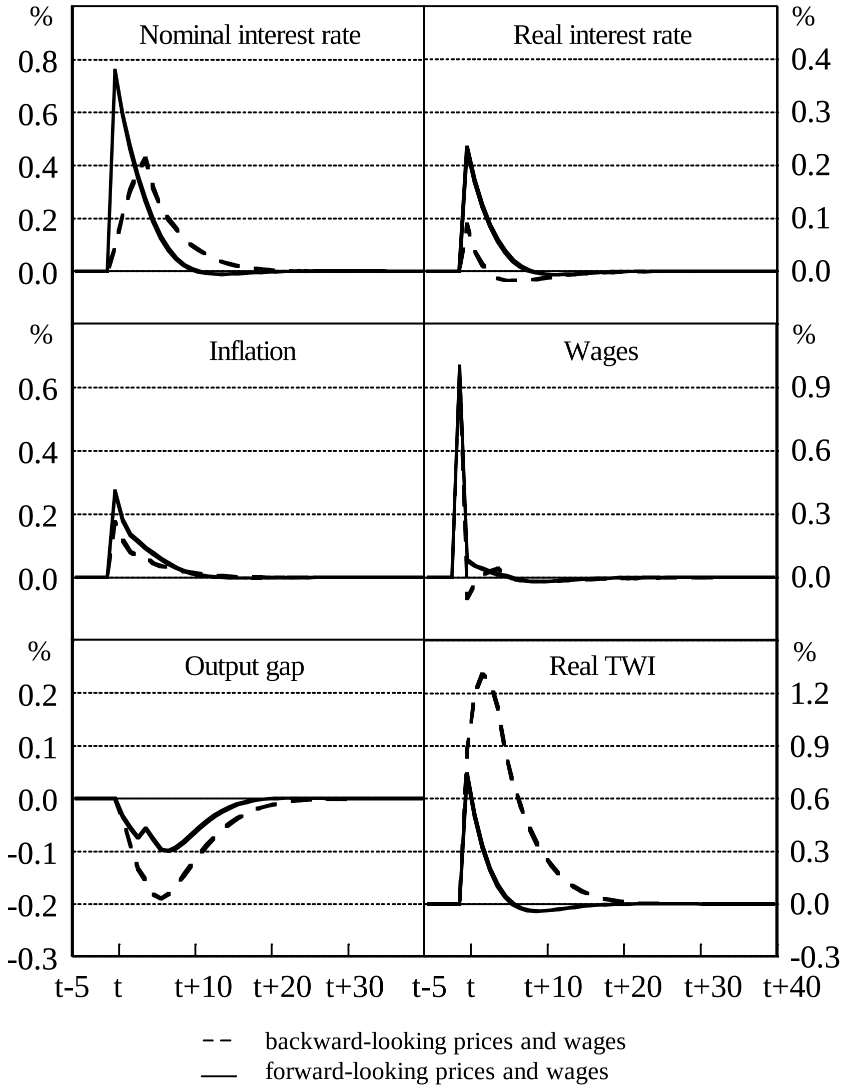
For example, if the inflation expectations of the foreign exchange market are formed on the basis of lags of inflation but price and wage setters have model-consistent expectations (as for Figure 5), then the foreign exchange market's *ex ante* real interest rate will initially rise more than that of price and wage setters (since their inflation expectations have not risen as much), but it will then fall below neutral since their inflation expectations will tend to be rising while price and wage setters' inflation expectations – and hence, nominal interest rates – are falling. Consequently, the exchange rate tends to appreciate more initially, but then depreciates. In other words, the exchange rate oscillates in response to inflation (and other) shocks when inflation expectations are adaptive in the foreign exchange market but model-consistent in goods and labour markets.

The story changes somewhat when the foreign exchange market is fully forward looking (Figure 6). Since the exchange rate depends on current and future real interest rates, it jumps up in response to tighter expected monetary policy. Consider what happens when price and wage setters' expectations of inflation are formed on the basis of recent past inflation. In this case, the sum of the foreign exchange market's *ex ante* real interest rates – and hence, the jump in the exchange rate – is bigger than when price and wage setters have model-consistent inflation expectations.[14] This is a standard result in rational expectations models of the exchange rate, since the degree of overshooting is higher, the more sticky are prices in goods and labour markets (Dornbusch 1976). Given that the jump in the exchange rate is larger when the foreign exchange market is forward-looking but price and wage setters form their expectations only on the basis of what has happened in the past, the output gap is larger and the fall in import prices is greater, making the net inflationary impulse from the wages shock smaller than in the explicitly forward-looking case (for a given set of reaction coefficients in a simple rule). Note that the exchange rate does not oscillate in this case of bifurcated inflation expectations, but overshoots.

[14] The foreign exchange market's *ex ante* real interest rate initially falls, since their inflation expectations are initially higher than those of the backward-looking price and wage setters, but this is later reversed, with the net effect a rise in the real interest rate differential.

Figure 6: Wages Shock

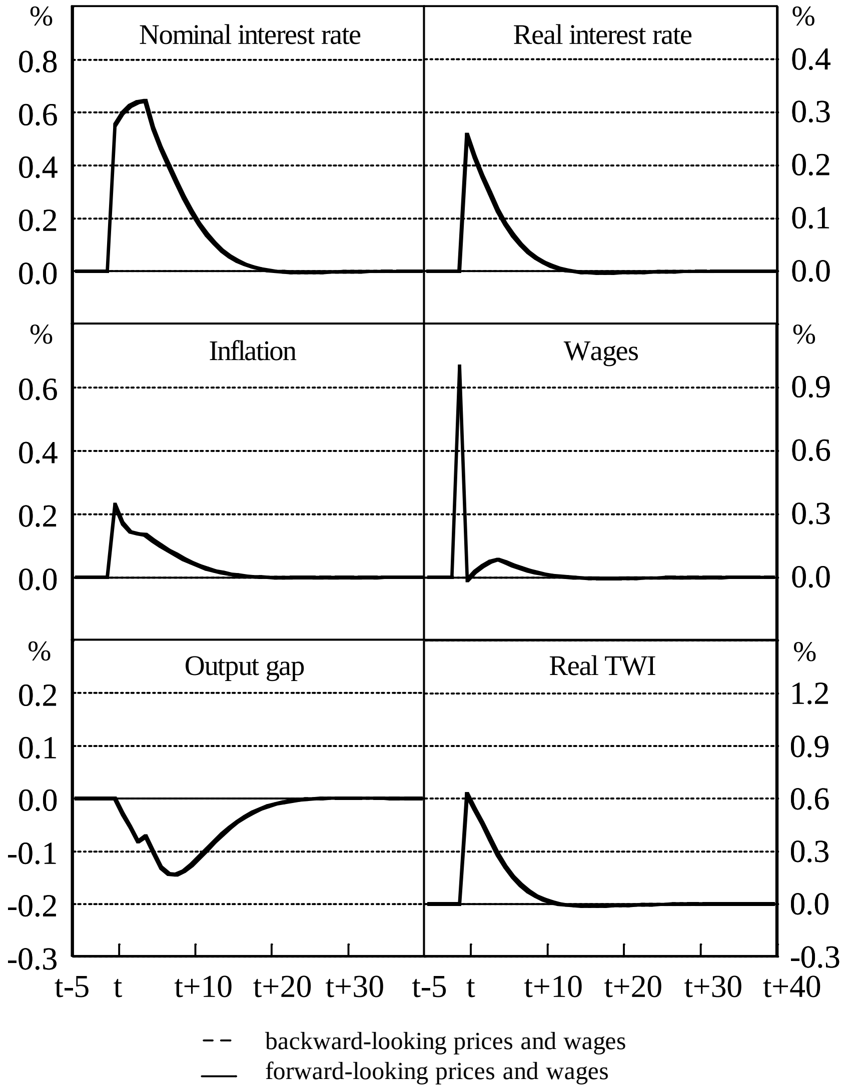
Forward-looking foreign exchange market



The assumption that goods, labour and foreign exchange markets are either fully ‘backward-looking’ or fully ‘forward looking’ is extreme. Consider, therefore, what happens when expectations draw on a mix of past and model-consistent values. Figure 7 shows the effect of a temporary wages shock when there is an arbitrary fifty-fifty mix of the two cases examined above. Since expectations are the same for all sectors, the system does not oscillate (since policy-makers are forward-looking) and there is only very moderate overshooting of the exchange rate. The inflation and output gap effects are, not surprisingly, an average of the other results. Under this particular policy rule, the nominal and real interest rates do not rise immediately to their respective peaks; there is some interest rate smoothing.

Figure 7: Wages Shock

Equal weighting of backward and forward-looking expectations



3.3 Optimal Policy

Given the basic underlying model and simple forward-looking policy reaction function, the way expectations are formed in goods and services, labour and foreign exchange markets matters to the way the economy responds to a shock to inflation (and implicitly to other variables in the system). The policy rule used in Section 3.2, however, is a simple feedback rule, and is neither efficient nor optimal. It is not efficient since the reaction weights (most probably) do not minimise the variability in inflation for a given variability in the output gap. And it is not optimal since it is only a simplification of the very complex rule that would result were the central bank to minimise its loss function, defined over forecasts of deviations of inflation from target and output from potential, subject to the equations that describe the economy.

The issue we examine in this section is whether policy-makers who set the instrument optimally can compensate for the lack of model-consistent behaviour elsewhere in the economy. In other words, are the inflation and output variability outcomes different for the various expectations processes when policy-makers set policy optimally, knowing what the expectations processes are?

To do this, we follow the characterisation of optimal policy outlined by Debelle and Stevens (1995) and Lowe and Ellis (1997). The central bank minimises a loss function – defined as deviations of forecast inflation from target, deviations of forecast output from potential, and the change in nominal interest rates – subject to the set of equations that describe the economy, to solve for a time path of its instrument, the nominal cash rate. This exercise is conducted every period, as new information is processed and forecasts are revised.[15] Clearly, the path of the nominal cash rate that is produced by this exercise depends on the model used, but we use it to demonstrate some features of optimal policy in the face of different expectations processes.

The loss function is given as:

$$\sum_{t=0}^{L}\left[\, l(gap_t^f)^2 + (1-\ l)(p_t^f - p^T)^2 + w\,(i_t^f - i_{t-1}^f)^2 \right] \qquad (8)$$

where f denotes the current forecast of the relevant variable. The larger is w, the more the central bank wants to smooth interest rates. We assume that w is 0.1

[15] A Lagrangean was derived from the loss function expressed over the period $t = 0$ to $t = 40$, with the constraints being the behavioural equations for the endogenous variables in each period. This expression was differentiated with respect to the policy variable (nominal interest rates) and endogenous variables at each point in time, and the corresponding Lagrange multipliers. The result is a system of 861 linear equations with algebraic terms for exogenous, endogenous and policy variables. The optimal path of interest rates is obtained by solving this system simultaneously for the interest rate, endogenous variables and Lagrange multipliers, given that the exogenous variables take their expected values. As in the Taylor-rule case, the actual realisation for the current period becomes part of the set of starting values for the next iteration. The exercise is repeated 200 times, using the first 200 shocks from de Brouwer and O’Regan (1997).

(Lowe and Ellis 1997). While this number affects the inflation/output variabilities in absolute terms, it does not affect the relative outcomes. The parameter λ is the weight on deviations of output from potential in the loss function, and is zero if the central bank is only concerned with stabilising inflation around the target.

We assume that price/wage inflation expectations and foreign exchange markets are either fully explicitly forward-looking or are keyed only off past values, yielding four possible scenarios. We assess the outcomes for the same set of shocks in order to directly compare the variance properties of the system for different expectations processes, but we readily acknowledge that the 'true' errors would most likely be different under each representation. Figure 8 shows the different outcomes for the variability of inflation and output for each of these scenarios using different weights on inflation and output in the objective function.

Figure 8: Optimal Policy Under Different Expectations Processes

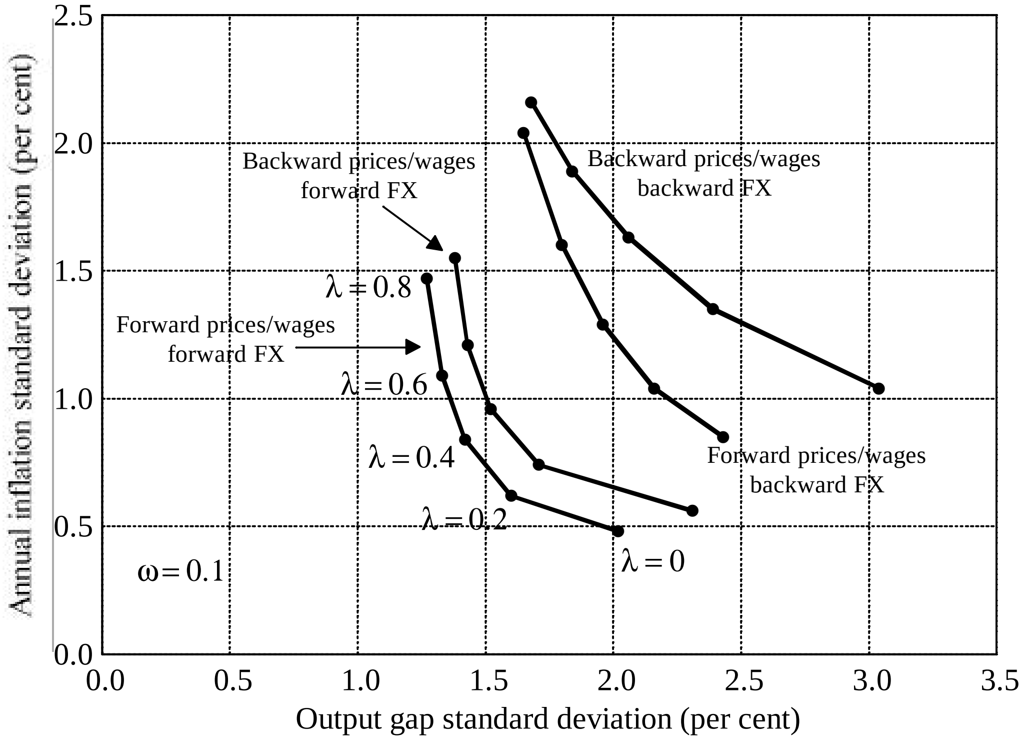


Figure 8 has three distinguishing features. The first is that the optimal policy outcomes differ depending on the expectations processes of other groups in the economy: the 'best' that policy-makers can do to reduce the variability in inflation and output depends on the structure of the economy that they have to work with. Policy-makers can reduce the variability in inflation and output most when goods, labour and foreign exchange markets are all forward-looking with model-consistent expectations, and least when markets form their expectations about the future only using past information. When people have model-consistent expectations, they know that shocks affect policy-makers' forecasts of the economic system, and they adapt their behaviour accordingly. They know, for example, that policy will respond to an inflation shock, and so they change their forecasts.

Second, the schedule which traces out the optimal outcomes becomes more convex the more explicitly forward-looking is behaviour. In other words, the reduction in the variability in inflation comes at a smaller cost to increased output variability. In this model, for example, when people focus only on the past, the 1 percentage point reduction in the standard deviation of inflation that is achieved by putting maximum weight on inflation in the objective function costs about a 1¼ percentage point rise in output variability. But when people form expectations based on the model of the economy, including how the central bank behaves, this cost is reduced to ¾ percentage point.

Stabilisation policy is enhanced if people take account of the way the economy works – including the fact that the central bank reacts to inflation – when they form their expectations about the future. This is perhaps one reason why many central banks in developed countries have adopted explicit inflation targets. Such targets focus people's attention on the future and are a strong statement that central banks are serious about maintaining low and stable inflation. In turn, this provides people with information about the likely path of inflation in the future, and helps to anchor inflation expectations to the inflation target. It also underscores why central banks have placed particular emphasis on establishing the credibility of their inflation target regimes.

The third feature is that there is a notable difference between outcomes when, on the one hand, inflation expectations in goods and labour markets are model-consistent but those in the foreign exchange market are backward looking, and when, on the other, inflation expectations in goods and labour markets are backward-looking but those in the foreign exchange market are model-consistent. In other words, the way in which expectations processes differ between markets matters. The system in which the foreign exchange market is model-consistent, and price and wage setters are not, yields the better outcome. The explanation is twofold. First, the exchange rate appreciates more in response to inflation shocks when inflation expectations in the foreign exchange market are model-consistent, thereby lowering the variability in inflation. Second, inflation expectations in the foreign exchange market which are extrapolations of past inflation generate cycles in the real exchange rate and, therefore, output and inflation, which induces more variability in inflation and output.

What is not evident from Figure 8 is what happens to the variability of the instrument, the nominal cash rate. The variability of changes in the cash rate falls substantially as expectations become more model-consistent. For example, when expectations of the future are based only on recent history, the standard deviation of changes in the cash rate is 2.5 per cent, but it is 0.3 per cent when expectations are all model-consistent (for a weight of one on inflation in the objective function). Implicitly, policy needs to be less activist when people are explicitly forward-looking and the central bank is credible.

4. Conclusions

The evidence on inflation expectations is mixed, with the empirical evidence in this paper suggesting that inflation expectations are a combination of simple extrapolation from the past and explicit consideration of what is likely to happen in the future, including the expected behaviour of the central bank. There are also differences between groups of people in the economy, with, for example, financial market economists' inflation expectations being much more consistent with rational expectations than households' expectations. The tests in this paper are not exhaustive, and so this assessment is only tentative.

We also examine some policy implications that arise from the different ways in which expectations can be formed. Since we present and analyse these implications using a model, the assessments are, to some extent at least, model dependent. We have three main conclusions.

First, inflation and output are substantially less variable when policy-makers are forward looking, setting interest rates using model-consistent expectations of inflation and the output gap. For the particular model used, forecasts of inflation and the output gap four quarters out are more efficient than forecasts over other horizons if interest rates are set by a Taylor-type rule. Given that the output gap contains information about future inflation, this implies that policy is reacting to forecasts of inflation four to seven quarters ahead.

Second, the effect of shocks depends on how private-sector expectations are formed, with forward-looking behaviour being more stabilising than simple extrapolations from the recent past. This additional stability is accounted for by people recognising that the central bank will respond to 'shocks' in order to stabilise inflation and growth. For example, if people think that the central bank will accommodate inflation shocks, but the central bank in fact does *not* do so (which is the case of an inflation target with no credibility), then inflation is still tied to the target in the medium term – because there is a policy response – but it is considerably more variable, as is output.

Also, in the simple model we use, it is straightforward to generate heterogeneous inflation expectations in the private sector, such that the *ex ante* real interest rates that affect activity and the exchange rate differ from each other. This can induce either oscillations or overshooting in the exchange rate (depending on the particular mix of expectations), with implications for the variability of inflation and output.

Third, optimal policy – by which policy-makers set a path for current and future interest rates which minimises variations in inflation around target and output around potential – does better than a simple rule. But expectations about the future which are only simple extrapolations from the past produce more variability in inflation and output than more explicitly forward-looking behaviour, and optimal policy cannot fully compensate for this difference in expectations (given that the shocks are the same in each case). In this sense, policy-makers have to do what they can, given the constraints imposed on them by the structure of the economy.

Appendix A: A Test for the Rationality of Inflation Expectations

In this appendix we formally test for rationality. The standard test for rationality of inflation expectations involves regressing actual inflation on what inflation is expected to be for that period:

$$p_t = g + \Phi_t^e + e_t \tag{A1}$$

If the survey measure is an unbiased predictor of actual inflation, then $g = 0$ and $d = 1$. The broad conclusion from the literature is that surveys of inflation expectations are usually not consistent with rational expectations (Roberts 1997). Table A1 presents the results of estimating Equation (A1) for the MMS measure of financial market economists' quarterly headline inflation expectations and the Melbourne Institute's households' annual inflation expectations.[16]

Table A1: Test of Rational Expectations – Equation (A1)

	Financial Market Economists (The dependent variable is quarterly headline inflation)	Households (The dependent variable is annual underlying inflation)
Constant (g)	-0.21	-2.06
	(0.08)	(0.56)
Expected inflation (d)	1.17	0.99
	(0.06)	(0.09)
R-bar-squared	0.89	0.71
Test that $g = 0$, $d = 1$	F(2,47) = 3.9 [0.03]	Chi-square(2) = 97.1 [0.00]

Notes: Standard errors are reported in ( ) and marginal significance is reported in [ ]. Since the Melbourne Institute expected inflation series is an annual rate, estimating a regression on a quarterly frequency induces an MA(3) process in the residual. The standard errors and exclusion tests are Newey-West (1987) adjusted using the Robusterrors option in RATS (and the exclusion statistic in this case is a Chi-square statistic).

In both cases the null hypothesis of rational expectations is rejected, although the rejection is clearly stronger for households' expectations than for financial market economists' expectations.

16 The Melbourne Institute survey measures inflation expected over the coming year, and so in this case annual inflation is regressed on the survey measure one year earlier.

Appendix B: A Framework for Analysis

B.1 The Model in de Brouwer and O'Regan (1997)

Most equations are written in error-correction form to capture long-run tendencies and relationships between variables, as well as dynamics. Parameters are generally estimated. The specifications of the equations, diagnostics and comments are given below. Numbers in parentheses ( ) are standard errors. Numbers in brackets [ ] are p-values. When lags of a variable enter an equation, the p-value for a joint test of their significance is given. All variables except interest rates are in log levels multiplied by 100. Equations are estimated using quarterly data from 1980:Q3 to 1996:Q3. The analytical framework draws on a number of published Bank papers and the contribution of several Reserve Bank economists, especially David Gruen, Geoff Shuetrim and John Romalis.

Endogenous Variables

Output

$$\begin{aligned} Dy_t = {} & a_1 \underset{(0.05)}{-0.23} y_{t-1} \underset{(0.06)}{+0.27} y^*_{t-1} \underset{(0.05)}{+0.06} tot_{t-1} \underset{(0.05)}{-0.05} rtwi_{t-1} \underset{[0.08]}{+0.01 D fy_{t-1} + 0.02 D fy_{t-2}} \underset{(0.18)}{+0.95} Dy^*_t \\ & \underset{[0.00]}{-0.03 r_{t-2} - 0.05 r_{t-3} + 0.10 r_{t-4} - 0.16 r_{t-5} - 0.06 r_{t-6}} \end{aligned} \tag{B1.1}$$

ARCH(4) test: 1.62[0.81] LM(4) serial correlation : 4.61[0.42] $\bar{R}^2 = 0.53$
Jarque-Bera test: 1.44[0.49] Breusch-Pagan test: 17.7[0.06] Standard error: 0.60

where y is non-farm output, y^* is OECD output, *tot* is the terms of trade, *rtwi* is the real TWI, r is the real cash rate and *fy* is farm output. The coefficients on the lagged levels of the terms of trade and real exchange rate are calibrated so that a 10 per cent rise in the terms of trade boosts output by 2.4 per cent and a 10 per cent appreciation of the real exchange rate reduces output by 2 per cent in the long run. The equation is based on Gruen and Shuetrim (1994) and Gruen, Romalis and Chandra (1997).

Prices

$$Dp_t = a_2 - \underset{(0.01)}{0.10} p_{t-1} + \underset{(0.01)}{0.06} ulc_{t-1} + \underset{(0.01)}{0.04} ip_{t-1} + \underset{(0.03)}{0.13} Dulc_t + \underset{(0.01)}{0.02} Dip_{t-3} + \underset{(0.02)}{0.07} gap_{t-3} \qquad \text{(B1.2)}$$

ARCH(4) test: 2.79[0.59] LM(4) serial correlation : 3.51[0.48] $\bar{R}^2 = 0.89$
Jarque-Bera test: 2.59[0.27] Breusch-Pagan test: 10.3 [0.07] Standard error: 0.24

where p is Treasury underlying CPI, ulc is a measure of underlying unit labour costs, ip is tariff-adjusted import prices and gap is actual less linear-trend output. The restriction that the coefficients on prices, unit labour costs and import prices sum to zero is imposed. The equation is based on de Brouwer and Ericsson (1995).

Unit Labour Costs

$$\Delta ulc_t = \underset{(0.05)}{0.33} \Delta p_{t-1} + \underset{(0.05)}{0.67} \Delta p_{t-2} + \underset{(0.06)}{0.17} egap_{t-1} \qquad \text{(B1.3)}$$

ARCH(4) test: 5.48[0.24] LM(4) serial correlation : 4.13[0.39] $\bar{R}^2 = 0.28$
Jarque-Bera test: 0.08[0.96] Breusch-Pagan test: 4.43[0.22] Standard error: 0.46

where $egap$ is the output gap plus 1 per cent (which is an estimate of the output gap required to generate the disinflation that occurred over the sample period). The equation was estimated by generalised least squares to correct serial correlation, and with the restriction that the coefficients on lagged inflation sum to unity.

Real Exchange Rate

$$\begin{aligned} Drtwi_t = {} & a_4 + \underset{(1.72)}{7.25} dum_t - \underset{(0.08)}{0.32} rtwi_{t-1} + \underset{(0.12)}{0.33} tot_{t-1} + \underset{(0.32)}{0.36} dum_{t-1}(r_{t-1} - r^*_{t-1}) + \\ & \underset{(0.21)}{0.63}(1 - dum_{t-1})(r_{t-1} - r^*_{t-1}) + \underset{(0.19)}{1.32} Dtot_t - 0.14 Drtwi_{t-2} - 0.09 Drtwi_{t-3} - 0.17 Drtwi_{t-4} \\ & \hphantom{\underset{(0.21)}{0.63}(1 - dum_{t-1})(r_{t-1} - r^*_{t-1}) + 1.32 Dtot_t - 0.14 Drtwi_{t-2} - 0.09}[0.15] \end{aligned} \qquad \text{(B1.4)}$$

ARCH(4) test: 4.51[0.34] LM(4) serial correlation : 5.97[0.20] $\bar{R}^2 = 0.59$
Jarque-Bera test: 1.48[0.49] Breusch-Pagan test: 5.46[0.79] Standard error: 2.74

where dum is a dummy variable which takes a value of one for 1980:Q3 to 1984:Q4 inclusive and zero otherwise; and r^* is the world real short interest rate. The equation is based on Gruen and Wilkinson (1991), Blundell-Wignall, Fahrer and Heath (1993) and Tarditi (1996).

Import Prices

$$Dip_t = a_5 - \underset{(0.05)}{0.11}(ip_{t-1} - wpi_{t-1} + twi_{t-1}) - \underset{(0.04)}{0.53}(Dtwi_t - Dwpi_t) - \underset{(0.05)}{0.24}(Dtwi_{t-1} - Dwpi_{t-1}) \quad \text{(B1.5)}$$

ARCH(4) test: 0.51[0.97] LM(4) serial correlation : 4.59[0.33] $\bar{R}^2 = 0.78$
Jarque-Bera test: 3.42[0.18] Breusch-Pagan test: 4.96[0.17] Standard error: 1.42

where *wpi* is Australia's trading partner weighted average export prices and *twi* is the nominal TWI.

Exogenous Variables

Farm output, foreign output and foreign export price are estimated as 'trend correction' models by which growth in the variable is regressed against a constant and the deviation of the level from a linear trend. This implies that the exogenous variables are not random walks, but return to trend after a shock.

Farm Output

$$Dfy_t = a_6 - \underset{(0.09)}{0.32}(fy_{t-1} - fy_{t-1}^{trend}) \quad \text{(B1.6)}$$

ARCH(4) test: 3.60[0.46] LM(4) serial correlation : 10.7[0.03] $\bar{R}^2 = 0.15$
Jarque-Bera test: 179[0.00] Breusch-Pagan test: 17.65[0.00] Standard error: 8.32

where fy^{trend} is the trend level of farm output.

Foreign Output

$$\Delta y_t^* = a_7 - \underset{(0.03)}{0.05}(y_{t-1}^* - y_{t-1}^{*trend}) + \underset{[0.00]}{0.42}\Delta y_{t-1}^* + 0.20\Delta y_{t-2}^* \quad \text{(B1.7)}$$

ARCH(4) test: 8.32[0.08] LM(4) serial correlation : 2.50[0.64] $\bar{R}^2 = 0.25$
Jarque-Bera test: 1.51[0.47] Breusch-Pagan test: 0.50[0.92] Standard error: 0.36

where y^{*trend} is the trend level of OECD output, estimated from 1980:Q4 to 1996:Q3.

Foreign Export Price

$$Dwpi_t = a_8 - \underset{(0.04)}{0.10}(wpi_{t-1} - wpi_{t-1}^{trend}) + 0.36Dwpi_{t-1} + 0.22Dwpi_{t-2} \quad \text{(B1.8)}$$
$$[0.00]$$

ARCH(4) test: 3.29[0.51] LM(4) serial correlation : 7.12[0.13] $\bar{R}^2 = 0.24$
Jarque-Bera test: 1.74[0.42] Breusch-Pagan test: 0.12[0.99] Standard error: 1.05

where wpi^{trend} is the trend of the Australian trading partner weighted average of world export prices. The trend was estimated over 1980:Q3 to 1996:Q3, while Equation (A8) was estimated over 1981: Q2 to 1996:Q3.

Terms of Trade

$$Dtot_t = a_9 - \underset{(0.04)}{0.13}tot_{t-1} + 0.11Dtot_{t-1} + 0.34Dtot_{t-2} + 0.36Dtot_{t-3} \quad \text{(B1.9)}$$
$$[0.00]$$

ARCH(4) test: 0.01[0.99] LM(4) serial correlation : 1.86[0.76] $\bar{R}^2 = 0.31$
Jarque-Bera test: 4.20[0.12] Breusch-Pagan test: 3.30[0.35] Standard error: 1.74

Foreign Real Interest Rate

$$r_t^* = \underset{(0.16)}{0.5} + \underset{(0.06)}{0.8}r_{t-1}^* \quad \text{(B1.10)}$$

ARCH(4) test: 9.11[0.06] LM(4) serial correlation : 6.89[0.14] $\bar{R}^2 = 0.72$
Jarque-Bera test: 1.86[0.40] Breusch-Pagan test: 3.840[0.05] Standard error: 0.64

Identities

Nominal Exchange Rate

$$twi_t \equiv rtwi_t - p_t + p_t^* \quad \text{(B1.11)}$$

where $p*$ is the foreign price level, a trade-weighted average of foreign consumer price indices.

See de Brouwer and O'Regan (1997) for a full description of the data sources.

B.2 Simulation Analysis

To assess the properties of the various rules, simulations were run for each rule and set of weights using the framework of equations described in Appendix B.1 above. Starting in equilibrium, the system was run over 200 periods using normal random errors for each equation which embody the historical covariance of those errors. The methodology follows Bryant, Hooper and Mann (1993, pp. 240–241).

For all the equations excluding the import price equation, a variance-covariance matrix of the residuals is generated from the variances of the equations and the correlation matrix of the historical residuals. The upper triangle of Table B2.1 shows the correlation coefficients, the main diagonal the variances of each of the series, and the lower triangle the covariances of the variables. The lower triangle of Table B2.1 is copied and transposed into the upper triangle to obtain the symmetric variance-covariance matrix, S. The variance-covariance matrix is transformed by a Choleski decomposition to yield a triangular matrix, P, which multiplied with its transpose gives the original matrix: $S = PP'$. In each period a vector of random errors, e_t, is drawn from a distribution of a standard normal random variable with a mean of 0 and a variance of 1. To calibrate the shocks with the historical covariances, e_t is multiplied by the lower triangular P, giving a vector $u_t = Pe_t$. The elements of u_t are the shocks used in the simulations. The same shocks were used in all the simulations. The simulations are performed using GAUSS (for the current-dated information rules) and Mathematica 3.0 (for the optimal policy and forward-looking Taylor-type rule cases), and the seed for the random number generator for 200 shocks is 1.

For the purposes of the simulations, the constant terms in the equations in Appendix B.1 are calibrated to place the system in equilibrium at the initial period. To place the system in equilibrium in the starting period, the initial value for output, prices, unit labour costs, the exchange rate, farm output, import prices, the terms of trade is 100. The calibrated constant term for output is -3.80, for inflation is 0.53, for the real exchange rate is -1.55, for import prices is 11.21, for world output is 0.26, for the terms of trade is 13.46, for world prices is 0.26, and for farm output is 0.56.

Table B2.1: Covariance-Correlation Matrix

	Farm output	Foreign output	Non-farm output	Unit labour costs	Price	Terms of trade	Real exchange rate	World export prices	World real interest rate
Farm output	**69.2451**	0.1494	0.0810	0.0649	-0.1442	-0.1713	0.1993	0.0209	-0.0824
Foreign output	0.4520	**0.1322**	-0.1078	-0.0329	0.1814	0.1677	-0.0225	-0.1627	-0.1803
Non-farm output	0.4028	-0.0234	**0.3567**	0.1134	-0.0035	-0.1389	0.0500	0.0324	-0.1206
Unit labour costs	0.2499	-0.0055	0.0313	**0.2141**	-0.1177	0.1579	0.0084	0.1636	-0.1487
Price	-0.2894	0.0159	-0.0005	-0.0131	**0.0582**	-0.0791	-0.1147	-0.2011	-0.0611
Terms of trade	-2.4811	0.1062	-0.1444	0.1272	-0.0332	**3.0292**	0.1348	0.3592	0.1806
Real exchange rate	4.5409	-0.0224	0.0817	0.0106	-0.0758	0.6425	**7.4982**	0.1636	-0.0311
World export prices	0.1831	-0.0623	0.0204	0.0798	-0.0511	0.6588	0.4720	**1.1104**	0.0494
World real interest rate	-0.4368	-0.0418	-0.0459	-0.0439	-0.0094	0.2004	-0.0543	0.0332	**0.4063**

B.3 The Stylised Model-consistent and Extrapolative Models

The price equations (consumer prices, unit labour costs and the exchange rate) in the model outlined earlier in Appendix B.1 are adjusted to take explicit account of different expectations processes. When expectations are fully model-consistent, these equations are as follows. Inflation is:

$$Dp_t = 0.25\left[-p_{t-1} + 0.7ulc_{t-1} + 0.3ip_{t-1}\right] + 0.1875\sum_{i=1}^{4} Dp^e_{t+i} + 0.07\,gap_{t-1} \qquad \text{(B3.1)}$$

where p is the price level, ulc is unit labour costs, ip is import prices in domestic currency, gap is actual output less potential (estimated as a linear trend) and a superscript e indicates a model-consistent expected value at time t.

Growth in unit labour costs is:

$$Dulc_t = Dp^e_t + 0.1\left[(ulc - p)^{eqm} - (ulc_{t-1} - p_{t-1})\right] + 0.17\,gap_{t-1} \qquad \text{(B3.2)}$$

where the superscript eqm indicates an equilibrium value.

The real exchange rate is:

$$rtwi_t = \sum_{i=0}^{8} (\tilde{r}^{e}_{t+i} - r^{*e}_{t+i}) + \sum_{i=0}^{8} (tot^{e}_{t+i} - tot^{eqm}) + tot^{eqm} \qquad \text{(B3.3)}$$

where an asterisk denotes a foreign variable, *tot* is the terms of trade, *rtwi* is the real exchange rate in terms of domestic currency (so a rise is an appreciation), $\tilde{r}$ is the real interest rate less the risk premium, and r is the real interest rate.

When expectations are fully extrapolative, inflation is:

$$Dp_t = 0.25\left[-p_{t-1} + 0.7ulc_{t-1} + 0.3ip_{t-1}\right] + 0.1875\sum_{i=1}^{4} Dp_{t-i} + 0.07_4\, gap_{t-1} \qquad \text{(B3.4)}$$

Unit labour costs growth is:

$$Dulc_t = 0.25\sum_{i=1}^{4} Dp_{t-i} + 0.1\left[(ulc - p)^{eqm} - (ulc_{t-1} - p_{t-1})\right] + 0.17gap_{t-1} \qquad \text{(B3.5)}$$

And the real exchange rate is:

$$rtwi_t = tot_{t-1} + 0.35(\tilde{r}_t - r^*_t) + 0.30(\tilde{r}_{t-1} - r^*_{t-1}) + 0.25(\tilde{r}_{t-2} - r^*_{t-2}) + 0.10(\tilde{r}_{t-3} - r^*_{t-3}) \qquad \text{(B3.6)}$$

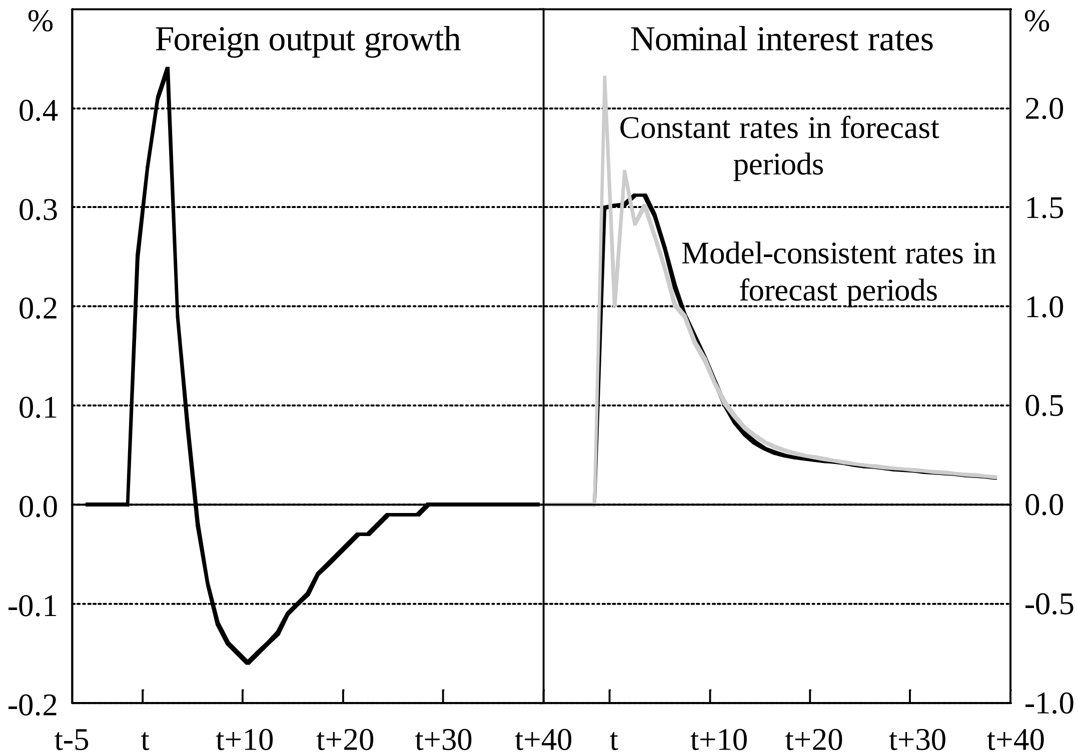
Domestic non-farm output, farm output, foreign output, foreign prices, foreign interest rates and the terms of trade are generated using the equations set out in Appendix B.1.

Appendix C: The Effect of Different Interest Rate Assumptions

This appendix sets out an example to show the effect on the variability of interest rates of different interest rate assumptions in forward-looking monetary policy rules. Figure C1 shows the effect of an anticipated 1 per cent shock to foreign output spread out over one year (as deviations from baseline). The left-hand side panel shows the shock itself, with foreign output rising over four quarters, and then easing back to its equilibrium value, as determined by Equation (B1.7) in Appendix B.1.

Figure C1: Interest Rate Response to a Foreign Output Shock

(Deviation from baseline)



The right-hand panel shows how nominal interest rates respond to this shock when policy-makers use a Taylor-type rule, responding to inflation and output forecasts four periods ahead, with a coefficient of 3 on the inflation forecast deviation and a coefficient of 1 on the output gap forecast. The shock is assumed to be anticipated, but the story is substantively the same if the shock is unanticipated. The grey line is the interest rate profile when the forecasts of inflation and output are generated assuming a constant nominal rate, and the black line is the profile when the policy-makers are assumed to use the Taylor-type rule in the forecast periods.

Forecasts are clearly less volatile and oscillatory in the model-consistent rate regime than in the constant rate regime. If the forecasts assume constant nominal interest rates, they do not take into account the policy response of policy to the shock, and so the initial policy response implied by the rule is larger than it needs to be. In the next period, policy has to correct the over-reaction. At higher reaction weights, these oscillations can become explosive.

If policy-makers are assumed to keep real, rather than nominal, interest rates constant in the forecast period, the results are very similar to the constant nominal interest rate outcome. This is because the shock assessed in this case is a real shock. When there is a nominal shock, such as an inflation shock, the system is considerably more variable when the nominal interest rate is kept constant than when the real rate is.

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