The Reserve Bank's forecasting performance

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For most of the period since 1994, the target range for annual Consumers Price Index (CPI) inflation, established by the Policy Targets Agreements (PTA), was 0 to 3 per cent. Over this period, actual CPI inflation has averaged 2 per cent. As one might expect, analysis shows that our medium-term CPI inflation forecasts since 1994 have been biased towards under-prediction, which is the subject of this article.

In any particular period, inflation is unlikely to be exactly as forecast, given that the economy is affected by unforeseeable events and inflation is far from perfectly controllable. However, it is important to have a good understanding of why inflation has evolved as it has, and not as predicted. We need to know whether particular events in the period under consideration have dominated inflation outcomes, or whether there is a fundamental problem with the policy process – such as a fundamental misunderstanding of the workings of the economy – that would systematically affect future monetary policy outcomes unless corrected.

In this article we focus particularly on our CPI inflation forecasting performance, but also examine our forecasts of other key macroeconomic variables, given their relevance for explaining our CPI forecasts.

We conclude that, in the mid-1990s, underestimation of growth, and overestimation of the economy's capacity to grow without generating inflation pressures, were the source of most of our under-prediction of medium-term CPI inflation. From 1998 until recently, the major factor explaining the under-prediction of inflation appears to have been sizeable and persistent differences between the assumptions we used for the path of the exchange rate and its actual evolution.

We also conclude that contributions to forecast inaccuracies have at times been made by our understanding of the non-inflationary output growth rate, the equilibrium exchange rate and exchange rate pass-through into CPI inflation. However, these factors do not appear to be systematic sources of inflation forecast bias.

1   Introduction

Most macroeconomic forecasters periodically examine their forecast performance in order to check their understanding of the workings of the economy and improve their forecasting capacity. Central banks, in particular, continually review their projection methodology and performance within the context of its relevance for the effective operation of monetary policy. This article discusses the Reserve Bank's forecast performance over the past decade, with a particular focus on Consumers Price Index (CPI) inflation.

Optimal monetary policy is forward-looking, taking account of time lags before policy actions affect the economy. For this reason, most inflation-targeting central banks use projections to guide policy. We do likewise, but we are relatively unusual among central banks in two respects: we publish relatively complete economic projections that are tied quite closely to the current monetary policy decision,[1] and we allow for monetary policy to evolve in the future depicted within those projections.

The primary reason we publish such projections is their value as a communication tool. Our projections provide a sense of where we currently believe the economy is headed, but just as importantly, also provide a framework for communicating our understanding of relationships within the economy. The implications of emerging information can then be assessed by both the Bank and financial markets against a well-articulated benchmark, thereby reducing uncertainty about our likely actions.

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[1]   The central banks of Britain and Sweden both regularly publish forecasts of inflation up to two years ahead. The Bank of Canada and the Reserve Bank of Australia publish less detailed information regarding projected inflation.

However, projections are not the "be all and end all" of monetary policy, and are highly conditional on the information available at the time the forecasts are prepared. They are almost invariably 'wrong' in some sense, due to the complexity and ever-changing nature of the economy, and a constant procession of unforeseeable events, such as large oil price movements, world trade policy changes, and droughts. Indeed, most variation in the economy comes from factors we cannot predict. In addition, economic data are often available only with a significant delay, and can be volatile and/or subject to measurement error and revision. Consequently, making projections as prominent as we do in communicating the rationale for policy actions carries with it the risk of observers imputing a spurious importance to the exact numbers contained in them, with attendant damage to our credibility.

Nonetheless, even though a set of economic projections cannot capture everything relevant to determining appropriate policy settings, it does reflect a central view of what we think is happening to the economy and how these forces will develop over time. It is important that we have a good grasp of how well we understand these factors.

An analysis of our historical forecast errors is one means of assessing our understanding of the economy and the operation of monetary policy over time. The inability to foresee the future means that we expect our projections to be wrong, but in a random way. If we are making non-random errors, it is important to understand why this has occurred and any implications for future projections and the operation of monetary policy. In this article we present the results of our most recent analysis of our forecast errors, with an emphasis on CPI inflation. We turn first to a brief description of key measures of forecast performance.

2 Assessing forecast performance

Allowing for the likelihood that economic outturns will be different from those projected, there are two basic yardsticks that can be used to measure forecast performance:

- A basic performance measure is how accurate the forecast is, in terms of the average size of its error. This can be measured by the mean absolute error or the root mean squared error.[2]

- Second, we can test whether or not forecasts are biased – ie whether they tend to consistently under- or over-predict.

We used these basic yardsticks in a recent review of our forecast performance, with particular emphasis on the issue of bias. Previous research has focused more on the accuracy of our projections, defined in terms of the average size of the error or squared error of the forecasts for particular variables. It has also tended to focus on our near-term forecast performance. The issue of bias, particularly at the longer horizons, which are generally most relevant for forward-looking monetary policy, has received less attention. Because economic cycles typically take several years to complete, and many cycles are required in order to get a range of different types of events, examination of bias requires very long samples to generate reliable results. It remains a moot point as to whether the sample period for this evaluation exercise is sufficiently long to give reliable results.

We also compared our projections for selected variables with those of some other forecasters. Comparing projections between one forecaster and another is problematic, as forecasts may be prepared at different times, with one forecaster having more recent data than another. In addition, the projections may have been produced for quite different purposes. However, with caveats, forecasting comparison can be a useful exercise.

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[2] For descriptions of these statistics see appendix 1.

3 The conditionality of Reserve Bank projections

Before assessing the properties of the Bank's published forecasts, it is useful to examine some of the issues around this process.

Prior to 1997, we framed our forecasts in terms of the question "What will happen to inflation if we don't change interest rates?" In addition, the real exchange rate was assumed to remain constant at its then current level – not reflecting that we thought this was the most likely outcome, but for consistency with the unchanged interest rate assumption. This approach was clearly not, and was not intended to be, a realistic representation of policy.[3] The projections were regarded as a useful tool for demonstrating the motivation behind the monetary policy decision, but they were not unconditional forecasts of the perceived most likely paths for each variable.

In the Forecasting and Policy System (FPS) model used at the Reserve Bank since mid-1997, a conditional monetary policy response is built into the model.[4] By construction, the projected interest rate path is one, but not the only one, that will result in an inflation projection consistent with the Policy Targets Agreement, given anticipated economic developments. In addition, the exchange rate is assumed gradually to trend back to a long-run equilibrium level, influenced along the way by the evolving interest rate path. In effect, these projections ask, "What do we have to do to keep inflation consistent with the Policy Targets Agreement?"

This monetary policy response is conditional on all other variables evolving exactly as projected, which is of course not considered particularly likely. New, unanticipated events inevitably arise. Moreover, like most economic forecasters, we project smoothly-evolving paths for economic variables, whereas in the real world economic developments tend to occur with greater volatility. For these reasons, we constantly stress the conditionality of the projections to discourage readers from misinterpreting our forecasts as a strongly-held view on future economic developments.

The forecast errors over the periods before and after mid-1997 must therefore be interpreted differently. Examining the forecasting performance of one variable in isolation in either period - and particularly across both - using traditional measures of forecast accuracy must be undertaken with this caveat in mind.[5]

We now turn to a brief description of our inflation forecasting performance.

4 Our inflation forecast performance

Over our sample period beginning in December 1994, we have on average significantly underestimated inflation in the CPI excluding interest rates, beyond the very near term. We have under-predicted annual inflation one year ahead by nearly 0.7 percentage points on average, and two years ahead by nearly 0.9 percentage points.[6] As one would expect, the size of our forecast errors increases as the

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[3] For this reason, if inflation was projected to go outside the target band, then we would occasionally assume a step adjustment in rates.

[4] For further information about the FPS model, see Reserve Bank of New Zealand (1997) and Hampton (2002).

[5] A further caveat to interpretation of our forecast errors is that they are also conditional on accepting others' views, such as The Treasury's forecasts of the fiscal position and *Consensus Economics* (or earlier, Organisation for Economic Co-operation and Development) forecasts of world growth.

[6] These data are adjusted for the large fall in Housing New Zealand rentals in 2001. We also examined quarterly inflation forecasts. Findings were entirely consistent; the bias in our quarterly inflation forecasts is at least 0.2 percentage points per quarter at these horizons.

projection horizon lengthens, reflecting the greater uncertainty inherent in looking further into the future. Key statistics are given in table 1 in appendix 2.

Note that there is a key period where we considerably overestimated inflation (1991-92). This period is not included in our analysis, both because of difficulties obtaining the background data, and because the disinflationary period of the early 1990s is conceptually different from the stable inflation period. If this period were to be included, there may be less evidence of bias in our average CPI forecast errors.

As discussed in section 3, in 1997 we changed the way in which our forecasts were generated. Prior to this, our projections incorporated largely flat-line technical assumptions for interest rates and real exchange rates. Subsequently, our projections have contained a conditional policy response, where the Reserve Bank is assumed to respond to projected inflation pressures in order to return inflation to an appropriate level. For short- to medium-term forecast horizons, our inflation forecasts were similar in terms of bias and accuracy under the two forecasting regimes, while at longer forecast horizons (8 to 10 quarters ahead) our inflation forecasts have in fact been less accurate since the adoption of conditional policy response forecasts (see figure 1).

Figure 1
Mean forecast errors for annual CPI inflation
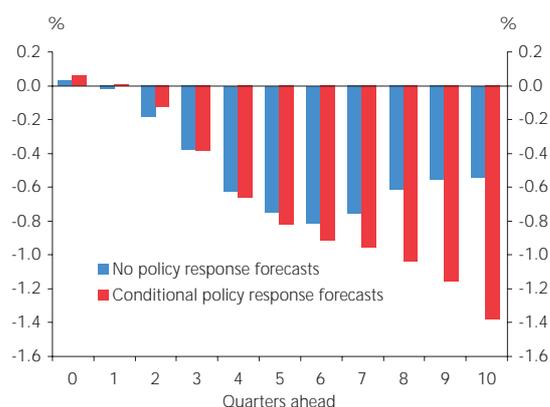
However, simply ascribing the different forecasting performance to the methodologies used in the two regimes is misleading, as the accuracy of our forecasts is strongly influenced by particular economic events during each period, including the "Asian crisis plus drought" event and the exchange rate cycle.

Comparison with other forecasters

We compared our annual CPI inflation forecasts since June 1992 with those of eight other forecasters.[7] Our CPI inflation forecasts have not been significantly more or less biased or accurate than those of most other forecasters.[8] However, two forecasters have produced medium-term inflation forecasts that are considerably less biased than ours. Key statistics comparing our inflation forecasts with these two are presented in table 3 in appendix 2.[9] We therefore examined their macroeconomic forecasts in greater detail and discuss the results throughout this paper.

International comparison

Because most central banks do not publish forecasts, there is not a great deal of information available regarding their forecasting performance. However, some key findings for foreign central banks and other public sector forecasters are given below.

- The Australian government's official forecasts have tended to under-predict year-ahead annual inflation by about 0.4 percentage points between 1978 and 1988, and over-predict by about the same amount from 1989 to 1999 (Richardson 2000).

- The International Monetary Fund April/May forecasts of following-year inflation for the G7 countries between 1990-96 tended to be too high (by about 0.3 percentage points), but less so than those of Consensus Economics (about 0.5 percentage points) (Batchelor 2001).

- The Federal Reserve Open Market Committee in the United States tended to over-predict year-ahead annual

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[7] The exact sample for each forecaster is dependent on available data.

[8] This conclusion contrasts slightly with previous research (see Reserve Bank of New Zealand 2001a), which had a smaller sample period and a slightly different methodology.

[9] A caveat to these results is that most of one forecaster's projections between May 1998 and September 2000 were published several weeks after the Bank finalised its projections. This includes the Asian crisis, a period during which the economic outlook was changing rapidly. However, even excluding this period, their inflation forecasts are less biased than our own.

inflation by around 0.4 percentage points on average during 1979 to 2001 (Gavin and Mandel 2002).

- In relation to the Bank of England's inflation forecasts, produced with an assumption of constant nominal interest rates, they have this to say: "During 1993 and most of 1994, the Bank's central forecasts were clearly too pessimistic about the path of future inflation. The forecasts made in November 1994 and February 1995 were, by contrast, too optimistic. Forecasts made from May to November 1995 were broadly on track. Quantifying these forecasting errors to date suggests a mean (absolute) error in the region of 1% one year ahead." (Haldane 1997).

This is by no means an exhaustive set of findings, but it illustrates that the Reserve Bank of New Zealand is not unusual in having experienced biased inflation forecasts from time to time.[10]

We now consider some of the possible causes of our CPI inflation forecast bias.

5   Possible causes of biased inflation projections

The process of creating our economic projections and finally reaching an Official Cash Rate (OCR) decision is outlined in figure 2.[11] Many different factors contribute to our final projections, and there are therefore several points at which bias could enter the process.

- Biased technical assumptions. Prior to 1997, the key technical assumptions were the interest rate and real exchange rate tracks, both of which were mostly held constant at the levels prevailing at the time the forecasts were prepared. Since mid-1997, both variables have been allowed to evolve through the projection, but the exchange rate's evolution still reflects a technical

assumption rather than a forecast. Any mechanical projection methodology, including the use of technical assumptions, can lead to biased estimates over a specific sample period.

- Biased fiscal and world growth forecasts. These forecasts are not made by the Reserve Bank, but are taken from other forecasters.[12] If these forecasts are biased, it could contribute to bias in the Bank's forecasts.

- Biased changes in data. Some data series, such as real Gross Domestic Product (GDP), are prone to revision, particularly in respect of the most recent data. If the latest data we receive are biased first estimates, this could cause biased forecasts.

- Biased understanding of economic relationships. If we make errors, such as overestimating how fast the economy can grow without causing inflation, miscalculating the impact of interest rates on activity, or misjudging the impact of the exchange rate on inflation, biased forecasts could result. It is therefore necessary to continually reassess the view of economic relationships as new information comes to hand.

- Biased judgement of 'special factors'. The FPS model is a useful tool for ensuring that the projections add up, both in an accounting and stock-flow consistency sense. However, FPS cannot capture all the complexities inherent in evaluating the current and future economic situation. Judgement is always applied to the FPS model in order to shape its output to reflect the special factors affecting the current outlook, and other non-model information, such as findings from our regular visits to businesses. If the judgement being applied is biased, this could also lead to biased inflation forecasts.

- Biased risk perception. We cannot build a full profile of perceived risks into our economic projections, but they are built into monetary policy decisions. If we were to have a biased perception of risks, this could lead to biased inflation outcomes. One way of measuring this is by assessing any bias between projected interest rates and actual interest rate decisions.

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[10]   Most of these analyses include the disinflation period of the early 1990s, when around the world, as in New Zealand, inflation was brought under control more quickly than generally anticipated.

[11]   For more information about the Reserve Bank forecasting process, see Drew *et al* (1998).

[12]   Fiscal forecasts are sourced from The Treasury. Forecasts of growth in our trading partners are sourced from Consensus Economics Inc. which survey a range of economic forecasters on a monthly basis and report average forecasts.

Figure 2
The monetary policy process
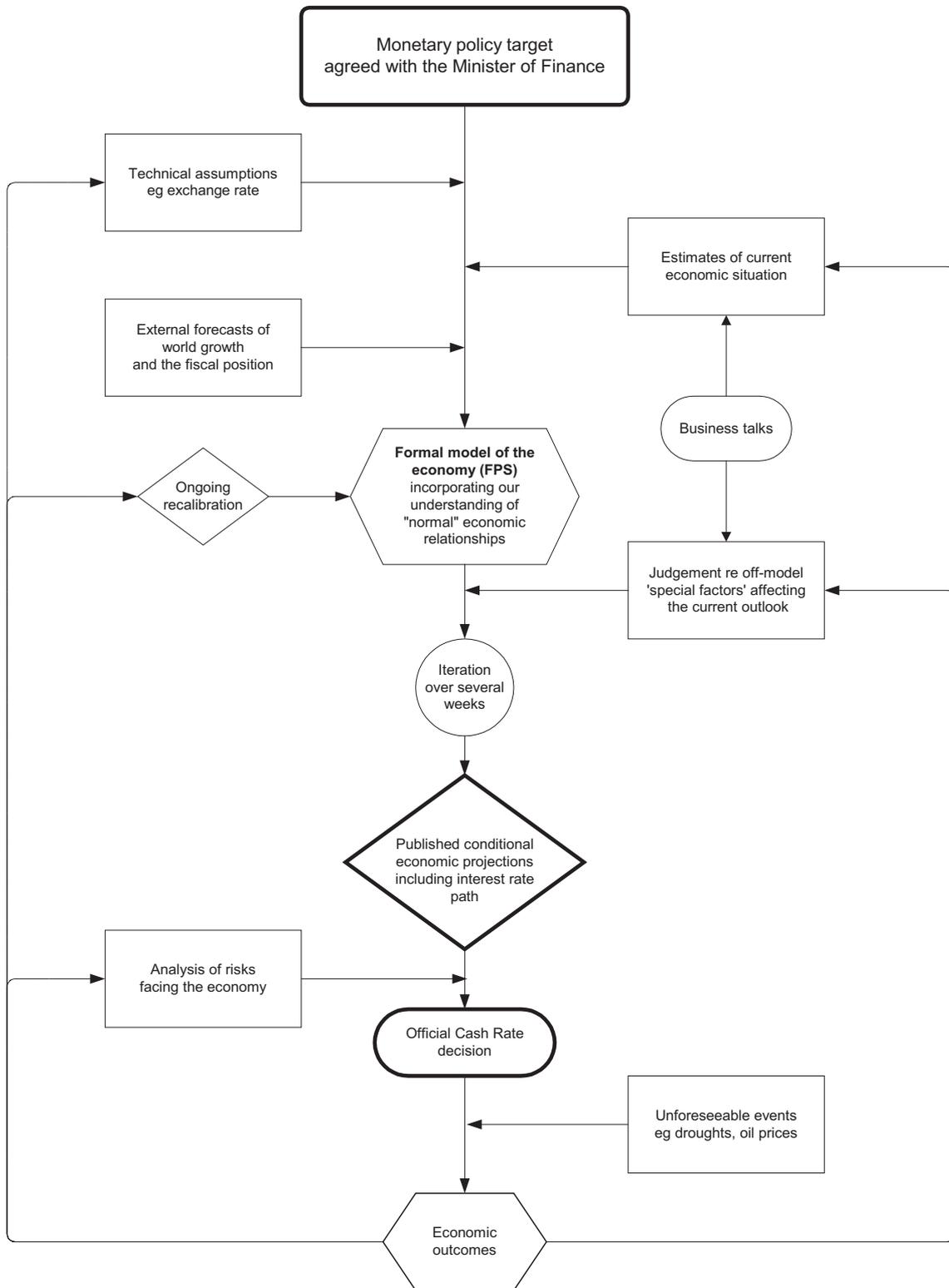
- Biased unforeseeable events. It is also possible that the pattern of unforeseeable events occurring over the forecast period could have a tendency to influence inflation predominantly in one direction or another, particularly over a limited sample period. Normally, forecasters rely on the pattern of unforeseeable future events being unbiased, particularly over longer time periods.

We now turn to the results of our investigations into the source of our inflation forecast bias. We examine each of the theoretically possible causes outlined above.

i)   Technical assumptions

The exchange rate is extremely difficult to forecast. We therefore make 'technical assumptions' about future values, with no claim that the given path is necessarily more likely than any other.

As discussed, prior to 1997, we used an assumption that the real exchange rate would stay constant at its then current level. By contrast, in the FPS model used since June 1997, the exchange rates (defined in terms of the Trade Weighted Index – TWI) is largely assumed to return to a long-run equilibrium level (although with some influence en route from interest rate differentials relative to other countries). The assumed long-run equilibrium can be adjusted over time. This essentially mechanical methodology should produce unbiased 'forecasts' over a number of full exchange rate cycles, to the extent that the assumption about the long-run equilibrium is correct. However, it may lead to errors being in the same direction for prolonged periods, depending on the nature of exchange rate cycles over the relevant periods, as shown in figure 3.

It can be seen that the exchange rate forecasts do not appear to be returning to the same equilibrium. We have revised down our estimate of the equilibrium long-run exchange rate since 1997-98. This earlier over-estimation contributed to our exchange rate over-prediction at that time.

We tended to over-predict the exchange rate when it was falling (as did other forecasters). Overall, we have a bias towards over-prediction in the sample period December 1994 to September 2002. The bias has been much more pronounced post-1997, which was the peak of the TWI cycle.

Figure 3
TWI levels and Reserve Bank assumptions
(3 quarter intervals)
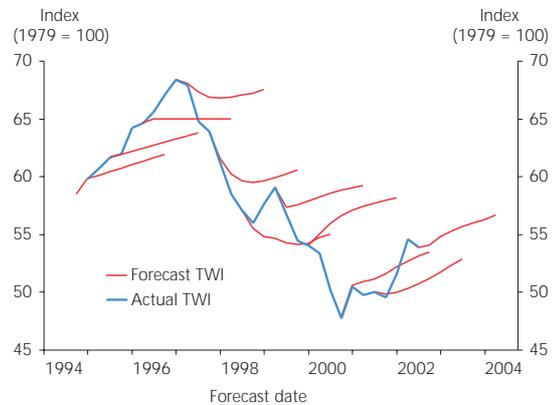
On average since March 1997, our one year-ahead forecasts have tended to be 7 per cent higher than the actual TWI, and two years out our forecasts have been 15 per cent higher (figure 4). There is some indication at the end of the period depicted in figure 3 that, as the exchange rate has started to rise, over-prediction has given way to under-prediction, as would be expected.

Figure 4
TWI mean projection errors (expressed in percentage level deviations)
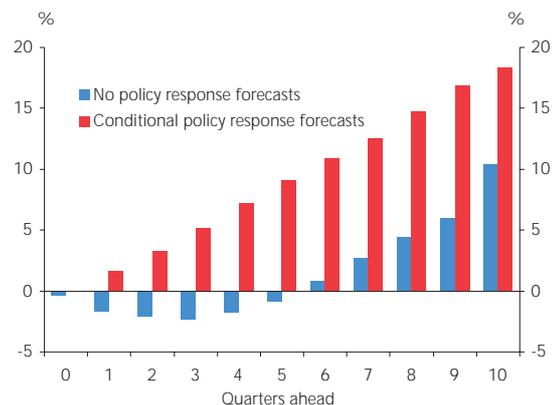
How much is the exchange rate bias likely to have contributed to our CPI inflation forecasting bias? An exchange rate fall makes the domestic currency price of imported goods rise, which causes CPI inflation to increase (depending on the level of exchange rate pass-through, among other factors). There is also a slower, second-round effect on inflation as the increase in exporters' incomes feeds into demand. If we

conservatively assume a TWI pass-through of 0.2, with half occurring in the first year, a 7 per cent movement in the TWI level would, all else being equal, lead to the CPI level being around 0.7 percentage points higher a year later. This would be enough to explain the observed CPI bias of 0.7 percentage points in the period since March 1997.[13]

We then compared our exchange rate forecasts with the two forecasters who had less biased CPI forecasts than we did. While one of the two forecasters may have had slightly better TWI forecasts, the other over-predicted it by a greater amount than we did over the sample period. Thus, exchange rate level forecasts alone cannot explain the difference in our inflation forecasting performance.[14]

ii) Fiscal and world growth forecasts

Any bias in externally-sourced forecast variables will affect the accuracy of our inflation projections to some degree. However, there was little evidence of bias in the fiscal forecasts we obtain from The Treasury. In addition, fiscal policy has been relatively stable since the Fiscal Responsibility Act 1994 was enacted, reducing the impact of fiscal impulses on the overall outlook.

It is also possible that biased world growth forecasts may have been a factor. Prior to 1998, we used Organisation for Economic Co-operation and Development (OECD) forecasts of industrial production. Since then, we have used Consensus Economics Inc forecasts of growth in our main trading partners. Only occasionally have we departed from these forecasts, each time reducing them. For example, during the Asian crisis and drought events over 1997/98, and also following recent equity market falls, we made slight adjustments out of concern that the externally-sourced forecasts did not fully reflect the then current overseas economic developments. The question of whether these forecasts are biased is difficult to examine because of the very short sample periods; more data are required to assess this.

iii) Estimation of demand pressure

When an economy is growing strongly, there tends to be more upward pressure on prices. However, GDP growth is not always the best measure of the 'heat' in the economy. Not all changes in GDP growth reflect changes in demand, and hence changes in potential inflation pressure. The capacity of the economy to meet that demand without causing inflation can also change, in response to such factors as large oil price movements, productivity developments and technological change. Failing to recognise this could lead to monetary policy errors, such as tightening policy in response to high economic growth even though it transpired that that pace of growth would not have generated unusual inflation pressure. At the other extreme, acting to stimulate demand when the economy's capacity to grow has in fact unexpectedly slowed could risk a severe inflation problem.

The output gap is one way of allowing for the fact that the supply side of the economy is just as important as demand, and is also subject to change. It is defined as the difference between the level of total economic output (GDP) and 'potential' output (which in this conception is the level of growth consistent with stable inflation). For details on how we calculate potential output and hence the output gap, see box 1.

Our analysis has revealed that, on average, we have underestimated the amount of inflation pressures in the economy related to the balance between demand and supply. That is, our estimates of the output gap at the start of our forecasts have been significantly biased towards underestimation since 1997 (when we started formally using the concept in our forecasts). Figure 6 shows our output gap starting-point errors through time. Our average mean error was quite significant at times during the late 1990s. We also consider that we underestimated demand-led inflation pressure in the mid-1990s. However, as we were not formally calculating and forecasting the output gap at this time, this period is not included in this numerical analysis.

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[13] We also tried putting the exchange rate bias into the FPS model as a shock, but results were very sensitive to assumptions regarding agents' learning, and other technical assumptions.

[14] In addition, our forecasting performance with respect to world import prices was not significantly different to these two forecasters.

Box 1: Estimating the output gap

The output gap is defined as the difference between the current level of output in the economy and the estimated level thought to be consistent with not generating any inflationary or disinflationary pressures (often referred to, somewhat misleadingly, as "potential output" or, less misleadingly, as "trend output"). Inevitably, estimating trend output is a problematic task and there is always a significant degree of uncertainty surrounding it. Despite our best efforts to estimate trend output with as much accuracy as possible, there is no perfect science in its estimation.

We use a flexible (non-linear) trend to estimate the unobservable level of trend output by smoothing through total GDP using both past and future observations. This methodology automatically allows for gradual changes in trend output growth over time, while more transitory movements in total output are generally assumed to reflect cycles in aggregate demand.

At the end of the sample, the filter lacks future data to guide it. The filter therefore also makes some use of other indicators of resource strain (eg capacity utilisation) to guide our output gap estimates. The final component

Figure 5
Actual output and estimated non-inflationary output
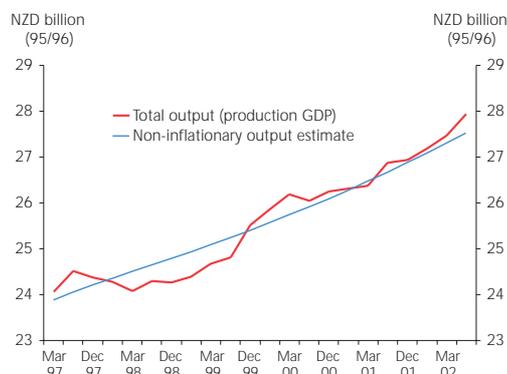
is a "stiffener", an adjustable factor which allows a constant assumed long-run growth rate of trend output to influence our estimates over the last few years of data.

Despite these extra sources of information, the end point of the historical output gap estimation (ie the start point of the forecasts) will always be prone to quite substantial revision from quarter to quarter.[16]

Figure 6
Starting-point output gap estimation errors[15]
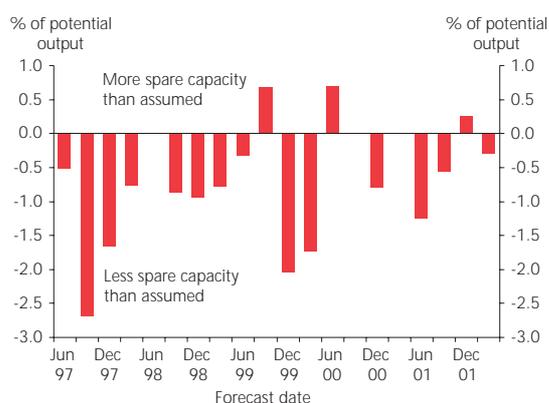
How important is the output gap bias in explaining our inflation forecast bias? As a very rough rule of thumb, we put this period-average output gap bias profile into the FPS model as a 'shock' simulation, not allowing monetary policy to respond for several quarters to emulate the 'forecast error' aspect. We found that, under reasonable assumptions about how quickly we learned about the error, the average output gap bias could explain about half of the average CPI forecast bias. (Note that the effect would have been bigger earlier in the period, when the output gap errors were larger).

There are several potential causes for underestimating demand-led inflation - underestimating total growth (either in our forecasts of, or Statistics New Zealand revisions to, GDP), or overestimating the sustainable speed at which the economy can grow. We examine each in turn.

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[15] Note that the 'actual' data here are the estimates from the September 2002 forecasts, as the 'true' output gap is unobservable.

[16] For more information on the Reserve Bank's usage of the output gap concept see Claus *et al* (2000).
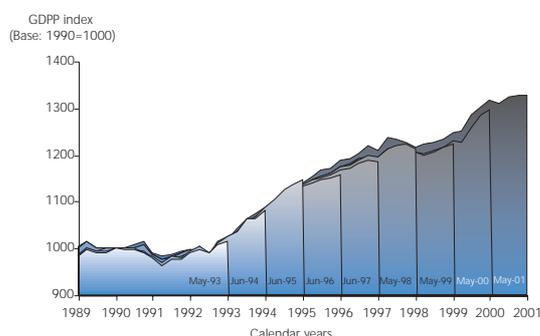
GDP forecasts

It appears that our near-term forecasts of GDP growth are unbiased, while in the medium-term we have tended to overestimate GDP growth, if anything.[17] It therefore does not appear that we have exhibited a general tendency to underestimate growth. That is not to say that we have not underestimated growth at times, and that this could have contributed to our inflation forecast errors for that period. We concluded in our 1999 business cycle review[18] that underestimating demand pressures in 1995-96 was one factor contributing to our under-prediction of inflation in the mid-1990s.

GDP revisions

Research has shown that the largest influence on changes to our view of the medium-term outlook for the economy is changes to our view about the current economic situation.[19] An accurate assessment of the economy's starting point is therefore very important. Data revisions to key series such as GDP can have a sizeable impact on our projections, influencing our interpretation of inflation pressures in the economy.

Revisions to historical GDP data since 1993 (figure 7) have tended to be one-sided. The average revision has tended to raise annual growth in expenditure GDP by 0.7 percentage points, and production GDP (which we focus on) by 0.3

Figure 7
Real production GDP revisions

percentage points. All else being equal, an underestimation of growth would lead to an underestimation of inflation pressures.

However, not all of this extra growth necessarily reflects growth on the demand side. Some of it may also be growth in the supply side of the economy, particularly through increased investment. This is captured automatically in our output gap framework: some of these revisions go into our estimates of non-inflationary growth, rather than all acting to increase our estimates of demand-led inflation pressures (see box 1). In figure 8, 'data issues' (the blue bars) reflect our estimate of the impact of GDP revisions on our starting-point output gap estimates. It appears that while revisions have led to quite substantial changes to our estimate of the output gap starting point, these have not been one-sided, and hence the contribution to the CPI inflation forecast bias has been both towards under- and over-prediction at times.

Figure 8
Contributors to the output gap starting-point bias

Therefore, while GDP revisions have added unhelpful noise to our output gap starting-point estimates (and hence, on occasions, worsened the accuracy of our inflation forecasts), we conclude that they have not added bias.[20]

Taking out the effect of data revisions, the remaining output gap errors are largely one-sided (the red bars in figure 8). We have ruled out our near-term GDP forecasts as the source

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[17] This bias in our quarterly growth estimates is approximately 0.2 to 0.3 percentage points 4 to 8 quarters ahead, though this is imprecisely estimated.
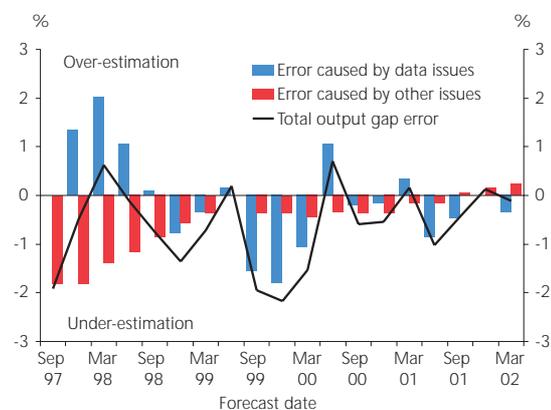
[18] Drew and Orr (1999).

[19] Reserve Bank of New Zealand (2001b)

[20] Statistics New Zealand are constantly improving their measurement methods and expect GDP revisions to be smaller in future.

of this bias, as they appear unbiased. This leaves over-optimism regarding the 'speed limit' at which the economy can grow without generating inflation pressures. Box 1 described how we estimate this growth rate. Although we begin with a mechanical filtering process, we then judgementally adjust this estimate.

Examination of revisions to our historical estimates and forecasts of trend output growth confirms that we have had a tendency to overestimate growth in the productive capacity of the economy. This has contributed to underestimation of inflationary pressures, and hence the CPI. Figure 9 gives our errors estimating the current quarter's growth in the economy's supply capacity, ie trend output.[21] We now consider that we over-predicted this in 1997-98 by up to 0.3 per cent per quarter, or over 1 per cent per year. As discussed above, some of the errors are due to data revisions. However, during 1997-98, data revisions were impacting on our output gap estimates in the opposite direction (see figure 8).[22]

Figure 9
Starting-point trend output quarterly growth forecast errors
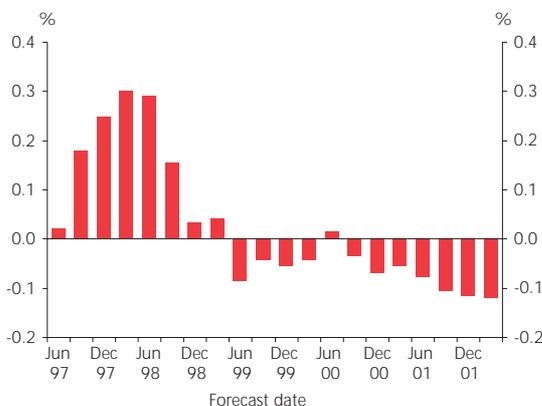
It therefore seems likely that overestimation of the economy's ability to grow without generating inflation pressure during 1997-98 was a driver of our inflation forecast bias during this period. These years were influenced by the Asian crisis

plus drought period: from September 1997 to March 1998 we considerably over-predicted near-term GDP growth.[23] All else being equal, this would lead to an over-prediction of inflation during this period. However, all else was not equal, because of our overestimation of the growth in the economy's ability to meet demand growth over the period.

Prior to 1997, our evaluation of the balance between demand and supply in the economy was made outside the output gap framework. We therefore cannot examine our estimates and forecasts of the economy's capacity to meet demand for this period quantitatively. However, we concluded in our 1999 business cycle review that "it appears that in the early to mid-1990s the Bank underestimated the strength of the demand pressures, and overestimated the increase in the supply capacity of the economy. The net result was the emergence of stronger inflation pressures than anticipated".[24]

There is little evidence that our estimates of the economy's capacity to grow without generating inflation pressures have been a driver of inflation forecast errors in either direction since 1999.

iv)   Our understanding of economic relationships

Modelling the economy is inherently difficult. Economic relationships are continually evolving. A period of rapid and large-scale structural reform, such as New Zealand underwent over the decade from 1984, makes for considerable uncertainty about how the economy will respond to monetary policy and other events, as history is no longer a good guide. We continually modify our economic model to reflect structural or behavioural changes in the economy. However, no model can perfectly capture these kinds of developments. Over time, we have gradually obtained more post-reform data, and our view of some key economic relationships has evolved accordingly.

In the previous section, we noted that over the 1990s we tended to overestimate the 'speed limit' of the economy. In

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[21]   The 'correct' data are the September 2002 estimates for the series, given that trend output is unobservable.

[22]   Note that we are examining quarterly growth in trend output, while the output gap is a levels concept. Therefore there is no simple quarter-to-quarter correspondence between the two.

[23]   This was then followed by a slight underestimation of how quickly the economy would recover in early 1999.

[24]   Drew and Orr (1999).

addition to this, we have gradually revised our view on exchange rate pass-through into CPI inflation. We believe that the pass-through has actually fallen over the past decade.[25] Now that we have the benefit of a full exchange rate cycle during the stable-inflation period, we also believe that we may have previously overestimated the pass-through. Importers' margins appear to be more flexible than previously thought. This could be a further contributor to the CPI forecast bias, as we overestimated not only the level of the exchange rate on average over the period, but possibly also the disinflationary impact of the projected appreciation.

Another potential explanation for our CPI forecast bias is that we might have overestimated the power of interest rates to brake the economy (ie underestimated the neutral real interest rate – the interest rate that is neither stimulatory nor contractionary on the economy). However, if this were the case, then we would expect to see GDP growth higher than projected, all else being equal.[26] While we certainly have underestimated GDP growth on occasion (eg 1994-95), over the sample period, quarterly GDP growth has been slightly lower than we projected, on average.

We also compared our GDP forecasts with those of other forecasters, to shed light on this question. Our growth forecasts have not been significantly more or less biased than other forecasters at any of the forecast horizons considered. Also, the two forecasters who had considerably higher (and hence less biased) medium-term CPI inflation forecasts than us had roughly similar nominal interest rate tracks, and hence considerably lower *real* interest rate forecasts. Hence, there is no evidence that our estimate of the power of interest rates is a large driver of the difference between our CPI inflation bias and others'.

v)   Judgement on special factors

A macroeconomic model is by necessity extremely simplified. It is therefore important that forecasts can be manually adjusted to reflect the complex and ever-changing realities of the economy. The Bank's Monetary Policy Committee's views on the structure of the economy, behavioural relationships and the current economic situation that are not already built into the FPS model are captured in judgements incorporated into the final forecasts. For example, we may have heard on business visits that firms are responding to the exchange rate somewhat differently to the traditional way because of strong views of its likely future path. Or we may have gleaned insights into the likely future paths for our commodity prices that lie outside the parameters built into the model.

Since we began using the FPS model, we have been able to archive early iterations of our forecasts. Generally, judgement included between the first 'sensible' run and the final published forecasts has tended to reduce the output gap forecasts and the interest rate track. This judgement has been appropriate in that it has made our interest rate projections more accurate, but it has worsened the output gap bias slightly (despite improving our growth forecasts). This would seem to suggest that judgement has worsened our inflation forecast bias. However, the judgements during 1997-98 dominate findings. During this period we were still learning about and recalibrating FPS. Since that time, the FPS model has become more consistent with the policy makers' and staff's views on how the economy works, meaning that less application of out-of-model judgement has been required.

vi)   Perception of economic risks

A single numerical projection cannot fully encapsulate the policy-makers' perceptions of risks facing the economy, even though perceived risks are very important for the policy decision. For example, after the events of 11 September 2001 we lowered rates more than was strictly consistent with our numerical forecasts. An average discrepancy between published and actual interest rates could be interpreted as a measure of asymmetric perceptions of risk over the period.

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[25]   "Since the early 1990s, it appears that the pass-through into local prices of nominal exchange rate changes has become more muted, thereby effectively lengthening monetary policy's lags." (Reserve Bank of New Zealand 2001c).

[26]   Note that, if anything, we have delivered interest rates slightly lower than forecast, on average.

There is some slight (not statistically significant) evidence that, on average, interest rates may have tended to be lower than we have shown in our projections (see table 4, appendix 2). Figure 10 plots the 90 day interest rate and our projected tracks at 3 quarter intervals. While, on average, interest rates have been lower than the published tracks, this is not the case in all quarters.[27] The largest errors were made during the Asian crisis plus drought event, which took most forecasters by surprise.

Figure 10
The 90 day interest rate and the Reserve Bank's forecasts (3 quarter intervals)
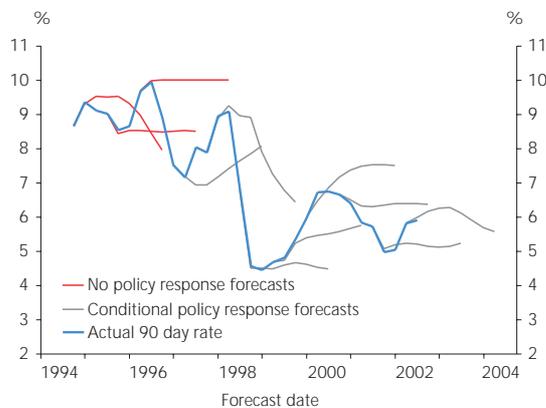
vii)   Unforeseeable events

An alternative potential explanation for the CPI forecast bias is that the economy was affected over the sample period with unforeseeable events that happened by chance to increase inflation on average.

We examined this issue in several ways. First, we compared the outlooks given in historical *Monetary Policy Statements* (*MPS*s) with what actually happened, and also looked at what recent economic developments we said had been unforeseen by us at the time. While there may of course be a tendency for *MPS* commentary to focus more heavily on upward unforeseen impacts on inflation, it does appear that unpredictable and non-demand-related significant price

changes, such as government charges and oil prices, have been positive for inflation, on average, since the early 1990s. Quantifying this is possible only for more recent data.

In a further piece of analysis we excluded from our one-year ahead forecasts sizeable unforeseen developments in the prices of individual items (mainly government policy-induced price changes and petrol prices) since 1997. We found that these had contributed both positively and negatively, and were not a major driver of the bias. (Note, however, that this is a very narrow definition of unforeseen surprises.)

We also compared our historical forecast stories with those of other forecasters. One forecaster who produced superior inflation forecasts to us put a greater emphasis on cost-side variables in their inflation story-telling. On a few occasions their more optimistic economic outlook was more accurate than our own, but in general it seems that 'shocks' such as the Asian crisis plus drought event and administered/foreign prices affected their forecast accuracy in much the same way as ours.

We conclude that, although unforeseeable events may well have contributed to our inflation forecast errors over the past decade, it seems unlikely that they can fully explain our forecast bias.

6   Weighing up the evidence

It appears from the foregoing discussion that the most substantial contributors to our inflation forecast bias have been as follows:

*   in the mid-1990s, the predominant issue seems to have been a general over-optimism about how fast the economy could grow without generating inflation pressures;

*   since this period, the main issue was probably a large and persistent over-prediction of the level of the exchange rate.

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[27]   A caveat to interpreting these results is the change in forecasting regimes in 1997 and the move to the Official Cash Rate (OCR) in March 1999. Also note that we do not set the 90-day rate analysed here. While the current OCR is an important influence, so too are traders' views on the future path of the OCR, which may differ from our own.

We can also examine the contributions of these two factors in recent years using the FPS model. Although it is only an approximation of reality, the FPS model splits projected CPI inflation into domestic price inflation, driven mainly by the output gap and inflation expectations, and the remainder, driven largely by imported inflation and the exchange rate. At a conceptual level, these roughly correspond to the split between non-tradables and tradables inflation respectively. Using this imperfect corollary we can split our quarterly CPI forecast errors (1 year ahead) into domestic and tradables components (figure 11) for the period for which data are available.[28] Findings show that:

- Year-ahead domestic inflation was slightly over-predicted in late 1997 and early 1998 (ie the late 1998 to early 1999 outturns). During these quarters we consider that our estimates of the economy's capacity to meet demand were reasonably accurate (figure 9), but due to the Asian crisis plus drought period we had surprisingly low total growth, and hence a lower than expected output gap.[29]

- Year-ahead domestic inflation was underestimated over 1999 (ie the calendar 2000 outturns). During this period, our estimates of trend output growth were fairly accurate but we underestimated the gap because we had under-predicted the speed at which the economy would emerge from the Asian crisis and drought-induced slowdown.

- Exchange rate-related factors dominate our December 1999 to March 2001 inflation forecast errors (ie the December 2000 to March 2002 outturns). This is the

Figure 11
Contributions of domestic and tradables inflation forecast errors
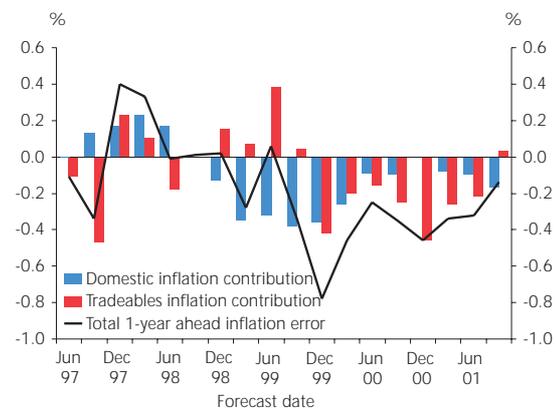
period in which exchange rate developments deviated most dramatically from our assumptions.

These findings confirm the importance of our exchange rate technical assumptions in recent years, as discussed above. However, this analysis suggests that much of the domestic inflation forecast error since 1997 appears attributable to economic events, in particular the unforeseeable combined Asian crisis and drought occurrence, rather than to generally flawed estimates of the capacity of the economy to grow without generating inflation. This contrasts with our conclusion regarding the mid-1990s.

7   The inflation forecast bias in context

Our projections are conditional on technical assumptions, externally-sourced forecasts, and prior to 1997, unrealistically static monetary policy assumptions. It is accepted by all commentators that economic outturns will seldom turn out exactly as projected. Additionally, our projections are only one input into the policy-making process, which also depends on a much broader range of information not explicitly captured in our published projections, particularly the perception of risks. Nonetheless, projections are an important input, and they embody a good deal of our understanding of how the economy works.

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[28]   The data are adjusted for "special factors" – ie large unforeseeable movements in the prices of individual items with a significant weight, eg petrol.

[29]   Although figure 6 shows an under-prediction of the output gap during this time, this is the *starting-point* estimate. Our year-ahead output gap forecasts for this period, for example, were too high.

One reason biased forecasts would be of particular concern is if they reflect a bias inherent in the forecasting methodology or in the policy-makers' understanding of the workings of the economy. Notwithstanding the existence of a forecast bias over the period being investigated, we do not believe that there is a systematic source of bias that is likely to persist into the future. We consider that the period of underestimation of inflation pressures in the mid-1990s (underestimating demand and overestimating the economy's capacity to meet that demand), followed by a period of very unusual and unforeseen exchange rate behaviour, are sufficient to explain the great majority of the calculated CPI forecast bias. Although we will continue to make inflation forecast errors, and they may well be persistently in one direction or another for a period, these particular historical sources of bias are not expected to persist, for the following reasons:

- **Underestimating demand.** While this has been a contributor to our inflation under-prediction at times, over the full sample period we have made errors on both sides, as one would expect with an economy that cycles in ways which are not entirely predictable. Indeed, over the sample period as a whole, it appears that we may have over-estimated GDP growth, if anything.

- **Overestimating the economy's capacity to grow without generating inflation pressures.** Again, this appears to be more period-specific than generic. With progressive learning about the economy's changing structure, one would reasonably expect periods of under- and over-estimation of the economy's capacity to meet demand without generating inflation. And there is evidence of progressive learning having taken place, with earlier over-estimates having given way to a subsequent period with no clear pattern.

- **Exchange rate assumptions.** The issue of the sample period is again relevant. The particular period in which the gap between the exchange rate assumption and subsequent reality was largest, was an episode of surprisingly large and sustained depreciation. We have also experienced a surprisingly large and sustained *appreciation* over the period under review, but we have roughly only half of this episode in our sample period.

Going forward, assuming the methodology remains unchanged, we would expect our exchange rate assumption to be a source of inaccuracy but not bias.[30]

Biased forecasts are a credibility risk for the central bank as they open us up to criticisms of not having a good understanding of the economy, but most importantly, a forecast bias is of concern if it leads to non-optimal operation of monetary policy. We concluded in our 1999 business cycle review that underestimation of the growth pressures in the economy over 1995-96 led us to tighten policy too late, necessitating a longer, higher cycle in interest rates than would otherwise have been necessary. Therefore, biased forecasts did lead to non-optimal policy on that occasion. However, we are broadly confident that our basic methodology is sound.

Although inflation has sat in the upper part of the inflation target band on average, we do not think it is reasonable to conclude that monetary policy should have been tighter than it was in order to be consistent with the Policy Targets Agreement (PTA). The PTA acknowledges that, *ex post*, inflation outcomes may well be towards the edge or even outside the target range, even if policy settings were intended to produce outcomes comfortably within that range. Moreover, the PTA acknowledges that in some cases, policy should not be set so as to produce outcomes comfortably within the range within the immediate period ahead. We argue that particular sample period events dominate the average inflation forecast bias over the period in question, and that outcomes have been on the whole entirely consistent with the PTA.

To be sure, existence of an inflation forecast bias over a medium-term horizon is not riskless. It is important to ensure that temporary inflation disturbances are not perceived as signalling the existence of an ongoing inflation problem. If inflation expectations creep up because we are perceived to

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[30] Early evaluation suggests that our current methodology for generating an exchange rate assumption is at least as good – or bad – as any other (in relation to forecast accuracy and bias). And the current methodology has the advantage of being broadly consistent with the idea that over time cycles tend to reverse direction, and that changes in interest rate differentials can matter for exchange rate behaviour. Assuming an unchanged exchange rate at current levels is inconsistent with either idea.

not be committed to fulfilling the targets outlined by the Government in the PTA, then the task of inflation targeting becomes much more difficult, with more painful consequences for short-term growth than would otherwise be the case.

Inflation expectations have followed inflation up in recent years, but no more so than is consistent with changes in the PTA inflation target range. As yet, we have no reason to believe that they will continue to increase, but this is obviously a factor which will require careful monitoring.

8   Conclusion

Even with the benefit of hindsight it can be difficult to establish unambiguously the factors that have influenced the accuracy of our forecasts. We do not have enough data to distinguish between competing explanations with any certainty. However, the analysis points towards the following general conclusions.

- Our CPI forecasts since 1994 have been biased towards under-prediction in the medium term. The largest under-predictions were made in the period 1996-97 and 2000.

- In the mid-1990s, we believe we overestimated the disinflationary impact of the high exchange rate at the time. However, the main drivers of our under-estimates of inflation in the mid-1990s were an underestimation of demand and an overestimation of the economy's capacity to meet that demand without generating inflationary pressures.

- Over-prediction of the level of the exchange rate is likely to have been a major driver of our inflation forecast bias in the period since 2000.

- Contributions have also likely been made at times by an overestimation of exchange-rate pass-through, inaccurate world growth forecasts, GDP revisions and unforeseeable events, but we have no evidence that these factors have contributed significantly to our forecast bias (though they have contributed to forecast inaccuracy).

We will continue to have difficulties with our exchange rate assumptions. So will other forecasters. This is unavoidable,

given the inherently unpredictable nature of the exchange rate. Moreover, because of the tendency for over- or under-estimates of the exchange rate to persist in one direction for a period, they may well contribute to persistent one-sided inflation forecast inaccuracies in particular periods. However, we believe that our method for generating reasonable exchange rate forecasts is as sound as any other, and that any over- or under-estimates of the exchange rate will cancel out over time.

We will also continue to be hit by unforeseeable events which will cause our growth and inflation forecasts to be wrong, perhaps persistently.

With respect to our understanding of economic relationships, this does not appear to have consistently contributed to forecast bias. However, we progressively learn about the structure of the economy, and for now believe we have a more accurate grasp of the following variables:

- the long-run equilibrium exchange rate,

- exchange rate pass-through into CPI inflation, and

- the economy's capacity to grow without generating inflation pressures.

Of course, all of these variables are constantly evolving and it is almost certain that at some stage in the future we will not have an accurate estimate of them for non-trivial periods of time. This reaffirms the importance of constantly reassessing our estimates of how the economy works.

We will continue to review our forecasting accuracy periodically and to use that analysis as part of the ongoing process of improving the Bank's forecasting processes and monetary policy-making capacity.

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Appendix 1: Statistical measures of forecast performance

The mean error (ME) is defined as:

$$\frac{1}{T}\sum_{t=1}^{T}(F_t - A_t)$$

where T = number of observations
F$_t$ = forecast
A$_t$ = actual outturn

The mean error (ME) reflects the overall bias in forecasting. A positive mean error indicates that, on average, the forecasts over-predicted the actual data. Conversely, a negative mean error reflects a tendency to under-predict. We can test whether the ME is statistically different from zero by conducting a t-test:

$$t = \frac{ME}{\sqrt{s^2/T}}$$

where s^2 = sample variance

The mean absolute error (MAE) is defined as:

$$\left(\frac{1}{T}\sum_{t=1}^{T}(F_t - A_t)^2\right)^{1/2}$$

This cancels out positive and negatives to give a measure of forecast error magnitude, with a lower MAE indicating greater accuracy. The MAE gives equal weighting to forecast errors regardless of their size.

The root mean square error (RMSE) is defined as:

$$\frac{1}{T}\sum_{t=1}^{T}|(F_t - A_t)|$$

This is another measure of forecast error magnitude, with a lower RMSE indicating greater accuracy. Unlike the mean absolute error, the RMSE gives a greater weighting to larger forecast errors by squaring the values before taking the mean. This means the RMSE penalises larger errors by proportionately more.

Appendix 2: Summary tables of forecast performance

Table 1

Summary statistics for the Reserve Bank's inflation forecast errors (December 1994 to September 2002)

Quarters ahead	Mean errors Annual		Quarterly		RMSE Annual	Quarterly	Observations
Current	0.05		0.04		0.27	0.24	32
1	0.00		-0.05		0.45	0.30	31
2	-0.15		-0.14	**	0.59	0.34	30
3	-0.39	***	-0.21	***	0.77	0.39	29
4	-0.65	**	-0.23	***	1.03	0.38	28
5	-0.80	***	-0.21	***	1.15	0.37	27
6	-0.88	***	-0.22	***	1.23	0.39	26
7	-0.88	***	-0.22	***	1.20	0.38	25
8	-0.87	***	-0.21	***	1.20	0.36	24
9	-0.90	***	-0.24	**	1.23	0.40	23
10	-1.01	***	-0.27	***	1.32	0.42	20

Notes: Inflation is measured using the CPI adjusted for interest rates. An adjustment is for Housing New Zealand rentals is also included in 2001.
Asterisks indicate the significance with which the null hypothesis: Mean Forecast Error = 0 can be rejected:
*** = Significant at the 1% level
** = Significant at the 5% level
* = Significant at the 10% level
Annual forecast errors for the current quarter and 1 to 3 quarters ahead horizons are not normally distributed. For these horizons we test the null hypothesis: Median Forecast Error = 0.

Table 2

Summary statistics for the Reserve Bank's annual inflation forecast errors: "No policy response" forecasts (December 1994 to March 1997) and "Conditional response" forecasts (June 1997 to December 2002)

Quarters Ahead	Mean errors No policy response		Conditional response		RMSE No policy response	Conditional response	Observations No policy response	Conditional response
Current	0.03		0.06		0.15	0.31	10	22
1	-0.02		0.01		0.27	0.52	10	21
2	-0.19	*	-0.13		0.31	0.69	10	20
3	-0.38	**	-0.39		0.52	0.88	10	19
4	-0.62	***	-0.66	*	0.75	1.16	10	18
5	-0.75	***	-0.82	**	0.87	1.30	10	17
6	-0.82	***	-0.92	**	0.91	1.39	10	16
7	-0.76	***	-0.96	**	0.83	1.40	10	15
8	-0.62	***	-1.04	**	0.72	1.44	10	14
9	-0.56	***	-1.16	**	0.72	1.51	10	13
10	-0.54	**	-1.39	***	0.81	1.62	9	11

Notes: Asterisks indicate the significance with which the null hypothesis: Mean Forecast Error = 0 can be rejected:
*** = Significant at the 1% level
** = Significant at the 5% level
* = Significant at the 10% level
Forecast errors for the 2 quarters ahead horizon during the conditional response period are not normally distributed. For this horizon we test the null hypothesis: Median Forecast Error = 0.

Table 3a
Mean annual CPI inflation forecast errors: Reserve Bank versus Forecaster A (June 1995 to June 2002)

Quarters ahead	RBNZ	Forecaster A	Significant difference
Current	0.06	0.01	-
1	0.02	-0.06	-
2	-0.17	-0.22	-
3	-0.40	-0.26	-
4	-0.72	-0.25	Yes
5	-0.91	-0.15	Yes
6	-0.88	-0.05	Yes
7	-0.85	0.06	Yes
8	-0.73	-0.03	Yes
9	-0.70	-0.09	Yes
10	-1.07	-0.57	-

Table 3b
Mean annual CPI inflation forecast errors: Reserve Bank versus Forecaster B (September 1992 to June 2002)

Quarters ahead	RBNZ	Forecaster B	Significant difference
Current	0.03	0.00	-
1	-0.02	-0.11	-
2	-0.15	-0.28	-
3	-0.33	-0.48	-
4	-0.54	-0.61	-
5	-0.66	-0.65	-
6	-0.72	-0.62	-
7	-0.77	-0.55	-
8	-0.83	-0.50	Yes
9	-0.82	-0.45	Yes
10	-0.87	-0.49	Yes

Notes to tables 3a and 3b:
We test for a difference between the mean forecast error from each organisation using F-tests. Where forecast errors are not normally distributed, we test for a difference in median forecast errors. We examined for the presence of a significant difference at the 10% significance level or better.

Table 4
Summary statistics for the Reserve Bank's interest rate projections: "No policy response" forecasts (December 1994 to March 1997) and "Conditional response" forecasts (June 1997 to December 2002)

Quarters ahead	Mean error		RMSE		Observations	
	No policy response	Conditional response	No policy response	Conditional response	No policy response	Conditional response
Current	0.03	-0.03	0.16	0.15	10	22
1	0.24	0.16	0.75	0.83	10	21
2	0.30	0.25	1.20	1.27	10	20
3	0.35	0.36	1.44	1.61	10	19
4	0.30	0.55	1.57	1.71	10	18
5	0.15	0.75	1.48	1.83	10	17
6	0.26	0.88	1.20	2.04	10	16
7	0.67	0.85	1.42	2.06	10	15
8	1.14	0.75	2.02	1.94	10	14
9	1.46	0.73	2.67	1.78	10	13
10	1.73	0.73	3.24	1.48	9	12

Notes: No mean errors were significantly different from zero at the 10% significant level.