Bulletin

Vol. 79, No. 13

August 2016

RESERVE BANK OF NEW ZEALAND
TE PŪTEA MATUA

Reserve Bank of New Zealand *Bulletin*

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ISSN 1177-8644

Evaluating the Reserve Bank's forecasting performance

Geordie Reid

Reviews of forecast performance help to update the forecaster's understanding of economic relationships and evaluate risks to the current outlook. This article compares the accuracy of the forecasts prepared for the Reserve Bank's quarterly *Monetary Policy Statement* with that of forecasts obtained from a suite of statistical models. It also examines whether the pattern of forecast errors has changed following the Global Financial Crisis.

1 Introduction

Reviewing forecasting performance is an important part of the forecasting process. Forecast errors will always occur as economic relationships evolve over time and random shocks hit the economy. There are several reasons why the Reserve Bank (the Bank) tracks forecast errors and investigates the reasons behind them. First, it is a useful way of keeping the Bank's understanding of the economic environment up-to-date. It can provide information about which relationships are most or least reliable and help to identify changes in economic conditions and relationships. Second, it may help the Bank to think about risks to the current outlook. Third, monitoring forecast errors enables the Bank to evaluate its monetary policy performance and consider whether it has responded reasonably to new information.

Given the inherent challenges in forecasting economic variables, it is often useful to use a benchmark when assessing the accuracy of a set of forecasts. This article relies on the Bank's suite of statistical models as the benchmark (see box 1). Methodologically, the article combines two approaches that have previously been used to evaluate the Bank's official forecasts published in the *Monetary Policy Statement* (*MPS*).

The first approach, used in several studies, compares the Bank's *MPS* forecasts to those made by a range of external forecasters.[1] As a general result, these studies have found that the Bank's forecasts are at least comparable to those of external forecasters, and often more accurate than most. The Bank's relative forecasting performance has been particularly good for forecasts of CPI inflation.

The second approach compares probability distributions implied by the *MPS* forecasts to those produced by forecasts from the Bank's suite of statistical models.[2] The probability distributions implied by the statistical models were comparable in performance to, and sometimes better than, the implied *MPS* forecast distributions across a range of macroeconomic variables and forecast horizons. However, the *MPS* forecast distributions were more accurate at near horizons for CPI inflation and the 90-day rate.

In this article we compare the accuracy of the *MPS* forecasts with that of the forecasts implied by combinations of models from the statistical suite. However, we rely on point forecasts instead of the ranges implied by forecast probability distributions, and use evaluation metrics similar to those employed in previous external forecaster comparisons.

1 See McCaw and Ranchhod (2002), Turner (2006), Labbe and Pepper (2009), and Lees (2016).

2 McDonald and Thorsrud (2011).

Box 1

The statistical model-combination forecasts

The Reserve Bank's suite of statistical models contains many types of models, including factor models, indicator models and vector autoregressive (VAR) models.[3] The forecasts from these models are combined into a single 'model-combination' forecast, using a weighting system that is based on past forecasting performance. Empirical studies have shown that combination forecasts are frequently superior to the best-performing individual model in real time.[4]

The Bank's statistical models provide a useful cross-check of forecast performance, as they provide data-driven forecasts that are produced independently from the Bank's main forecasting model.[5] However, they do not provide a 'structural' interpretation of the drivers of economic activity and may not adjust well to idiosyncratic events such as the Christchurch earthquakes. Thus additional cross-checks of *MPS* forecasts, such as comparisons with external forecasters, are also useful.[6]

In the Bank's current forecasting framework, the model-combination forecasts from the statistical models are provided to the Monetary Policy Committee to supplement the 'first pass' staff forecasts prepared using the main forecasting model.

3 Bloor (2009) provides more details about the statistical model suite.

4 For example, see Bjørnland et al. (2012).

5 The Bank's current core economic model is the New Zealand Structural Inflation Model (NZSIM). See Kamber *et al.* (2015) for a technical description of this model.

6 Lees (2016) provides an updated comparison of this sort.

The results show that, since 2003, *MPS* forecasts have similar forecast accuracy to the statistical model forecasts, with slightly more accurate forecasts for inflation, near-term interest rates and near-term GDP growth. Neither set of forecasts performed well at forecasting the exchange rate, although the statistical models performed slightly better.

The structure of the article is as follows. Section 2 describes the data used in this analysis, section 3 details the methodology, section 4 presents and discusses the results, and section 5 concludes.

2 Data

Previous analysis of forecast errors by the Bank has generally used forecasts for four variables: GDP growth, CPI inflation, the 90-day interest rate and the exchange rate. The analysis in this paper covers the same four variables and additionally includes tradable and non-tradable inflation. Table 1 summarises the data used.

The forecast data was sourced from the Bank's historical forecast archive. The forecast horizons considered are from one-quarter ahead to eight-quarters ahead. The availability of forecasts for tradable and non-tradable inflation limits the sample period to begin in the third quarter of 2003 and is taken up to the first quarter of 2016. This results in a maximum of 51 observations for one-quarter-ahead forecasts and 44 observations for 8-quarter-ahead forecasts.

Table 1
Summary of data

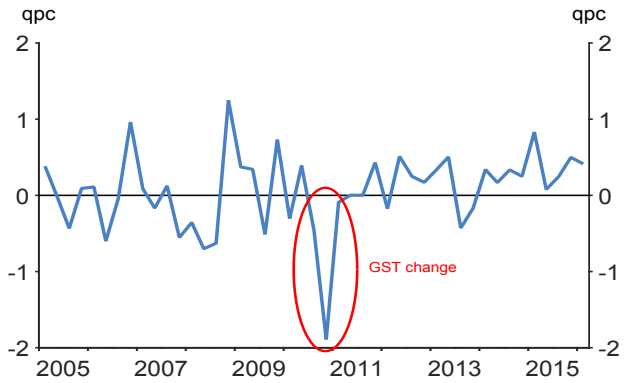
Variable	Measure	Data source
Total production GDP (real, seasonally adjusted)	Annual percent change	Statistics New Zealand
Headline consumer price index (CPI)	Annual percent change	Statistics New Zealand
Non-tradable CPI component	Annual percent change	Statistics New Zealand
Tradable CPI component	Annual percent change	Statistics New Zealand
90-day bank-bill rate	Quarterly average	Reserve Bank
Trade-weighted exchange rate index (TWI)	Quarterly average	Reserve Bank

Box 2

GST changes

One factor complicating this analysis is the increase in the Goods and Services Tax (GST) rate from 12.5% to 15% on 1 October 2010. This change was announced in May 2010 and incorporated into *MPS* forecasts from the June quarter of 2010 onwards. This change caused large errors in inflation forecasts for the fourth quarter of 2010 (remaining in annual inflation forecasts until the third quarter of 2011) for forecasts made before the announcement. The impact is clear to see in figure 1, which shows four-quarter-ahead forecast errors for headline CPI.[7] Because of the large, one-off nature of this change – unrelated to the usual drivers of inflation – the dataset has been adjusted to remove the effect of the GST increase.[8]

Figure 1 Headline inflation: four-quarter-ahead forecast errors



Source: Statistics New Zealand, RBNZ estimates.

7 Quarterly percent change errors are shown here to more clearly illustrate the impact of the GST change. During the analysis annual percent changes were used.

8 The data have been adjusted assuming full pass-through of the GST increase in the December 2010 quarter. This adds 2.22 percentage points to tradable inflation, 1.81 percentage points to non-tradable inflation and 2.0 percentage points to quarterly headline CPI inflation in that quarter.

3 Methodology[9]

The evaluation metrics follow those used by Labbe and Pepper (2009), and Lees (2016). The root mean square error (RMSE) is used to evaluate forecast accuracy, and the mean forecast error (MFE) is calculated to evaluate forecast bias.

The RMSE is calculated using the formula shown in equation 1. Squaring the errors before averaging penalises large errors more than small ones, so a forecaster who makes a series of small errors is generally penalised less than one who makes a few large errors. A lower RMSE implies a more accurate forecast.

Equation 1: $$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(y_i - y)^2}{n}}$$

where y_i is the forecast and y is the actual value of the macroeconomic variable, while n is the number of forecasts for evaluation.

The MFE is simply the sample mean of the forecast errors (equation 2). This is used as a measure of bias – whether a forecaster is persistently over- or under-predicting a given variable. For example, a positive mean forecast error for inflation would mean that a forecaster is persistently predicting inflation to be higher than the actual outturn.

9 Forecast errors are defined in this article as error = forecast – actual outturn to be consistent with the definition used in Lees (2016). The more conventional definition is error = actual outturn – forecast.

Equation 2: $MFE = \frac{\sum_{i=1}^{n}(y_i - y)}{n}$

In addition, a Diebold-Mariano-West test[10] is used to check whether differences between the *MPS* forecasts and the model-combination forecasts are statistically significant.

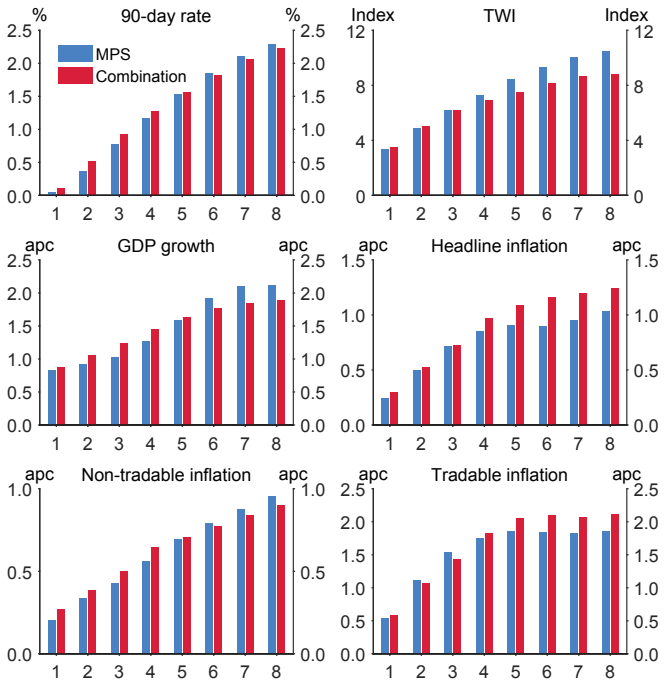
4 Results

4.1 Full sample results

The full sample results are shown in figures 2 and 3.[11] In general, there appears to be little difference between the *MPS* forecasts and the model-combination forecasts. In terms of forecast accuracy, notable differences are that the *MPS* forecasts for headline inflation are statistically more accurate than model-combination forecasts at horizons past five quarters ahead, and that *MPS* forecasts for the 90-day rate and GDP growth are more accurate at short horizons. Model combination forecasts for the TWI are more accurate than *MPS* forecasts at longer horizons.

Forecasts for most variables, except non-tradable inflation, show some bias (figure 3, overleaf). However, the bias is generally small in economic terms for both *MPS* and model-combination forecasts – about one quarter the size of the standard deviation of the historical data for tradable and headline inflation, GDP growth and interest rate forecasts. The exception is the TWI, which shows a large, statistically significant negative forecast bias at all horizons, meaning that TWI outturns have persistently been higher than forecast over the sample period.

Figure 2
Full sample: Root mean square errors



Source: Statistics New Zealand, RBNZ estimates.

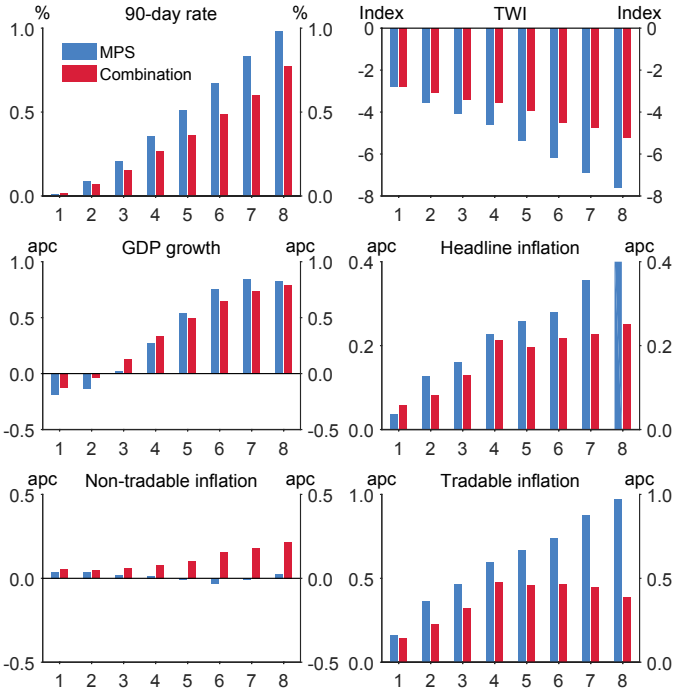
4.2 Comparison of sub-samples

A second way of analysing the dataset is to split the sample into two parts and compare the two sub-samples. This can be used to check if the pattern of forecast errors has changed over time. A natural place to break the sample is the Global Financial Crisis (GFC), as the increased uncertainty and volatility of economic data during this time led many

10 See Diebold and Mariano (1995).

11 See Table A1 and Table A2 in Appendix A for the full results and the tests for statistical significance.

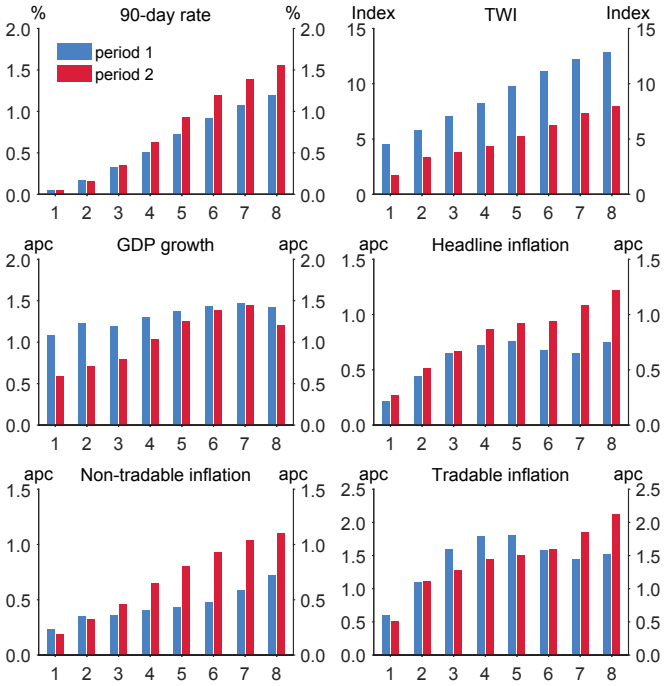
Figure 3
Full sample: Mean forecast errors



Source: Statistics New Zealand, RBNZ estimates.

Note: Horizontal axes show the forecast horizon, i.e. 1 relates to one-quarter-ahead forecast errors.

Figure 4
RMSEs for *MPS* forecasts, sub-samples



Source: Statistics New Zealand, RBNZ estimates.

Note: Horizontal axes show the forecast horizon, i.e. 1 relates to one-quarter-ahead forecast errors.

forecasters to make large errors. The first sub-period (period 1) covers the first five years of the sample (from 2003q3 to 2008q2). The second sub-period (period 2) is taken from 2010q1 until the end of the sample. Thus, the period from 2008q3 to 2009q4 (inclusive) – where the largest errors were made – is not attributed to either sample.[12]

Figure 4 shows the RMSEs for *MPS* forecasts in the two sub-periods.[13] The accuracy of 90-day rate forecasts is broadly the same in both periods, while forecast accuracy for the TWI and GDP growth has increased in the later sub-period. However, forecasts of inflation have become less accurate at horizons beyond four quarters ahead.

The bias for inflation forecasts over the later period has been positive (that is, outturns have generally been lower than forecast) and this has coincided with a period of historically low inflation.[14] Understanding low

12 Note that this leaves two short sub-samples. Thus, while useful as an exercise, we must be wary of placing too much weight on these results.

13 See tables A3-A6 in Appendix A for full sub-sample results.

14 CPI inflation has averaged 1.3% during the later sub-period compared to an average of 2.3% between 1993q1 and 2008q2. (Inflation targeting was introduced in New Zealand in 1990 and the inflation rate first fell to within the initial target range of 0-2% in the first quarter of 1993.)

15 McDermott (2015) noted that with the benefit of hindsight, the tradable inflation forecast errors can be explained by the higher-than-expected exchange rate and observed import prices.

inflation is a research focus of the Bank and has been made a strategic priority in the Bank's 2016 *Statement of Intent*. The following section comments on recent forecast errors and elaborates on some of this research.

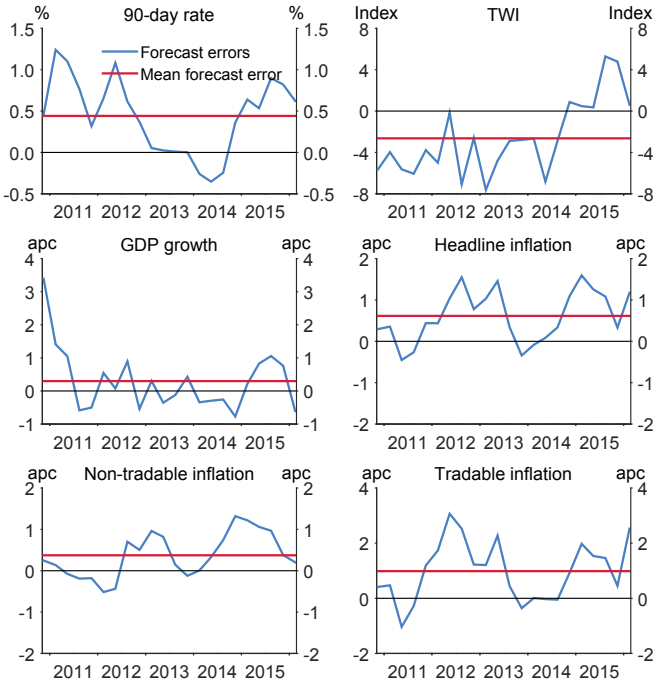
4.3 Recent forecasting performance

In this section, the Bank's recent forecasting performance is discussed. For simplicity, four-quarter-ahead forecasts made between 2010q1 and 2016q1 are examined (the same date range as the later sub-period in section 4.2). The forecast errors are shown in figure 5. Two observations stand out.

First, over this period the Bank persistently under-forecast the TWI, resulting in negative forecast errors. The statistical model-combination forecasts show a similar pattern – suggesting that the strength of the exchange rate over this period was unusual and not in line with past relationships. The Bank expected a lower exchange rate to flow through into higher prices for traded goods, partly explaining why tradable inflation forecast errors are largely positive over this period.[15]

The second observation is that forecast errors for GDP growth have a small upwards bias. Under a standard Phillips curve framework, this is consistent with persistently positive non-tradable inflation errors.[16] However, over the last couple of years the non-tradable inflation errors have become larger while GDP forecasts have been fairly accurate. Recent research suggests that capacity pressures appear to be passing through to inflation in the usual way,[17] but it is possible that the large

Figure 5
Monetary Policy Statement **four-quarter-ahead forecast errors**



Source: Statistics New Zealand, RBNZ estimates.

Note: The mean forecast error has been computed for the period 2010q4 to 2016q1.

increase in labour supply from strong net migration in recent years has led to a slower-than-expected decrease in spare capacity.[18] Recent work suggests the differences in the composition and drivers of migration in the current cycle help explain why inflationary pressures have been more muted than expected.[19]

The upward bias in non-tradable inflation forecasts could also be due to inflation expectations. There is some evidence that inflation expectations

15 McDermott (2015) noted that with the benefit of hindsight, the tradable inflation forecast errors can be explained by the higher-than-expected exchange rate and observed import prices.

16 The Phillips curve shows the relationship between the output gap (actual output minus potential output) and inflation for any given level of inflation expectations.

17 Karagedikli and McDermott (2016).

18 Capacity pressure is often measured in terms of the output gap. Armstrong (2015) explains how the Bank estimates the output gap and finds that the June 2015 estimate of the output gap over 2013 and 2014 was much lower than the output gap estimated in real time.

19 Armstrong and McDonald (2016) and Vehbi (2016).

have become more backward-looking over time, which means that inflation may take longer to return to the midpoint of the target range following a period of low inflation outturns.

Positive forecast errors for both tradable and non-tradable inflation may explain the positive bias for the 90-day rate. Lower-than-expected inflation outturns contributed to the Bank setting the policy interest rate lower than it had earlier predicted.[20]

Overall, however, it is difficult to say whether the *MPS* forecasts could have been improved at the time they were produced. The model-combination forecasts generally produced similar forecast errors over the same period, indicating that the forecasts were reasonable based on past experience. In addition, the Bank's forecasting performance compared favourably with a range of external forecasters over a similar time period.[21] As part of normal practice the Bank continues to monitor forecast errors and adjust the forecasting process as needed.

5 Conclusion

The Bank monitors its forecast errors to make sure its understanding of economic relationships and drivers is up-to-date. This article uses forecasts from a suite of statistical models as a benchmark to evaluate the Bank's *MPS* forecasts. Since 2003, *MPS* forecasts have shown similar forecast accuracy to the statistical model forecasts, with slightly more accurate forecasts for near-term interest rates and GDP growth, and inflation at longer horizons. Neither set of forecasts performed well at forecasting the exchange rate. In recent years, the Bank has under-predicted the level of the TWI, leading to lower-than-expected tradable (and headline) inflation. Non-tradable inflation has also been lower than forecast, while forecasts for GDP growth have been largely unbiased. The Bank continues to undertake research to understand these developments.

20 The Bank sets the Official Cash Rate (OCR) with regard to future expected inflation, rather than current inflation. However, persistently low inflation outturns may lead to lower expected inflation, which may in turn perpetuate low inflation outcomes. The March 2016 *MPS* explicitly noted this concern.

21 Lees (2016).

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Appendix 1

Results

Table A1
Full sample results: Root mean square error

Quarters ahead	90-day rate		TWI		GDP growth		Inflation		Non-tradables		Tradables	
	MPS	Stat	MPS	Stat	MPS	Stat	MPS	Stat	MPS	Stat	MPS	Stat
1	0.05	0.11	3.37	3.49	0.82	0.88	0.24	0.30	0.20	0.27	0.53	0.59
2	0.36	0.52	4.86	5.04	0.92	1.05	0.50	0.52	0.34	0.38	1.11	1.06
3	0.78	0.92	6.19	6.16	1.02	1.23	0.71	0.72	0.43	0.50	1.53	1.43
4	1.17	1.28	7.29	6.90	1.26	1.45	0.85	0.96	0.56	0.65	1.75	1.82
5	1.54	1.55	8.44	7.52	1.58	1.63	0.91	1.09	0.69	0.71	1.86	2.05
6	1.85	1.82	9.32	8.14	1.91	1.76	0.90	1.16	0.79	0.77	1.85	2.10
7	2.11	2.06	10.06	8.62	2.10	1.84	0.95	1.19	0.88	0.84	1.83	2.07
8	2.28	2.23	10.51	8.81	2.11	1.88	1.03	1.24	0.95	0.90	1.86	2.11

Note: Blue (red) text indicates the MPS forecast is more (less) accurate than the combination forecast at a 5% significance level.

Table A2
Full sample results: Mean forecast error

Quarters ahead	90-day rate		TWI		GDP growth		Inflation		Non-tradables		Tradables	
	MPS	Stat	MPS	Stat	MPS	Stat	MPS	Stat	MPS	Stat	MPS	Stat
1	0.01	0.01	-2.80	-2.78	-0.19	-0.13	0.04	0.06	0.04	0.05	0.16	0.14
2	0.08	0.07	-3.54	-3.09	-0.13	-0.04	0.13	0.08	0.04	0.05	0.36	0.23
3	0.21	0.15	-4.06	-3.40	0.02	0.13	0.16	0.13	0.02	0.06	0.46	0.32
4	0.36	0.27	-4.59	-3.55	0.27	0.33	0.23	0.21	0.01	0.08	0.59	0.48
5	0.51	0.36	-5.35	-3.94	0.54	0.49	0.26	0.20	-0.01	0.10	0.67	0.46
6	0.67	0.49	-6.19	-4.49	0.75	0.65	0.28	0.22	-0.04	0.15	0.74	0.47
7	0.83	0.60	-6.90	-4.77	0.84	0.74	0.36	0.23	-0.01	0.18	0.88	0.45
8	0.98	0.77	-7.59	-5.24	0.82	0.79	0.42	0.25	0.02	0.22	0.97	0.38

Note: Red text indicates the mean forecast error is statistically different from zero at a 5% significance level.

Table A3
Sub-sample results: Root mean square error (*MPS*)

Quarters	90-day rate		TWI		GDP growth		Inflation		Non-tradables		Tradables	
ahead	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
1	0.04	0.05	4.55	1.72	1.09	0.58	0.21	0.27	0.23	0.19	0.59	0.51
2	0.17	0.16	5.84	3.34	1.22	0.71	0.44	0.52	0.35	0.32	1.09	1.11
3	0.33	0.35	7.11	3.81	1.19	0.79	0.65	0.67	0.36	0.46	1.60	1.28
4	0.51	0.63	8.21	4.39	1.30	1.04	0.72	0.87	0.40	0.64	1.79	1.45
5	0.72	0.92	9.74	5.27	1.37	1.25	0.75	0.92	0.43	0.80	1.80	1.50
6	0.92	1.19	11.18	6.25	1.43	1.38	0.68	0.94	0.48	0.92	1.58	1.59
7	1.07	1.39	12.23	7.35	1.47	1.44	0.65	1.09	0.59	1.03	1.44	1.85
8	1.20	1.56	12.86	8.00	1.42	1.20	0.75	1.22	0.72	1.10	1.52	2.11

Table A4
Sub-sample results: Mean forecast error (*MPS*)

Quarters	90-day rate		TWI		GDP growth		Inflation		Non-tradables		Tradables	
ahead	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
1	-0.02	0.02	-4.49	-1.19	-0.52	-0.04	0.02	0.08	0.05	0.04	0.27	0.15
2	-0.09	0.08	-5.25	-1.99	-0.47	-0.05	-0.04	0.32	-0.02	0.12	0.17	0.61
3	-0.23	0.22	-6.23	-2.35	-0.44	0.11	-0.10	0.43	-0.07	0.21	0.10	0.76
4	-0.43	0.44	-7.41	-2.64	-0.47	0.37	-0.16	0.62	-0.17	0.37	0.05	0.99
5	-0.64	0.67	-8.75	-3.25	-0.59	0.65	-0.21	0.71	-0.26	0.47	0.00	1.08
6	-0.83	0.87	-10.35	-4.22	-0.66	0.81	-0.21	0.76	-0.36	0.52	0.11	1.14
7	-0.99	1.02	-11.49	-5.06	-0.74	0.73	-0.23	0.97	-0.49	0.63	0.20	1.49
8	-1.12	1.15	-12.22	-5.86	-0.74	0.50	-0.27	1.13	-0.61	0.69	0.22	1.80

Table A5
Sub-sample results: Root mean square error (model combination)

Quarters	90-day rate		TWI		GDP growth		Inflation		Non-tradables		Tradables	
ahead	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
1	0.11	0.08	4.69	1.86	1.12	0.67	0.23	0.32	0.22	0.30	0.64	0.53
2	0.36	0.28	5.87	3.63	1.42	0.75	0.48	0.45	0.35	0.40	1.13	0.86
3	0.65	0.46	6.98	4.31	1.41	0.91	0.66	0.68	0.44	0.54	1.54	1.21
4	0.92	0.70	7.73	5.08	1.41	1.13	0.79	1.07	0.58	0.76	1.79	1.83
5	1.19	0.82	8.73	5.49	1.27	1.16	0.93	1.22	0.67	0.84	1.90	2.21
6	1.44	0.96	9.23	6.82	1.00	1.04	0.99	1.32	0.70	0.94	1.82	2.33
7	1.65	1.07	9.57	7.85	0.91	0.93	1.06	1.35	0.75	1.02	1.81	2.39
8	1.79	1.29	9.58	8.14	0.91	0.81	1.12	1.44	0.81	1.04	1.92	2.48

Table A6
Sub-sample results: Mean forecast error (model combination)

Quarters ahead	90-day rate		TWI		GDP growth		Inflation		Non-tradables		Tradables	
	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
1	-0.02	0.03	-4.60	-1.06	-0.51	0.05	0.02	0.11	0.01	0.11	0.23	0.10
2	-0.28	0.16	-5.10	-1.27	-0.58	0.11	-0.15	0.28	-0.11	0.21	0.01	0.40
3	-0.56	0.31	-5.66	-1.62	-0.60	0.24	-0.30	0.50	-0.23	0.34	-0.20	0.76
4	-0.83	0.50	-6.12	-1.74	-0.63	0.35	-0.49	0.86	-0.39	0.53	-0.45	1.36
5	-1.09	0.64	-6.91	-2.13	-0.58	0.29	-0.69	0.98	-0.52	0.64	-0.75	1.68
6	-1.32	0.78	-7.53	-3.22	-0.21	0.14	-0.81	1.12	-0.60	0.78	-0.89	1.81
7	-1.50	0.87	-7.96	-3.40	-0.05	0.01	-0.87	1.24	-0.65	0.87	-1.03	2.08
8	-1.62	1.09	-8.29	-3.63	0.09	-0.15	-0.92	1.37	-0.69	0.92	-1.29	2.27