Analysis of bias and RMSE in our forecasts of key variables

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Editor's note

This paper examines the bias and size of our errors in our forecasts of key variables other than CPI inflation, with a view to discovering which variables may warrant closer investigation.

A caveat in comparing the results of this paper with those of the other papers in this set is that these figures took the most recent forecasting round as 'actual' data for forecast error calculation purposes. This was done in order to extend the sample period greatly, but has the drawback that it can lead to understatement of both the size of the errors and any bias. However, it is adequate for the purpose of getting an overview of the relative forecast bias for the different variables. We then examined variables of interest more precisely in other papers.

Note also that the simple approach taken in this paper does not consider the time-series aspects of the forecast errors, nor make allowances for changes in forecasting methodology. However, this was addressed more satisfactorily for key variables in later papers.

A note to interpreting the tables: the "quarters ahead" numbers refer to the quarter after publication of the statistics. This varies for different variables; nominal variables are released more quickly, with a delay before activity variables such as GDP are released. The forecast quarter '1' for the CPI and the TWI, for example, is the quarter in which the forecasts are published. However, the forecast quarter '1' for GDP is actually the quarter preceding the quarter in which the forecasts are published. This differs from the convention used in Satish Ranchhod's papers, which line up the quarters such that '1' will always refer to the same calendar quarter.

In brief

- As part of the analysis the bias in our CPI inflation forecasts since the early 1990s, it is useful to examine whether our forecasts of other key macroeconomic variables have also been biased. Such a finding does not prove causality, but it identifies potential factors worthy of further investigation.
- There is evidence of bias in our forecasts of the exchange rate, world prices for our imports, and the output gap. While less conclusive, there is also some evidence that we tend to under-predict near-term consumption and world growth.
- There is no significant evidence of bias in our forecasts of 90-day rates or wages.

Analysis

Although inflation forecast errors are the primary focus of our current investigation, it is useful to know what biases exist in our forecast errors for other variables. Note that in this analysis the June 2002 forecast round is taken as representing 'actual' data from the first quarter of 2002. While it is conceptually a bit problematic to effectively assume that these most recent forecasts are correct (or at least unbiased) when bias in our forecasts is the very issue at hand, the alternative was to throw away a large chunk of an already small sample. Note that this may lead to an understatement of both bias and the size of errors, meaning that

further analysis will be required of variables of interest. However, the analysis should still provide a good guide as to which variables we should focus on in further work.

Forecasts from December 1994 to March 2002 were examined, and two performance measures of forecast accuracy were employed. The mean error (ME) is a measure of bias,[1] and the root mean square error (RMSE) is a measure of forecast accuracy. The formulae for these measures are given here.

The exact form of the data can make a difference about whether significant bias is found. Real variables were examined in quarterly, annual and annual average per cent changes. The TWI was examined in levels as well, 90-day rates in levels alone, and the output gap in levels and first differences.

Nominal variables

Table 1 (appendix 1) gives the calculated mean error (bias) and root mean squared error for key nominal variables, at forecast horizons up to 8 quarters ahead.[2]

The main conclusions are:

- The evidence of bias in our CPI forecasts is stronger than for any other variables examined.
- There is no statistically significant evidence of bias in our forecasts of the 90-day rate (though there is strong serial correlation in the errors, as we tend to revise our forecasts in the same direction for a time).
- Our assumptions of the exchange rate 7 and 8 quarters ahead out have been too high on average, with the bias significantly different from zero. Not surprisingly, perhaps, we tend to over-predict it when it is falling and under-predict it when it is rising. We will examine our forecasts of this variable in more detail in following work.
- The forecasts of world prices for our imports have been too low on average, and significantly so 3 to 5 quarters ahead.
- There is little or no evidence of bias in our forecasts of world prices of our exports, the GDP deflator, or wages.

Real variables

Table 2 (appendix 1) shows the same statistics for our forecasts of a range of real activity variables.

- Using latest data, at the quarterly growth frequency, there is little evidence of bias in our GDP forecasts or its components.
- In annual and annual average growth terms, there is some evidence of under-estimation of GDP growth in the near-term. However, these errors are, by construction, as much the product of data revisions to recent quarterly outturns than of the forecast error for the quarter in question. This issue is discussed further below.

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[1] The mean error ('bias') would be exactly zero for any variable only by chance. However, the statistical significance of the bias, ie whether the mean is significantly different from zero, can be tested with t-statistics. The errors are defined as 'forecast minus actual'.

[2] The first and second quarters are the 'monitoring quarters' calculated outside the FPS model.

- There is some evidence that we have tended to over-predict investment growth. Conversely, we have tended to under-predict annual growth in private consumption. There is little evidence of bias in our forecasts of export and import volumes.
- There is significant evidence that our output gap forecasts have been too low on average up to one year out. Our forecasts of the change in the output gap are unbiased.[3]
- The way world growth enters our forecasts was changed, meaning that we have to test first our 1996 to 1998 forecasts of trade-weighted industrial production, and second, our forecasts of trade-weighted world GDP since 1999. This split sample makes statistical significance harder to demonstrate. However, it tentatively appears as though we have tended to under-predict world growth in the near term, and perhaps over-predict it two years out.[4]

Data revisions

The issue of sizeable revisions to national accounts data makes examining forecast errors considerably more complicated. For example, as mentioned earlier, the one-quarter ahead 'forecast error' for the annual or annual average per cent change in GDP will be more a function of data revisions to earlier quarters' data than the actual error made forecasting the new outturn. (This is corroborated by the fact that there is no evidence of bias in our near-term quarterly GDP growth forecasts).

Since 1993, revisions to GDP data have generally been in the direction of increasing its measured level. We can calculate the 'errors' between the latest data and the historicals that we had as at each forecast round. The average revision *x* quarters later can then be tested for bias just as the forecasts at each horizon can. Table 3 shows that the revisions to annual growth in GDP have not been mean-zero; but rather have tended to increase the reported annual growth, particularly for expenditure GDP. Average revisions to quarterly growth have not generally been statistically significantly different from zero (though they have of course been in the same direction on average).

Table 3
GDP growth revisions

Production GDP revision bias								
Quarter[5]	-7	-6	-5	-4	-3	-2	-1	0
Annual per cent change	-0.13	-0.20	-0.29**	-0.32*	-0.32*	-0.30	-0.31	-0.34
Quarterly per cent change	-0.06	-0.06	-0.09	-0.10	-0.04	-0.08	-0.08	-0.13
Expenditure GDP revision bias								
Quarter	-7	-6	-5	-4	-3	-2	-1	0
Annual per cent change	-0.21	-0.49**	-0.57**	-0.64**	-0.72**	-0.76***	-0.75**	-0.84**
Quarterly per cent change	-0.12	-0.18	-0.16	-0.16	-0.18	-0.27*	-0.16	-0.19

[3] Note that this analysis uses an approximation of the output gap, with potential output constructed with an HP1600 filter. (Our real-time estimates of potential output are only available from 1997). While in theory this should give similar results, it is a caveat to the findings.

[4] The finding of more bias in the forecasts of industrial production than in *Consensus* world GDP is more likely to be a function of the sample periods than intrinsic properties of the forecasts.

[5] Given the long publication lags for GDP, the "first" forecast quarter is actually that preceding the quarter in which the forecasts are published. The "0" quarter is the one before that, "-1" for the quarter preceding that, etc. eg for the March 2000 forecasts, "quarter -1" is June 1999.

As well as making our GDP 'forecast errors' calculated in this paper difficult to interpret, the revisions also affect our estimates and forecast errors for the output gap. This complex issue is worthy of further investigation.

The forecast errors in this paper are calculated using the most recent series for GDP as the 'actual' data. But it is also useful to examine our errors using 'real-time' data, and revisions say a year later. An accompanying paper addresses this issue, and finds that there *is* bias in our quarterly GDP forecasts when using these alternative outturns.[6]

Conclusion

The following variables show a statistically significant bias towards under-prediction that could have contributed to our CPI forecast bias:

- The exchange rate
- World import prices
- Near-term private consumption growth
- The output gap
- Near-term world industrial production growth.

We cannot conclude much about our forecasts of Quarterly Employment Survey (QES) wages, 90-day rates, world export prices and the GDP deflator. The mean forecast errors are in a direction consistent with potentially having contributed to the bias in our CPI forecasts, but are not statistically significant.

The following variables appear unlikely to have contributed to the bias in our CPI forecasts:

- Plant and machinery investment (any bias in it is towards over-prediction)
- System of National Accounts (SNA) export and import volumes (the errors look mean-zero).

The findings of this paper are consistent with the results of the Report, which found that import prices, the exchange rate, and the output gap have played a role in explaining our inflation forecast errors.

It is interesting that GDP revisions may have played a part in our underestimation of the output gap. It is also notable that our forecast biases appear concentrated in exogenous variables, ie the exchange rate and world import prices. However, the operation of monetary policy and/or our understanding of how it affects the economy may yet have been important. We are currently investigating how we may be able to use the FPS model to untangle the contributions of the various factors.

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6 Ranchhod, S (2002), "GDP Forecast Errors," Reserve Bank memorandum.

Appendix 1: Data tables

The statistical significance of the bias is indicated with asterisks:
* = significant at the 10 per cent level
** = significant at 5 per cent
*** = significant at 1 per cent

The significant bias results are also shaded for convenience. In recognition that the sample size is relatively small, those biases that were not significant at conventional statistical levels but with a t-statistic over 1.5 (p ≈15 per cent) are also shaded.

Table 1
Statistics for forecast errors of key nominal variables

	Forecast quarters ahead							
	1	2	3	4	5	6	7	8
a) Level								
90-day rates								
Bias	-0.02	0.18	0.26	0.31	0.35	0.37	0.40	0.48
RMSE	0.16	0.81	1.25	1.54	1.64	1.67	1.70	1.72
TWI								
Bias	-0.01	0.30	0.73	1.23	1.77	2.31	2.90*	3.49*
RMSE	0.58	2.21	3.23	4.03	4.80	5.51	6.04	6.42
b) Quarterly per cent change								
CPI								
Bias	0.04	-0.04	-0.12**	-0.19***	-0.21***	-0.19***	-0.19***	-0.19***
RMSE	0.25	0.35	0.36	0.41	0.39	0.38	0.39	0.37
TWI								
Bias	-0.03	0.57	0.75	0.84	0.92*	0.89*	0.98*	0.95*
RMSE	1.06	3.23	3.08	3.08	2.98	2.95	2.94	2.97
World import prices[7]								
Bias	-0.30	-0.94**	-0.52	-0.34	-0.16	0.16	0.27	0.41
RMSE	1.86	2.23	2.24	2.20	2.29	2.04	1.99	1.97
World export prices[19]								
Bias	-0.48	-1.06*	-0.05	0.03	0.02	0.33	0.60	0.69
RMSE	2.18	3.04	2.99	2.67	2.51	2.42	2.47	2.53
QES wages								
Bias	-0.06	-0.02	0.07	-0.01	-0.07	-0.03	0.05	-0.02
RMSE	0.47	0.43	0.47	0.46	0.47	0.47	0.48	0.48
Production GDP deflator								
Bias	0.10	-0.02	-0.14	-0.11	-0.09	-0.08	-0.11	-0.14
RMSE	0.68	0.80	0.95	0.95	0.70	0.77	0.82	0.72

[7] OTI prices are multiplied by our TWI forecasts to obtain the implicit world price forecast.

c) Annual per cent change								
	1	2	3	4	5	6	7	8
CPI								
Bias	0.05	0.01	-0.12	-0.32**	-0.57***	-0.72***	-0.79***	-0.79***
RMSE	0.29	0.47	0.58	0.70	0.92	1.04	1.10	1.07
TWI								
Bias	-0.04	0.48	1.19	2.02	3.00	3.32	3.55*	3.66*
RMSE	1.00	3.83	5.53	6.86	7.77	7.45	7.25	7.22
World import prices[19]								
Bias	-0.17	-1.12*	-1.70*	-2.09*	-1.95*	-0.86	-0.07	0.67
RMSE	1.91	3.07	3.90	4.28	4.20	4.11	4.42	4.44
World export prices[19]								
Bias	-0.36	-1.47*	-1.53*	-1.56	-1.08	0.30	0.92	1.59
RMSE	2.14	4.30	5.08	5.97	5.63	5.60	5.36	5.63
QES wages								
Bias	-0.10	-0.12	-0.04	-0.02	-0.03	-0.05	-0.07	-0.08
RMSE	0.53	0.60	0.63	0.67	0.72	0.65	0.70	0.68
Production GDP deflator								
Bias	0.01	0.02	-0.08	-0.18	-0.37	-0.43	-0.40	-0.43
RMSE	1.02	1.14	1.41	1.70	1.92	2.14	2.02	1.95

Table 2
Statistics for forecast errors of key activity variables

a) Quarterly per cent changes								
	1	2	3	4	5	6	7	8
Production GDP								
Bias	-0.14	-0.11	-0.03	0.05	0.11	0.17	0.19	0.22
RMSE	0.72	0.86	0.83	0.84	0.84	0.84	0.81	0.78
Expenditure GDP								
Bias	0.09	-0.02	0.01	0.11	0.17	0.20	0.19	0.20
RMSE	0.92	0.95	0.93	0.90	0.90	0.92	0.91	0.84
Plant &Machinery Investment								
Bias	0.27	0.31	-0.09	0.35	0.36	0.72	0.97	0.78
RMSE	7.97	10.51	10.47	10.78	10.26	10.7	10.18	10.15
Private consumption								
Bias	-0.21**	-0.18	-0.16	-0.03	-0.01	0.08	0.06	0.10
RMSE	0.69	0.84	0.82	0.84	0.78	0.82	0.74	0.63
SNA Export volumes								
Bias	-0.03	0.03	-0.05	0.24	0.16	0.23	-0.09	0.16
RMSE	2.15	2.64	2.75	2.58	2.53	2.53	2.47	2.34
SNA Import volumes								
Bias	-0.42	0.09	-0.52	0.46	-0.05	-0.15	0.51	0.15
RMSE	2.29	2.77	4.38	4.95	4.80	4.50	4.18	4.06
World industrial production (1996-1998) (5-country TWI-weighted)								
Bias	-0.17	0.17	0.04	0.06	0.00	0.13	0.04	-0.11
RMSE	0.41	0.44	0.57	0.54	0.64	0.70	0.71	0.83

World GDP (1999-2002.1) (14-country trade-weighted)								
Bias	-0.12	-0.06	0.00	0.08	0.14	0.19	0.20**	0.20**
RMSE	0.37	0.49	0.54	0.51	0.47	0.45	0.37	0.34

b) Annual per cent change								
	1	2	3	4	5	6	7	8
Production GDP								
Bias	-0.41	-0.47	-0.42	-0.25	0.02	0.30	0.54	0.71
RMSE	1.24	1.55	1.62	1.55	1.69	1.74	1.78	1.67
Expenditure GDP								
Bias	-0.45	-0.17	-0.05	0.18	0.25	0.50	0.67	0.75
RMSE	1.40	1.72	1.85	1.89	1.94	1.99	2.06	1.94
Plant & Machinery investment								
Bias	4.87**	3.39	2.94	2.81	3.08	3.94	4.24*	4.91**
RMSE	11.95	11.59	11.41	12.46	13.45	13.10	13.50	12.79
Private consumption								
Bias	-0.52**	-0.58**	-0.70**	-0.56	-0.34	-0.07	0.15	0.26
RMSE	1.21	1.23	1.41	1.44	1.38	1.34	1.39	1.43
SNA Export volumes								
Bias	-0.53	-0.17	-0.11	0.21	0.33	0.58	0.53	0.49
RMSE	3.04	3.30	3.68	3.89	3.71	3.77	3.35	3.18
SNA Import volumes								
Bias	0.26	-0.02	-0.91	-0.47	-0.04	-0.28	0.82	0.51
RMSE	2.49	3.92	5.46	5.04	4.67	5.20	6.06	5.82
Employment								
Bias	-0.16**	-0.33*	-0.42	-0.44	-0.35	-0.06	0.21	0.36
RMSE	0.40	0.82	1.12	1.34	1.52	1.45	1.30	1.38
World industrial production (1996-1998) (5-country TWI-weighted)								
Bias	-1.01***	-0.66***	-0.40*	0.10	0.28	0.24	0.24	0.06
RMSE	1.36	1.04	0.78	0.82	1.01	1.15	1.23	1.68
World GDP (1999-2002.1) (14-country trade-weighted)								
Bias	-0.36	-0.37	-0.32	-0.11	0.15	0.40	0.61	0.74
RMSE	0.78	1.07	1.41	1.68	1.78	1.72	1.52	1.32

c) Annual average per cent change								
	1	2	3	4	5	6	7	8
Production GDP								
Bias	-0.37**	-0.40*	-0.43	-0.38	-0.26	-0.06	0.21	0.42
RMSE	0.72	0.92	1.10	1.21	1.30	1.33	1.38	1.44
Expenditure GDP								
Bias	-0.71**	-0.57*	-0.38	-0.10	0.08	0.26	0.46	0.57
RMSE	1.19	1.20	1.25	1.35	1.46	1.46	1.52	1.58
Plant & Machinery investment								
Bias	6.06***	5.14***	4.46**	3.75*	3.21	3.65	3.93	4.49
RMSE	8.84	8.22	8.09	8.21	8.30	8.73	9.69	9.64
Private consumption								
Bias	-0.47**	-0.48**	-0.57***	-0.62**	-0.53**	-0.39	-0.13	0.09
RMSE	0.90	0.89	0.95	1.06	1.07	1.03	1.00	1.14

SNA Export volumes								
Bias	-0.44*	-0.34	-0.17	-0.07	0.09	0.24	0.41	0.52
RMSE	1.26	1.66	2.10	2.56	2.83	2.94	2.83	2.54
SNA Import volumes								
Bias	1.01*	0.68	0.13	-0.37	-0.37	-0.38	0.04	0.29
RMSE	1.90	1.88	2.42	3.18	3.58	3.72	3.76	4.07
Employment								
Bias	-0.20**	-0.23**	-0.30*	-0.38	-0.40	-0.30	-0.12	0.11
RMSE	0.33	0.43	0.65	0.91	1.15	1.23	1.22	1.19
World industrial production (1996-1998) (5-country TWI-weighted)								
Bias	-0.83***	-0.84***	-0.76***	-0.49***	-0.17	0.06	0.22	0.21
RMSE	0.98	0.97	0.92	0.70	0.58	0.72	0.89	1.12
World GDP (1999-2002.1) (14-country trade-weighted)								
Bias	-0.35	-0.35	-0.29	-0.16	0.03	0.27	0.48	0.63
RMSE	0.71	0.91	1.18	1.43	1.58	1.58	1.47	1.29

d) The output gap								
	1	2	3	4	5	6	7	8
Output gap								
Bias	-0.42*	-0.54**	-0.58**	-0.56**	-0.47	-0.34	-0.18	0.00
RMSE	0.97	1.06	1.13	1.11	1.16	1.19	1.28	1.25
Change in the gap								
Bias	-0.14	-0.12	-0.04	0.03	0.08	0.14	0.16	0.18
RMSE	0.71	0.84	0.82	0.82	0.82	0.83	0.82	0.78