An analysis of CBI's inflation forecast errors

A report to taskforce on reviewing Iceland's monetary and currency policies

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1 Introduction

The Central Bank of Iceland (CBI) started using inflation targeting as a framework for monetary policy in March 2001. Following that, it started publishing inflation forecasts on a quarterly basis in the Monetary Bulletin. In this paper, we present an anlysis of the errors of these forecasts.

Uncertainty is natural in forecasting since forecasts are based on estimated economic models containing uncertain shocks as well as uncertainty due to estimated parameters etc. Hence, forecast errors are inevitable and are not due to bad modelling or bad forecasting. However, one requires that forecasts are not systematically wrong (unbiasedness) and make use of all available information at the time of a forecast (efficiency). Further, it is required that forecasts made using sophisticated economic model, like the QMM model (see Daníelsson, et. al., 2015) used by the CBI, do better in forecasting than simple naive models (accuracy).

The quality of inflation forecasts (accuracy, unbiasedness and efficiency) are important from the viewpoint of implementing inflation targeting since inflation targeting entails inflation forecast targeting (see Svensson, 1997), i.e. central banks use inflation forecasts when deciding on their policy rates under inflation targeting. The quality of inflation forecasts is also important from a welfare viewpoint since these are important tools for central banks in anchoring inflation expectations, i.e. the less the quality of inflation forecasts the less credible they are and the more difficult it is for central banks to get economic agents (individuals, firms etc.) to form their inflation expectations based on them.

The paper is organized as follows: The data used is discussed in chapter 2. Chapter 3 gives an overview of the CBI's inflation forecast errors in 2001-2017 and chapter 4 gives an analysis of performance or quality of the inflation forecasts. Chapter 5 concludes the paper.

2 Data

Inflation in a quarter is here defined and measured as an (relative) increase in the CPI from the same quarter last year and the data frequency is therefore quarterly. Data on CPI was obtained from the CBI's QMM database (see QMM database) and data on inflation forecasts was obtained from the bank's quarterly Monetary Bulletin in 2001 - 2017 (see Monetary Bulletin).

As is discussed above, the CBI started using inflation targeting in March 2001. We therefore analyse its inflation forecasts since that date in this paper. For most of the quarters in the period, the bank has published inflation forecasts for up to eight to twelve quarters ahead. An overview of the forecasts made during the period 2001-2017 is given in the following table:

Table 1. CBI's inflation forecasts in 2001-2017
published in the Monetary Bulletin

Forecasts made in	Quarters ahead
2001Q2	$0-10$
2001Q3	$0-9$
2001Q4-2004Q2, 2004Q4-2006Q2, 2006Q4	$0-8$
2007Q1-2007Q2, 2007Q4, 2008Q2-2009Q3	$0-11$
2009Q4-2017Q3	$0-12$

where 2001Q2 stands for the second quarter of 2001 etc. and 0 quarters ahead is the quarter in which the forecast is made. For most of the forecasts, the dates in the table correspond to the dates of publications of the Monetary Bulletins.[1]

3 Inflation forecast errors

Inflation forecast error for a forecast q quarters ahead made in quarter t is defined as:

$$e_{t+q,t} \equiv \pi_{t+q,t} - \pi_{t+q} \tag{1}$$

where $q \geq 0$, $\pi_{t+q,t}$ is inflation forecast q quarters ahead made in quarter t and π_{t+q} is realized inflation in quarter $t+q$. Hence, a positive inflation forecast error means that forecasted inflation is higher than realized inflation etc.

The following figure shows forecast errors for inflation foracests one, four and seven quarters ahead:[2]

[1] There are few exceptions to this. For example, the forecast published in the Monetary Bulletin 2006/2 dated July 1st 2006 (third quarter of 2006) is dated 2006Q2 (instead of 2006Q3) in this paper since data on inflation for the second quarter of 2006 was not available on July 1st 2006.

[2] Forecast errors for forecasts 0-12 quarters ahead are shown in the appendix.

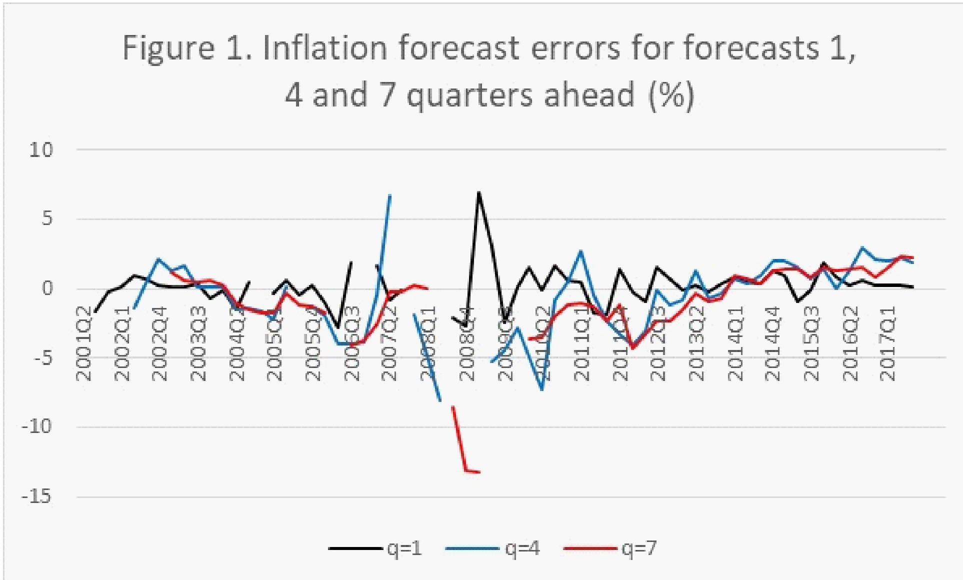

Figure 1. Inflation forecast errors for forecasts 1, 4 and 7 quarters ahead (%)

where the dates on the x-axis are the quarters for which forecasts are made (and not the quarters in which foracasts are made). For example, the value of the black line in the fourth quarter of 2004 is the inflation forecast error for that quarter of a forecast made in the third quarter of 2004. The breaks in the lines are due to missing forecasts (see table 1).

Figure 1 (and the figures in the appendix) shows extreme forecast errors in 2008 and 2009, which are due to the global financial crises and the boom-bust cycle of the Icelandic economy during these year. Further, the figure shows that inflation forecast errors have been positive during the past few years implying that the CBI's inflation forecasts for the quarters of these years have been higher than realized inflation.

Including forecasts made for the quarters of 2008 and 2009 in the analysis below would have large impact on the results and preclude interpretation of the results as representing "normal times". We therefore exclude forecast errors for these years in the analysis below. Summary statistics for the data on forecast errors and p-values for normality tests are given in the following table:

Table 2. Summary statistics and normality tests

q	Av. (%)	St. dev. (%)	p-val.[3]	Obs.
0	0.09	0.31	0.18	55
1	0.16	0.97	0.15	54
2	0.03	1.43	0.39	54
3	-0.28	1.96	0.10	53
4	-0.30	2.39	0.07	52
5	-0.39	2.34	0.35	51
6	-0.48	2.00	0.11	51
7	-0.61	1.76	0.18	50
8	-0.69	1.70	0.33	48
9	-0.53	1.85	0.06	32
10	-0.49	1.70	0.08	30
11	-0.52	1.69	0.09	29
12	0.26	1.02	0.03	20

One quarter ahead forecasts were on average 0.16% higher than realized inflation the period 2001-2017 (excluding 2008 and 2009) and the standard deviation of one quarter ahead forecast errors was 0.97%. Inflation foreasts were higher than realized inflation on average for $0-2$ quarters ahead forecasts but lower than realized inflation for the longer forecasts (more than two quarters ahead forecasts) except for twelve quarters ahead forecasts.

It is expected that the variance, or the standard deviation, of forecast errors increases with the number of quarters ahead forecasted since there is more uncertainty the longer the forecast horizon. Here, this only holds for $0-4$ quarters ahead forecast errors. It should be noted that the CBI did not start publishing $9-12$ quarters ahead forecasts on a regular basis until the end of 2009, which results in fewer observations (obs.) for these forecasts. This may at least partly explain this result.

The null hypothesis of normally distributed forecast errors cannot be rejected for forecasts $0-2$ and $5-8$ quarters ahead while the results of the normality test for the errors of 3, 4 and $9-11$ quarters ahead forecasts depend on the significance level chosen (5% or 10%). The null hypothesis can be rejected for forecasts 12 quarters ahead. These results are important for the analysis of unbiasedness and efficiency below since the sample size (the number of observations) is limited.

4 Forecast performance

We use three critiques for evaluating inflation forecast performance of the CBI's inflation forecasts: accuracy, unbiasedness and efficiency. Accuracy gives a measure of how close forecasts were to realized inflation during the period 2001-2017, i.e. the smaller the forecast errors are the greater is efficiency. Unbiasedness

[3] Doornik-Hansen test for normally distributed forecast errors.

shows whether inflation forecasts are systematically too high (biased upward) or too low (biased downward) or neither (unbiased) and efficiency shows how well forecasters use the available information when forecasting, such that better use of available information gives more efficient forecasts.

Due to missing forecasts prior to 2010 and omitting forecasts for the quarters of 2008 and 2009 from the anlysis, we only use data on forcasts and forecast errors for forcasts made for the quarters of 2010-2017 in the anlysis below.

4.1 Accuracy

We use two measures of forecast accuracy; mean absolute forecast error (MAE) and root mean squared forecast errors ($RMSE$). The first gives the mean of numerical values of forecast errors:

$$MAE_q = \frac{1}{obs} \sum_{t=2010Q1-q}^{2017Q3-q} |e_{t+q,t}| \tag{2}$$

over the sample while the second gives the square root of the mean of squared forecast errors:

$$RMSE_q = \sqrt{\frac{1}{obs} \sum_{t=2010Q1-q}^{2017Q3-q} e_{t+q,t}^2} \tag{3}$$

The higher MAE and $RMSE$ are the greater are deviations of forecasted inflation from its realized values and the less is forecast accuracy. Note that larger forecast errors get more weight in $RMSE$ since forecast errors are raised to the second power.

MAE_q can be interpreted as the average deviation of forecasts q quarters ahead from realized inflation during the period while $RMSE_q$ is non-informative on its own and should be used in comparison to other forecasts (other models, other countries, different time periods etc.). Here we compare the $RMSE_q$-s of the CBI's inflation forecast to a naive forecast where inflation is assumed to follow a random walk process and, hence, forecasted inflation in current ($q = 0$) and future quarters ($q = 1, ..., 12$) is given by inflation in the previous quarter:

$$\pi_{t+q,t} = \pi_{t-1}$$

The results are given in the following table:

Table 3. Measured MEA_q and $RMSE_q$ ratio

q	MEA_q (%)	$\frac{RMSE_q^{CBI}}{RMSE_q^N}$	Obs.
0	0.27	0.37	31
1	0.75	0.61	31
2	1.07	0.60	31
3	1.38	0.64	31
4	1.79	0.67	31
5	1.81	0.59	31
6	1.67	0.47	31
7	1.67	0.43	31
8	1.58	0.40	30
9	1.46	0.38	29
10	1.33	0.34	28
11	1.28	0.33	27
12	0.93	0.35	20

The deviation of one quarter ahead forecasts from realized inflation was on average 0.75% during the period and the forecast accuracy is greatest for zero quarters ahead forecasts ($MEA_0 = 0.27\%$). The average deviation is increasing with the number of quarters ahead forecasted up to five quarters and then decreasing implying that forecast accuracy is first decreasing with the number of quarters ahead forecasted and then increasing. Forecasts five quarters ahead were the least accurate ones during the period.

The ratio between $RMSE$ of CBI's inflation forecasts ($RMSE^{CBI}$) and naive forecasts ($RMSE^N$) shows that it is less than one for all quarters ahead forecasted implying that the CBI's forecasts were more accurate than naive forecasts during the period.

4.2 Unbiasedness

A forecast is unbiased if the mean of its forecast error equals zero; $E\left(e_{t+q,t}\right) = 0$, indicating that there are no systematic errors in the forecast. However, a forecast is biased upward (downward) if the mean is positive (negative); $E\left(e_{t+q,t}\right) > 0$ ($E\left(e_{t+q,t}\right) < 0$), indicating that a forecast is systematically too high (too low).

An estimate of bias in CBI's inflation forecasts is obtained by estimating the following equation by OLS using data on errors of forecasts made for 2010Q1-2017Q3 for each of forecasts $0-8$ quarters ahead ($q = 0, 1, 2, ..., 8$):

$$e_{t+q,t} = \alpha_q + u_{t+q,t} \tag{4}$$

where α_q is a parameter and $u_{t+q,t}$ is a residual with zero mean and a constant variance. We therefore have that $E\left(e_{t+q,t}\right) = \alpha_q$ implying that the mean inflation forecast error of a forecast q quarters ahead is non-zero and inflation forecast therefore biased if $\alpha_q \neq 0$. Further, it is biased upward if $\alpha_q > 0$ and downward if $\alpha_q < 0$. The estimation results are given in the following table:

Table 4. Results from estimation of equation (4)

q	α_q (p-value[4])	Obs.
0	0.0012 (0.02)	31
1	0.0036 (0.02)	31
2	0.0039 (0.16)	31
3	0.0003 (0.96)	31
4	−0.0008 (0.90)	31
5	−0.0024 (0.71)	31
6	−0.0030 (0.60)	31
7	−0.0039 (0.47)	31
8	−0.0041 (0.43)	30

The null hypothesis of unbiasedness ($\alpha_q = 0$) is rejected for zero and one quarters ahead forecasts while it cannot be rejected for $2 - 8$ quarters ahead forecasts. Further, since $\alpha_0 > 0$ and $\alpha_1 > 0$, the data indicates that zero and one quarters ahead forecasts are biased upward indicating that the CBI systematically forecasts too high inflation for the current ($q = 0$) and the following quarter ($q = 1$).

4.3 Efficiency

A forecast is efficient if it makes use of all available information when it is made. This implies that the forecast error should be uncorrelated with all information available to forecasters at the time a forecast is made. One such piece of information is last quarter's inflation.

To analyse efficiency we estimate the following equation by OLS for each of forecasts $0 - 8$ quarters ahead ($q = 0, 1, 2, ..., 8$) using data on forecast errors of forecasts made for 2010Q1-2017Q3 and inflation in 2008Q1-2017Q2:

$$e_{t+q,t} = \alpha_q + \beta_q \pi_{t-1} + u_{t+q,t} \tag{5}$$

where α_q and β_q are parameters, π_{t-1} is inflation in the quarter before a forecast is made (known information) and $u_{t+q,t}$ is a residual with zero mean and a constant variance. $\beta_q \neq 0$ implies non-zero correlation between known inflation and inflation forecast errors of a forecast q quarters ahead and, hence, that a forecast is not efficient. This implies that forecasters could improve their forecasts by accounting more for past inflation in their forecasts. Further, if $\beta_q > 0$ ($\beta_q < 0$) then forecasters predict high (low) inflation if it is high in the quarter prior to the one a forecast is made implying that they predicted more (less) persistency in inflation than is supported by data. The estimation results are given in the following table:

[4] Two-sided t-test for $\alpha_q = 0$ using HAC standard errors to account for potential autocorrelation in residuals.

Table 5. Results from estimation of equation (5)

q	α_q (p-value[5])	β_q (p-value[6])	R^2	p-val.[7]	Obs.
0	−0.0005 (0.65)	0.0505 (0.06)	0.10	0.05	31
1	−0.0000 (0.99)	0.0971 (0.06)	0.06	0.30	31
2	0.0021 (0.68)	0.0453 (0.50)	0.01	0.03	31
3	0.0128 (0.07)	−0.2830 (0.03)	0.25	0.01	31
4	0.0173 (0.03)	−0.3692 (0.00)	0.35	0.24	31
5	0.0178 (0.02)	−0.3842 (0.00)	0.44	0.12	31
6	0.0144 (0.04)	−0.3142 (0.00)	0.42	0.00	31
7	0.0107 (0.12)	−0.2553 (0.01)	0.30	0.00	31
8	0.0092 (0.17)	−0.2283 (0.01)	0.26	0.03	30

The null hypothesis of efficient forecasts ($\beta_q = 0$) can be rejected for all forecasts except those $0 - 2$ quarters ahead, where the results of the tests for forecasts 0 and 1 period ahead depend on the significance level chosen (5% or 10%). Further, since β_3, β_4, β_5, β_6, β_7 and β_8 are all negative, this indicates that the CBI predicted too little persistency in inflation. Note that the null hypothesis of normally distributed residuals in (5) can be rejected for all except forecasts 1, 4 and 5 quarters ahead ($q = 1, 4, 5$). Due to the small sample used here, this should be kept in mind when interpreting the results of the significance test in table 5.

5 Conclusions

The main conclusions of the analysis are the following:

- Inflation forecasts made by the CBI for the first quarter of 2010 to the third quarter of 2017 were much more accurate than naive ones implying that using a sophisticated model to forecast inflation resulted in forecasts being much more accurate.
- The data indicates that zero and one quarter ahead forecasts made by CBI are biased upward indicating that the CBI predicts too high inflation in their current and next periods forecasts.
- The data indicates that forecasts three to eight quarters ahead are not efficient indicating that the CBI does not make use of all available information when forecasting. Further, the data indicates that the CBI predicts too little persistency in inflation.

[5] Two-sided t-test for $\alpha_q = 0$ using HAC standard errors to account for potential autocorrelation in residuals.

[6] Two-sided t-test for $\beta_q = 0$ using HAC standard errors to account for potential autocorrelation in residuals.

[7] Doornik-Hansen test for normally distributed residuals in (5).

References

[1] Daníelsson, Ásgeir, Bjarni G. Einarsson, Magnús F. Guðmundsson, Svava J. Haraldsdóttir, Thórarinn G. Pétursson, Signý Sigmundardóttir, Jósef Sigurðsson and Rósa Sveinsdóttir (2015), QMM, A Quarterly Macroeconomics Model of the Icelandic Economy, Version 3.0, Central Bank of Iceland's Working Paper No. 71

[2] QMM database: https://www.sedlabanki.is/utgefid-efni/frettir-og-tilkynningar/frettasafn/frett/2017/11/15/Peningamal-2017-4/

[3] Monetary Bulletin: https://www.cb.is/publications/publications/publications-all-archive/?all=1&

[4] Svensson, Lars (1997), Inflation forecast targeting: Implementing and monitoring inflation targets, European Economic Review, 41, pp. 1111-1146

Appendix

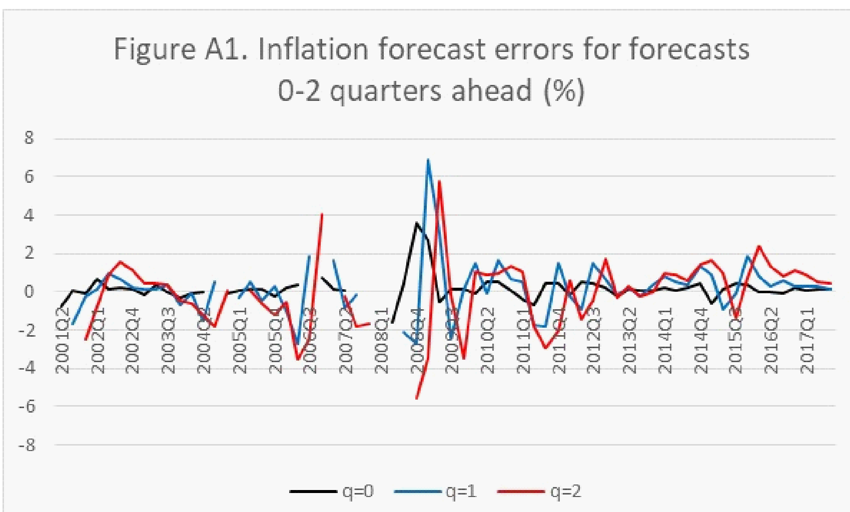

Figure A2. Inflation forecast errors for forecasts 3-5 quarters ahead (%)

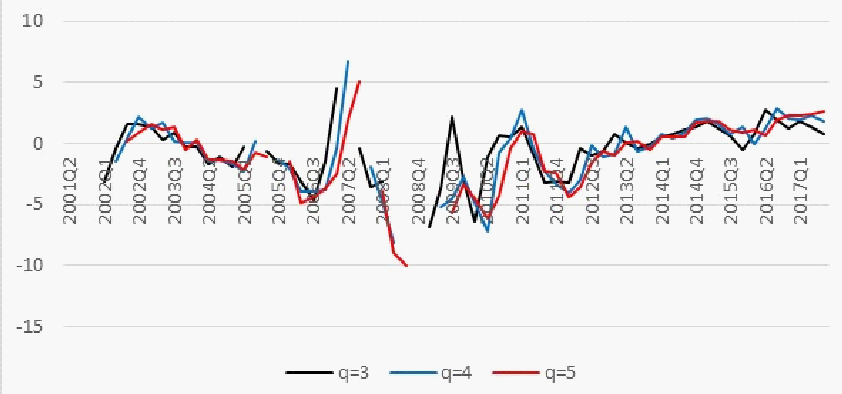

Figure A3. Inflation forecast errors for forecasts 6-8 quarters ahead (%)

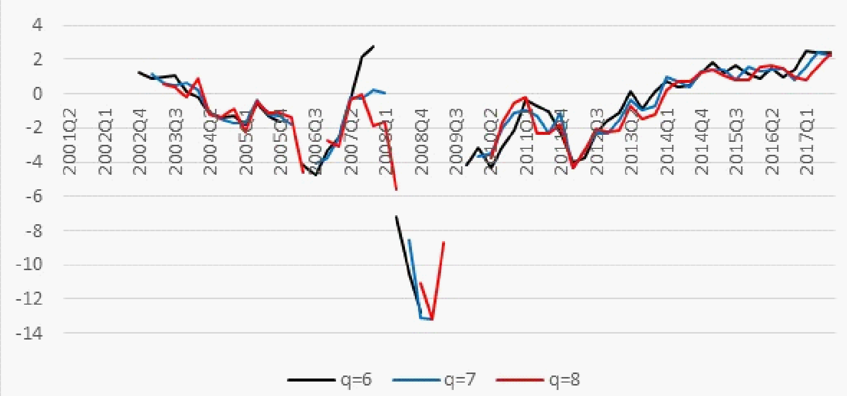

Figure A4. Inflation forecast errors for forecasts 9-12 quarters ahead (%)