Real-Time Forecasting for Monetary Policy Analysis: The Case of Sveriges Riksbank

Jens Iversen Stefan Laséen Henrik Lundvall Ulf Söderström*

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Abstract

We evaluate forecasts made in real time to support monetary policy decisions at Sveriges Riksbank (the central bank of Sweden) since 2007. We compare model forecasts made with a DSGE model and a BVAR model with judgemental forecasts published by the Riksbank, and we evaluate the usefulness of conditioning information for the model-based forecasts. We also study the perceived usefulness of model forecasts for central bank policymakers when producing the judgemental forecasts.

Keywords: Real-time forecasting, Forecast evaluation, Monetary policy, Inflation targeting.

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*Iversen, Lundvall and Söderström: Monetary Policy Department, Sveriges Riksbank, Stockholm, Sweden; Laséen: Strategy, Policy, and Review Department, IMF, Washington, DC, USA. Corresponding author: Ulf Söderström, e-mail: ulf.soderstrom@riksbank.se. The material included in this paper was initially part of a paper prepared for the conference "Macroeconomic Modeling in Times of Crisis" organized by the Banque de France, the Federal Reserve Bank of Atlanta, CEPREMAP and CAS on October 25–26, 2012. We are grateful to our discussant Christopher Erceg and participants at this conference, at a seminar at Sveriges Riksbank, and at the conference "Judgment and Combination in Forecasting and Policy Models" organized by the Euro Area Business Cycle Network and the Bank of England in March 2014 for comments and suggestions. We also thank Ard Den Reijer, Jesper Lindé, Stefan Palmqvist, Ingvar Strid, and Karl Walentin for many helpful comments, and Marcus Rommedahl and Henrik Siverbo for research assistance. The views expressed in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Executive Board of Sveriges Riksbank.

1 Introduction

Since the introduction of inflation targeting regimes during the late 1980s and early 1990s monetary policy decisions have been based on forecasts for key variables, in particular inflation. Today many central banks regularly publish forecasts for a large number of variables to support and motivate their monetary policy decisions. Several central banks (including the Reserve Bank of New Zealand, Norges Bank, Sveriges Riksbank and the Czech National Bank) also publish forecasts for their main interest rate instrument.

To produce their forecasts, central banks typically rely on a range of forecasting models, including short-term indicator models, factor models, VAR (vector autoregressive) models, and DSGE (Dynamic Stochastic General Equilibrium) models. However, the forecasts eventually published by the central banks typically include also judgemental adjustments. Some of this judgement is motivated by a need to take into account extra-model information. Other judgement is motivated by the aim to reach the inflation target in a few years' time, which may require policymakers to deviate from model-based forecasts that do not necessarily produce an appropriate path for monetary policy and inflation.

In this paper we study forecasts made to support monetary policy decisions at Sveriges Riksbank (the central bank of Sweden) since 2007. During this period, the Riksbank has published forecasts for a large number of variables, including the main interest rate instrument (the repo rate). We evaluate the published forecasts for the repo rate, consumer price inflation, GDP growth, and the trade-weighted nominal exchange rate, and compare them with forecasts from a DSGE model and a Bayesian VAR (BVAR) model. Importantly, the model forecasts were produced in real time in the process leading up to each monetary policy decision, and so provided input into the published judgmental forecasts.[1]

We show that model-based forecasts have provided important input into the Riksbank's published forecasts, but the model-based forecasts have often been more accurate than the published forecasts. In particular, forecasts for inflation and the repo rate from the BVAR model have performed very well, both in absolute terms and relative to the DSGE model forecasts and the Riksbank's published forecasts. In spite of this pattern, the published forecasts for inflation and the repo rate have been more closely related to the DSGE model forecasts than the BVAR forecasts. We argue that this is because of the DSGE model's advantages when it comes to interpreting the forecasts and building a story around the forecast.

[1] The Riksbank regularly evaluates its published forecasts and compare with external forecasters. See, for instance, Sveriges Riksbank (2014) or Andersson and Palmqvist (2013).

The paper studies the period since 2007, a period that has been characterized by a deep financial crisis and a global recession, and then a slow recovery in many parts of the world. This period puts forecasting models to a difficult test: most econometric models have difficulties making forecasts in periods of large volatility and enduring recession. DSGE models in particular have also been criticized for failing to capture the sources and effects of financial market volatility in recent years. Overall, our results demonstrate that forecasting models can provide policymakers with useful information about the outlook for the economy, also in a period of financial stress.

The paper is organized as follows. We begin in Section 2 by providing some background about the monetary policy framework in Sweden, the process at the Riksbank to produce a forecast and analyze monetary policy, a brief history of macroeconomic modelling at the Riksbank, and we summarize the macroeconomic developments in recent years. We proceed in Section 3 by evaluating model forecasts since 2007 and comparing with the Riksbank's published forecasts. In Section 4 we relate model forecasts to the published judgemental forecasts to evaluate the perceived usefulness of model forecasts for Riksbank policymakers. Finally, we sum up and draw some conclusions for future work in Section 5.

2 Monetary policy and macroeconomic modelling at the Riksbank

In this section we give some background about the monetary policy framework in Sweden, and the process to produce a forecast and analyze monetary policy at the Riksbank. We also provide a brief history of macroeconomic modelling at the bank, and summarize the economic developments in Sweden over the last decade.

2.1 Monetary policy framework

Monetary Policy at Sveriges Riksbank is guided by a mandate for price stability that was originally introduced in 1993 and applied from 1995. The Riksbank has specified this mandate as a target for inflation of two percent, measured in terms of the annual change in the consumer price index (CPI). As the CPI in Sweden measures the cost of housing using mortgage rates, monetary policy decisions are also guided by inflation measured by the index CPIF, CPI with a fixed mortgage rate.[2] In addition to stabilizing

[2]Until April 2008, the Riksbank instead used the index CPIX, defined as CPI excluding household mortgage interest expenditure, and adjusted for the direct effects of changes in indirect taxes and subsidies.

inflation around the inflation target, monetary policy also strives to stabilize production and employment around long-term sustainable paths. The Riksbank therefore conducts what is sometimes referred to as "flexible inflation targeting."[3]

Since 1999 decisions on monetary policy are made by an Executive Board with six members, each of whom is individually responsible for his or her decisions. Regular monetary policy meetings are scheduled six times a year. After each meeting, the Riksbank publishes 12-quarter forecasts for a large number of variables to motivate the monetary policy decision. These forecasts are published in three *Monetary Policy Reports* after the meetings in February, July, and October, and three *Monetary Policy Updates*, after the meetings in April, September, and December. Since 2007, the Riksbank also publishes a forecast for the main interest rate instrument, the repo rate. Thus, at the monetary policy meeting, the Executive Board votes for the level of the repo rate as well as for the repo rate forecast, or "repo rate path," along with the full set of forecasts.

Ahead of each monetary policy meeting, staff at the Monetary Policy Department prepares the set of forecasts in a process that is four to eight weeks long.[4] The forecasting process consists of several steps: First, a forecast is produced for the international (trade-weighted) economy, in terms of GDP growth, CPI inflation, and a short-term interest rate. Second, short-term forecasts (or "nowcasts"), typically for the current and the next quarter, are constructed for a large number of variables, using indicator models and high-frequency data. Third, a set of medium-term forecasts is produced for the main variables (GDP growth, hours worked, CPI and CPIF inflation, the real and nominal exchange rate, and the repo rate). These forecasts are conditioned on the international forecast and the short-term forecast. Fourth, the small set of forecasts is "disaggregated" into forecasts for a large number of variables, including the components of GDP, various labor market variables, and various measures of inflation and resource utilization.

The forecasts are presented to the Executive Board one to two weeks ahead of the monetary policy meeting, along with the staff's view (or, more recently, a recommendation) on the appropriate level and path for the repo rate. The staff view is informed by various experiments and simulations of the core DSGE model "Ramses," as well as other models. Subsequently, the Executive Board takes ownership of the forecasts and the *Monetary Policy Report* or *Update*, which are published on the day after the monetary policy meeting.

The forecasts are supported by a large number of short-term forecasting models and a smaller suite of empirical macroeconomic models: the DSGE model "Ramses," a

[3]See Sveriges Riksbank (2010) for details on the monetary policy framwork in Sweden.

[4]See Hallsten and Tägtström (2009) for a detailed description of the forecasting and decision-making process at the Riksbank.

Bayesian vector autoregressive (BVAR) model, and the dynamic error-correction model "Moses." The macro models are mainly used for the medium-term forecast, but also as input into the short-term forecast. The DSGE model Ramses is also used to study the consequences of alternative repo rate paths, in the process to arrive at the staff recommendation for the repo rate and to assist Executive Board members to make a decision on monetary policy. The final published forecasts are judgemental, and are produced through an informal combination of the model forecasts and outside judgement. This judgement is informed by other auxiliary models or by various rules of thumb.

An important aspect of forecasting in an inflation targeting regime with an endogenous interest rate forecast is that the final forecasts are conditional on an appropriate monetary policy. Model forecasts therefore need to be adjusted so that inflation approaches the inflation target at a suitable pace of the forecast horizon. At the Riksbank, this conditioning is based both on model simulations and on judgemental adjustments.

2.2 Macroeconomic modelling at Sveriges Riksbank

In the early 2000s, the Monetary Policy Department at the Riksbank decided to develop an empirical DSGE model to assist forecasting and monetary policy analysis. The first version of the DSGE model "Ramses" was developed in 2003–05 by Adolfson, Laséen, Lindé, and Villani (2008), and has been in use at the Monetary Policy Department since 2005. The model was an extension of Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2003) to a small open economy, and included a unit-root technology shock, as in Altig, Christiano, Eichenbaum, and Lindé (2011). The model was estimated with Bayesian techniques on 15 quarterly data series from 1980 to 2004, with a break in the monetary policy rule in 1993Q1, to capture the shift from a fixed exchange rate regime to an inflation targeting regime.

The second version of Ramses (Ramses II) was originally developed in 2007–09 by Christiano, Trabandt, and Walentin (2011), and is documented in Adolfson, Laséen, Christiano, Trabandt, and Walentin (2013). This version of the model is in use since early 2010. Ramses II extended Ramses I in three important respects. First, financial frictions and a financial accelerator mechanism were introduced following Bernanke, Gertler, and Gilchrist (1999) and Christiano, Motto, and Rostagno (2003, 2008). Second, the model includes equilibrium unemployment using a specification with search and matching frictions in the labor market following the version of Gertler, Sala, and Trigari (2008) implemented in Christiano, Ilut, Motto, and Rostagno (2008). Finally, the model allows imports to enter export production as well as in the aggregate consumption and investment baskets. The model was estimated using data from 1995Q1 to 2008Q2 on 18

series, including the rate of unemployment and the spread between the average corporate loan rate and the six-month government bill rate.

For monetary policy analysis at the Riksbank, the Ramses model is occasionally complemented by other smaller DSGE models, for instance, a model with housing as in Iacoviello and Neri (2010) (see Walentin (2014)), a model with an explicit banking sector as in Meh and Moran (2010), and a smaller open economy model building on Galí and Monacelli (2005) and Monacelli (2005).

Since 2003 the Riksbank has also used a Bayesian VAR model for forecasting. This BVAR model is estimated using steady-state priors to help pin down the long run values of all variables, along the lines of Villani (2009). The BVAR model is estimated using data since 1995, and is re-estimated in each forecast round.[5]

The third macroeconomic model, Moses, is in use since 2011. It is a Vector Error Correction Model estimated on data since 1980 or 1995, depending on the data series, and is also re-estimated each forecast round. However, since forecasts from Moses are available only since 2011, they are not considered in this study.[6]

2.3 The macroeconomy and monetary policy in Sweden since 2005

To summarize the macroeconomic developments in Sweden in recent years, Figure 1 plots annual CPIF inflation, annual GDP growth, the rate of unemployment, the nominal and real exchange rate, and the repo rate from 2005 until 2013.

In 2005–07 the Swedish economy was performing fairly well. Average GDP growth in these years was 3.7% and unemployment was falling, although inflation was below target, between 1 and 1.5%. Monetary policy was in a tightening phase after a slowdown in 2003–04 with the repo rate gradually increased from a low of 1.5%.

In early 2008 the economy started slowing down, GDP growth fell and unemployment began to increase. At the same time inflation had increased and was above the two percent target, and inflation expectations were also increasing. Monetary policy was therefore tightened further, and at the monetary policy meeting of September 3, 2008, the repo rate was raised from 4.5% to 4.75%.

When the financial crisis escalated in September 2008, export demand plummeted, and exports fell five quarters in a row, by at most 5% in 2008Q3 and close to 6% in 2008Q4. GDP therefore fell dramatically and unemployment increased from 6% to close to 9% at the end of 2009. Inflation kept fairly stable, partly due to a large exchange

[5]See Adolfson, Andersson, Lindé, Villani, and Vredin (2007) for a description of the BVAR model.

[6]See Bårdsen, den Reijer, Jonasson, and Nymoen (2012) for a description of Moses.

rate depreciation (the exchange rate weakened by more than 20% from July 2008 to March 2009).[7] The repo rate was therefore reduced in a series of steps. On October 8, in between scheduled monetary policy meetings, the repo rate was cut to 4.25% in a move coordinated with the Bank of Canada, the Bank of England, the European Central Bank, the Federal Reserve, and the Swiss National Bank. At the meeting of October 22 the repo rate was cut to 3.75%, and at the meeting of December 3 the repo rate was cut by another 175 basis points to 2%. Eventually the repo rate reached 0.25% in September 2009.

The acute crisis and the deep recession in 2008–09 was followed by a sharp rebound in 2010, with high GDP growth and falling unemployment. This rapid recovery led the Riksbank to start tightening monetary policy, and the repo rate was increased gradually to 2%. Inflation kept falling, however, partly due to an appreciating exchange rate.

In 2012–13 the economy again entered a weaker phase, largely due to weak external demand. Average GDP growth was 1.3% in 2012 and 1.6% in 2013, unemployment has increased again, and inflation has fallen to levels below 1%. The repo rate was therefore reduced from 2% to 0.75% in December 2013. Due to low inflation, the repo rate was eventually reduced to 0.25% in July 2014.

3 Model forecasts and monetary policy since 2007

We now investigate the use and usefulness of model forecasts, by comparing forecasts from the DSGE model and the BVAR model with actual outcomes and with the judgemental forecasts published by the Riksbank. We focus on forecasts of annual consumer price inflation, annual GDP growth, the trade-weighted nominal exchange rate, and the repo rate. We compare the forecasts over the period from February 2007 to December 2013, and we evaluate them against data from 2007Q1 to 2014Q2. In this period, the Riksbank has published forecasts at 40 occasions.[8] The first part of the sample includes the dramatic developments during the financial crisis, and the second part is characterized by a slow recovery with low interest rates and low inflation. In addition to the full sample we therefore also split the sample in two: before and after 2009Q4.

We make use of a unique dataset consisting of real-time forecasts from the two models, with and without the incorporation of external information into the model

[7] The trade-weighted exchange rate is measured in terms of the domestic currency price of foreign currency, and is indexed to 100 on November 18, 1992, the day before Sweden moved from a fixed exchange rate against the European Currency Unit (ECU) to a floating exchange rate regime.

[8] The Riksbank published four forecasts in 2007 (in February, June, October, and December), and six forecasts in 2008–13 (in February, April, July, September, October, and December).

forecasts, and published forecasts over the period 2007Q1–2013Q4. The model forecasts are exactly those that were presented in real time by Riksbank staff to the Executive Board ahead of monetary policy meetings. These forecasts thus provided input into the final judgemental forecasts and the actual monetary policy decision.

To evaluate the forecasts we report root mean squared errors (RMSE) and bias (average forecast errors) for model forecasts as well as for the published forecasts. In the forecast evaluation exercise, we place special emphasis on the incorporation of external information into the model-based forecasts, in the form of a short-term (two-quarter) forecast for all variables and a medium-term (three-year) forecast for international variables. Del Negro and Schorfheide (2013) show that external information can improve on the forecasting accuracy of DSGE models. As external information is routinely used at the Riksbank in terms of the short-term forecast and the international forecast, and both unconditional model forecasts and forecasts conditional on external information are included in our data set, it is straightforward to evaluate whether this information has improved the forecasting performance of the two models.

In addition to evaluating the usefulness of external information, we are able to evaluate the judgement applied in each forecasting round, by comparing the model forecasts with the published judgemental forecast.[9]

3.1 Are models useful for forecasting?

Figures 2–9 show forecasts from the two models and the published forecasts for annual consumer price inflation, annual GDP growth, the nominal exchange rate and the repo rate.[10] Figures 2, 4, 6, and 8 show the actual forecasts on each occasion along with the outcomes, while Figures 3, 5, 7, and 9 report RMSEs and bias (the average forecast errors, defined as the difference between outcomes and forecasts) of each of the five forecast methods.

As benchmarks we also report RMSE and bias for inflation and GDP forecasts based on the historical mean, exchange rate forecasts based on a random walk, and repo

[9]There are a few occasions in our sample where model forecasts are missing or are incorrect, and have therefore been excluded. For the BVAR model, there are no inflation forecasts for December 2008 and February 2009. For the DSGE model, the forecasts in July 2009 were based on an erroneous estimate of the long-run real exchange rate, and therefore implied a large weakening of the exchange rate and an increase in inflation. In addition there are a number of occasions where the model forecasts have not been stored properly. Hence, in general the number of published forecasts exceeds the number of models forecasts.

[10]Consumer price inflation is measured as CPIX (CPI excluding household mortgage interest expenditure adjusted for the direct effects of changes in indirect taxes and subsidies, previously called UND1X) until February 2009, and CPIF (CPI with a fixed mortgage rate) from April 2009 onwards.

rate forecasts based on financial market expectations extracted from forward rates.[11] As the conditional forecasts incorporate the short-term forecast for the current and next quarter, RMSE and bias are reported for forecast horizons from three to twelve quarters.[12]

3.2 Inflation forecasts

We begin by studying forecasts of annual consumer price inflation in Figures 2 and 3. The DSGE model forecasts tend to be more dispersed than the BVAR forecasts. This is partly due to the exchange rate forecasts which are rather volatile in the DSGE model (see Figure 6) and have a significant impact on inflation. The DSGE model forecasts also tend to approach the inflation target of two percent over time, whereas the BVAR forecasts do not.[13] The published forecasts are always close to two percent after two years, as monetary policy has focused on returning inflation towards the target after two to three years.

Figure 3 reports the RMSE and bias of the inflation forecasts over the full period 2007–13 and the two subperiods 2007Q1–2009Q4 and 2010Q1–2014Q1.

Looking at the whole sample, we note that at all horizons the BVAR forecasts (unconditional and conditional) have the lowest RMSE. The conditional DSGE model forecast is competitive with the BVAR forecasts at horizons up to six quarters, but performs considerably worse at longer horizons, where the conditional DSGE forecasts have the highest RMSE of all. The unconditional DSGE model forecasts performs similarly to the published judgemental forecast and the historical mean.

The pattern for the bias is similar to that for the RMSE, so the differences in terms of RMSE are driven by differences in bias. In contrast to the BVAR forecasts, the DSGE

[11]The historical means are calculated recursively using real-time data from 1995Q1 until the last outcome quarter for each forecast round. The random walk forecasts use the second quarter of the short-term forecast for each forecast round. Financial market expectations are based on forward rates calculated using interest rates on derivative contracts (RIBA futures and forward rate agreements), adjusted for risk premia using a rule of thumb of one basis point per month.

[12]Until September 2010 and from April 2013 onwards the DSGE model forecasts were conditioned on the international forecasts using unanticipated shocks, but from October 2010 to February 2013 the forecasts were conditioned using anticipated shocks. Since 2009 the judgemental forecasts for foreign interest rates have been considerably lower than the endogenous forecasts from the DSGE model (based on a small VAR model). Conditioning on this lower interest rate forecast with anticipated shocks then produced an immediate strengthening of the exchange rate and a dramatic decrease in the inflation forecast. A forecast evaluation made in early 2013 revealed that the inflation forecasts with unanticipated shocks were more accurate than with anticipated shocks. Forecasts from April 2013 are therefore conditioned on the international forecasts with unanticipated shocks.

[13]The DSGE model assumes a steady-state inflation rate of two percent. The BVAR model is estimated using steady-state priors which keep the steady-state inflation rate close to two percent, but the forecasts approach the steady-state level very slowly.

model and the published forecasts have a clear bias at longer horizons, leading also to larger RMSE.

Looking at the two sub-periods, the results for the second period since 2010 are similar to the full sample, while the first period reveals a different pattern. For the first sub-period, all models do about equally well for horizons up until eight quarters (perhaps except the unconditional DSGE forecasts), while for longer horizons the BVAR forecasts are less clearly dominating the other forecasts (except the conditional DSGE forecasts). For the second period, the pattern is similar to the full sample, and the results in terms of RMSE are largely caused by differences in forecast bias.

The value of incorporating external conditioning information can be judged by comparing the RMSE and bias for the conditional and the unconditional model forecasts. This difference is rather small for the BVAR forecasts, so external information has not been particularly important. For the DSGE model forecasts, conditioning information has been important for short horizons, but not for longer horizons.

The most striking finding for the inflation forecasts is the dominance of the BVAR model forecasts for the late part of the sample, especially at longer horizons. Indeed, for the full sample, the BVAR forecasts are nearly as accurate at the 12-quarter horizon as at very short horizons. The BVAR forecasts perform considerably better than the benchmark (historical mean) at all horizons. An alternative benchmark would be to use the actual (ex-post) mean of the data for the evaluation period. This would yield an RMSE of 0.70 over the full sample and 0.67 and 0.53, respectively, for the first and second sub-periods. Thus, the BVAR forecasts perform better for all horizons over the full sample period, and for horizons up to 10 or 11 quarters for the late sub-period. This is an impressive performance.

The reason the BVAR forecasts are so dominant relative to the DSGE model and the published forecasts is that the latter have a clear tendency to approach two percent over time, leading to a downward bias as inflation has remained below that level since 2011. This tendency for the inflation forecast to approach the target over time is natural for the judgemental forecast, which is conditional on the Riksbank view of an appropriate path for monetary policy. The tendence is also fairly strong in the DSGE model, especially in the unconditional forecasts. The conditional forecasts have a weaker tendency to approach two percent, in particular in the period 2012, when the forecasts for international interest rates have been very low, leading to a tendency for the exchange rate to strengthen over the forecast period.

3.3 GDP forecasts

Figures 4 and 5 analyze forecasts of annual GDP growth. It is immediately clear that all forecasts missed the deep recession in 2008–09 but also underestimated the strong recovery in 2010. As a consequence, when evaluated over the full sample period all forecasts have high RMSE (especially at medium-term horizons) and a negative bias (the forecasts have systematically overpredicted GDP growth). These large forecast errors in the first sub-sample dominate the results for the full sample.

For the full sample, the published forecast has the lowest RMSE for horizons up to six quarters. Beyond that there are small differences between the forecasting methods, but the historical mean and the DSGE models perform slightly better than the BVAR forecasts and the published forecasts. When looking at bias a similar story emerges: the published forecast performs well for shorter horizon, whereas the DSGE forecasts have the smallest bias for longer horizons. The results from the first sub-period match those from the whole sample, but for the more recent sub-period a somewhat different picture emerges: the DSGE forecasts have the lowest RMSE for all horizons, and their RMSE decrecase as the horizon lengthens. Also, for this period the BVAR forecasts perform the worst.

Finally, for both the DSGE and the BVAR forecasts there seems to be little value of adding conditioning information.

3.4 Exchange rate forecasts

Figures 6 and 7 show forecasts of the nominal exchange rate, a variable that is notoriously difficult to forecast. Again, no forecast captured the dramatic movements in 2008–09, and the BVAR model was more successful in capturing the subsequent strengthening, whereas the DSGE model forecasts and the published forecasts tend to flatten out after four to six quarters.[14]

Again, the large forecast errors in the first sub-period dominate the picture for the full sample period. In terms of RMSE, the published forecasts perform best at shorter horizons, at medium-term horizons (six to nine quarters) there are no large difference between the forecasting methods, and at long horizons the conditional BVAR forecasts perform best while the conditional DSGE forecast perform worst, except the random walk forecast. An interesting result is that the random walk performs so poorly at all horizons beyond four quarters. This is likely driven by the downward (strengthening)

[14]The exchange rate forecasts in the DSGE model are also conditioned on an estimate of the long-run real exchange rate, and this estimate increased (i.e., weakened) somewhat during 2008–09. This conditioning tends to affect also the published forecasts.

trend in the exchange rate over the sample period, which is better captured by the more sophisticated forecasts. Nevertheless, it goes against many results in the literature, following Meese and Rogoff (1983). For the second sub-period, the published forecast performs very well in terms of RMSE.

Looking at bias over the whole sample the only model that really performs poorly is the random walk, which tends to overpredict the exchange rate. The models and the published forecast tend to have a positive bias for short horizons, and a negative bias for long horizons. However, these results are not constant across sub-periods. For the first sub-period, when the exchange rate first weakened dramatically and then strengthened, all forecasting methods (including the random walk) have a positive bias for short horizons and a negative bias for long horizons, but in the second sub-period, with a persistent strengthening in the exchange rate, the methods are approximately unbiased for short horizons and have a negative bias at long horizons.

The conditioning information has had little impact on forecast accuracy in the first sub-period. Since 2010 it has marginally improved the BVAR forecasts but has tended to worsen the DSGE model forecasts.[15]

3.5 Repo rate forecasts

Finally, Figures 8 and 9 evalute forecasts of the repo rate. Evaluating the published repo rate forecasts is complicated by the fact that this "repo rate path" can be seen as both a forecast and as an instrument for monetary policy that aims to affect expectations of future monetary policy and therefore longer-term interest rates. Nevertheless, the published forecasts are intended to be mean forecasts, so standard evaluation methods should be valid also for the repo rate forecasts.

For the model forecasts, those produced by the DSGE model tend to return towards the steady-state level (which is slightly above four percent) more quickly than the BVAR forecasts. Instead, the BVAR forecasts are more closely related to international interest rates, which have been depressed since mid-2009. Also the published forecasts tend to approach the steady-state level over time.

As the repo rate has remained low over most of the sample period, the BVAR model forecasts outperform the DSGE model and the published forecasts at all horizons in terms of both RMSE and bias, and the DSGE and published forecasts have a strong negative bias at longer horizons. This is the same pattern as for the inflation forecasts above. The value of extra-model conditioning information is small for the BVAR model

[15]This is related to the fact that from late 2010 to early 2013 the DSGE model was conditioned on foreign variables using anticipated shocks, which tended to create a large initial exchange rate appreciation due to a positive interest rate differential over the forecast period.

forecasts. For the DSGE model since 2010 the value-added of conditioning information is large. Over this period international interest rates have been low and the Riksbank's forecasts have been substantially lower than the endogenous forecasts in the DSGE model. This has pulled down the conditional DSGE model forecasts relative to the unconditional forecasts. For the BVAR model forecasts this effect has been smaller, so the low international interest rate forecasts have not had a large effect on the repo rate forecasts.

Finally, forecasts based on financial market expectations tend to be more accurate than the DSGE and published forecasts since 2010, but perform worse than the BVAR forecasts.

3.6 Summary and discussion

Overall, this evaluation suggests that model forecasts perform well compared with judgemental forecasts. Indeed, model forecasts are often more accurate than the judgemental forecasts. Which model produces the best forecasts varies across variables, however. For inflation and the repo rate, the BVAR forecasts outperform the DSGE and the published forecasts. For GDP growth, the published judgemental forecasts perform well in the short run, but the DSGE model forecasts are better at long horizons, especially in more recent years. For the exchange rate, the published forecasts perform well at all horizons.

Using external conditioning information has improved the DSGE forecasts for inflation and the repo rate (confirming the the results of Del Negro and Schorfheide (2013)) but not for GDP and the exchange rate. For the late sub-sample, external information has even worsened the exchange rate forecasts.

One reason why the BVAR model forecasts are more accurate than the DSGE model forecasts for inflation and the repo rate could be that the BVAR model is re-estimated in each forecast round, and therefore has been able to adjust to the more recent period with low inflation and a low repo rate. The DSGE model, in contrast, is not re-estimated each round: since 2010 forecasts have been based on estimates using data up until 2008Q2, that is, before the financial crisis and the period with very low interest rates.

Another, possibly related, reason is the tendency for the BVAR model forecasts to stay low throughout the forecast period while the DSGE model forecasts tend to approach steady state faster. That is, the steady-state values are more hard-wired in the DSGE model, while the BVAR is more flexible in letting the forecasts approach steady state very slowly over time.

4 Are model forecasts useful for monetary policy?

We now move to a second potential task of macroeconomic models: their role in providing monetary policy advice and assist in story-telling. We evaluate the usefulness of model-based forecasts for monetary policy analysis by studying how closely related these are to the published judgemental forecasts. The idea is that if policymakers find a model forecast useful, they will tend to publish a judgemental forecast that is similar to the model forecast.

To evaluate the usefulness of model forecasts for the judgemental forecast, we estimate for each variable the regression

$$Y_{j,t} = \alpha_1 X_{j,t}^{\text{DSGE}} + \alpha_2 X_{j,t}^{\text{BVAR}} + (1 - \alpha_1 - \alpha_2)\, Y_{j,t-1} + \varepsilon_{j,t},$$

where $Y_{j,t}$ is a vector containing the published forecasts for variable j at policy round t, $X_{j,t}^{\text{DSGE}}$ and $X_{j,t}^{\text{BVAR}}$ are vectors containing the corresponding conditional DSGE model forecast and conditional BVAR forecasts, respectively, and $Y_{j,t-1}$ is a vector containing the published forecasts at the previous policy round $t-1$. We use the whole forecasting horizon for each policy round which means that the vectors $Y_{j,t}$, $X_{j,t}^{\text{DSGE}}$, $X_{j,t}^{\text{BVAR}}$, and $Y_{j,t-1}$ have 12 elements, as the forecasting period is 12 quarters long. We estimate the equation by minimizing the mean squared error, under the restriction that $\alpha_1, \alpha_2 \in [0, 1]$ and $\alpha_3 = (1 - \alpha_1 - \alpha_2) \in [0, 1]$.

Table 1 shows the regression coefficients estimated over the full sample, in panel (a) including the previous published forecast and in panel (b) without including the previous forecast. For all variables, but in particular for inflation and the repo rate, there is substantial inertia in the forecasts between forecast rounds, so the coefficient on the previous forecast is substantial. For inflation and the repo rate the estimated weight of the DSGE model forecast is larger than that of the BVAR forecast, a pattern that is even clearer when excluding the previous forecast from the regression. Thus, the DSGE model forecasts have been judged more useful for monetary policy purposes. For GDP and the nominal exchange rate the two model forecasts have almost equal weight.

This pattern may be puzzling in light of the results presented above, which have shown that the BVAR model forecast clearly outperform the DSGE model forecasts for inflation and the repo rate. It is of course possible that Riksbank staff and policymakers have not been aware of the relative forecast performance of the two models. We believe, however, that there are more fundamental reasons for this pattern.

First, the DSGE model forecasts may have been judged more useful as they tended to approach the steady state over the forecast horizon. This is particularly important for inflation, where the judgemental forecasts typically should approach the inflation

target over time. It may be difficult for policymakers to relate to model forecasts for inflation that have a very weak tendency to approach the inflation target. Second, the DSGE model forecasts are easily decomposed into the contribution of various structural shocks, and this is regularly done by Riksbank staff during the forecast round. This gives a strong advantage to the DSGE model, as it makes it easier to understand forecasts and forecast revisions from the DSGE model than from the BVAR model. Therefore, the DSGE model forecasts may also have been judged more useful for story-telling.

5 Conclusions and final remarks

Our study has revealed several interesting patterns in the real-time forecasts produced by the Riksbank since 2007. We have shown that model-based forecasts have provided important input into the Riksbank's published forecasts, but the model-based forecasts have often been more accurate than the published forecasts. In particular, the BVAR model forecasts for inflation and the repo rate have performed very well, both in absolute terms and relative to the DSGE model forecasts and the Riksbank's published forecasts. We also showed that in spite of this pattern, the published forecasts for inflation and the repo rate have been more closely related to the DSGE model forecasts than the BVAR forecasts. We argue that this is because of the DSGE model's advantages when it comes to interpreting the forecasts and building a story around the forecast.

We have also shown that extra-model conditioning information (in terms of a short-term forecast and a forecast for international variables) has often been useful to improve on the model forecasts, typically more so for the DSGE model than for the BVAR model.

There are several extensions that could be pursued in future work. First, it would be interesting to more formally analyze the accuracy of the different forecasts, along the lines of Mincer and Zarnowitz (1969) and others. Second, our forecast evaluation has focused on univariate forecasts, variable by variable. But the usefulness of a given forecasting model for monetary policy analysis also depends on its overall forecasting record for several key variables at the same time. For instance, if a given model performs very well for inflation forecasts, but very poorly for interest rate forecasts, it is not clear how useful that particular model is for monetary policy analysis. One extension could therefore be to evaluate multivariate forecasts, for instance, building on Herbst and Schorfheide (2012). Finally, the present paper has focused on real-time forecasts stored by the Riksbank over the years, in order to better understand the value of model-based forecasts for monetary policy analysis in real time. An alternative route that could also be helpful would be to formally evaluate the forecasting ability of the current suite of forecasting models.

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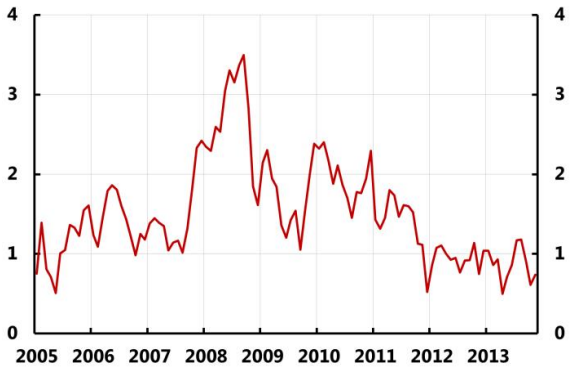
Table 1: Model forecast weights for published judgemental forecast

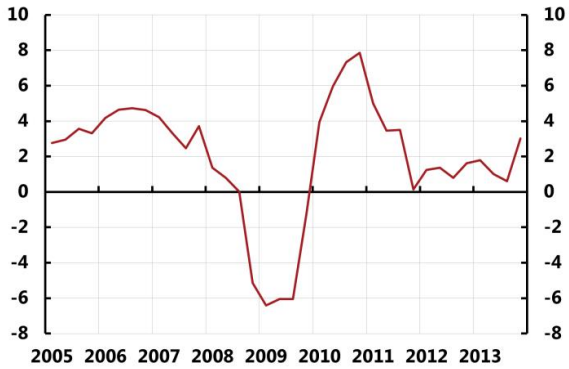
	Weight on		
	DSGE forecast	BVAR forecast	Lagged published forecast
(*a*) *Including lagged forecast*			
Inflation	0.14	0.00	0.86
GDP growth	0.26	0.25	0.49
Nominal exchange rate	0.43	0.36	0.22
Repo rate	0.19	0.07	0.74
(*b*) *Excluding lagged forecast*			
Inflation	0.67	0.33	
GDP growth	0.48	0.52	
Nominal exchange rate	0.53	0.47	
Repo rate	1.00	0.00	

Figure 1: Macroeconomic developments in Sweden, 2005–2013

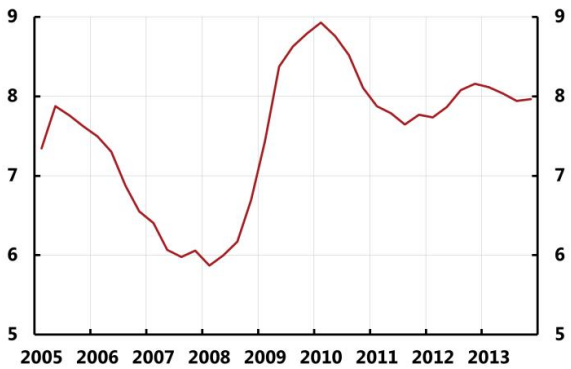
(a) CPIX/CPIF inflation



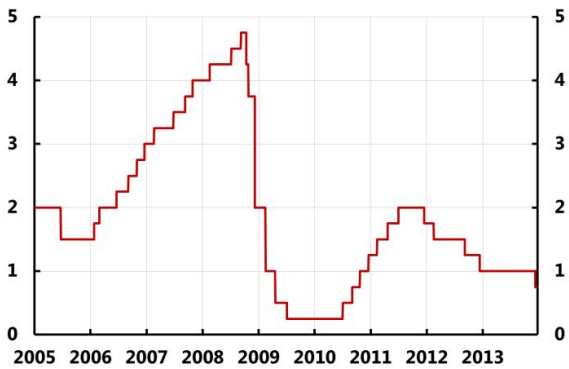
(b) GDP growth



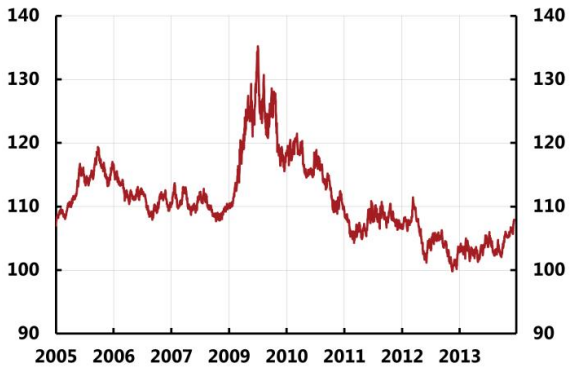
(c) Unemployment



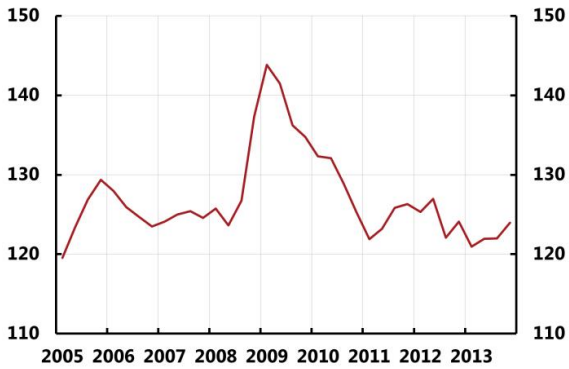
(d) Repo rate



(e) Nominal exchange rate

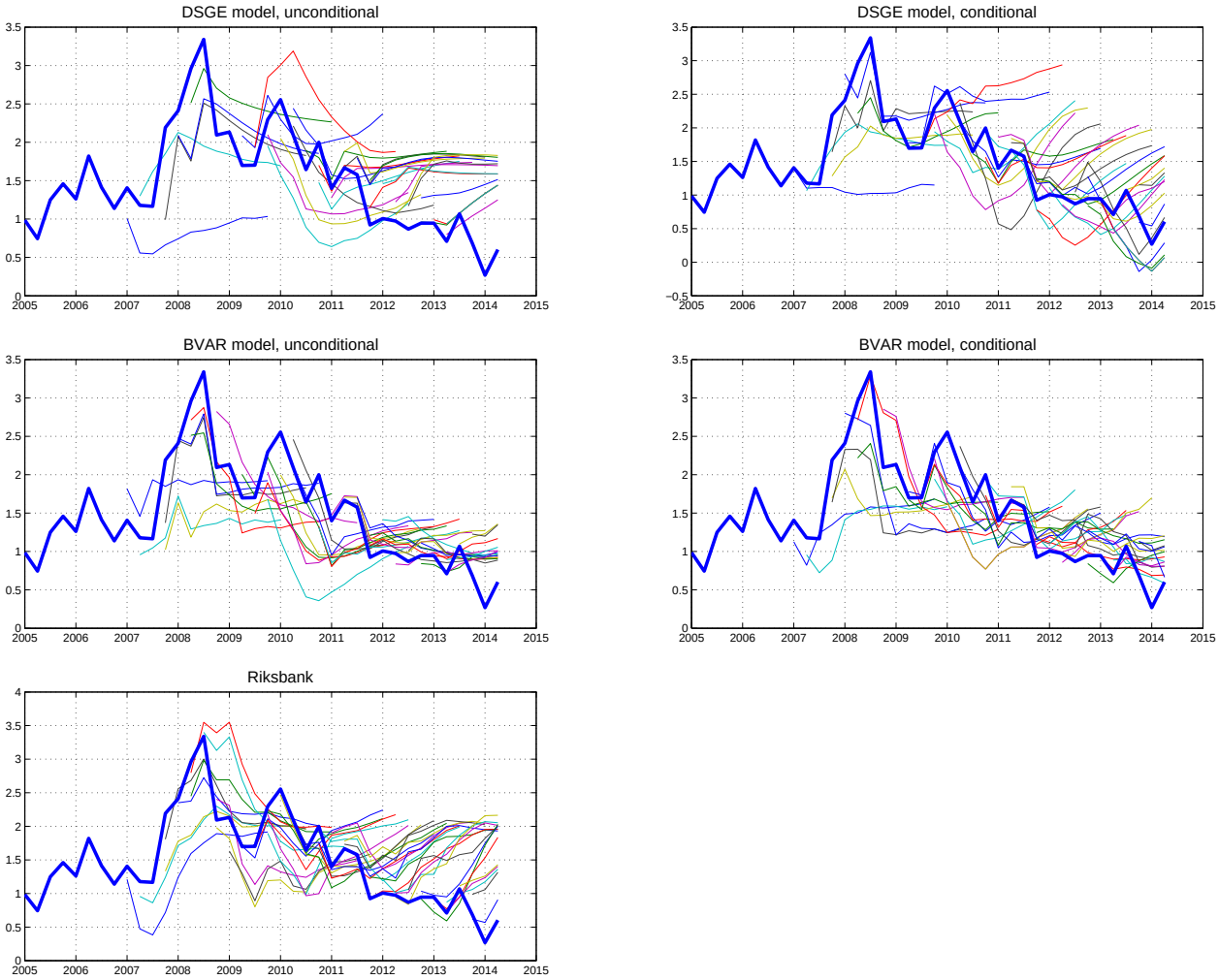


(f) Real exchange rate



Inflation: annual percentage change of CPIX or CPIF; GDP growth: annual percentage change, seasonally adjusted data; Unemployment: unemployed as percentage of labor force aged 15–74 years, seasonally adjusted data; Repo rate: per cent; Nominal exchange rate: trade-weighted (KIX) index, $1992 - 11 - 18 = 100$; Real exchange rate: trade-weighted (KIX) index, $1992 - 11 - 18 = 100$. Source: Statistics Sweden, the Riksbank, and national sources.

Figure 2: Inflation and real-time forecasts



Annual percentage change in CPIX or CPIF. Source: Statistics Sweden and Sveriges Riksbank.

Figure 3: Inflation forecasts: RMSE and bias

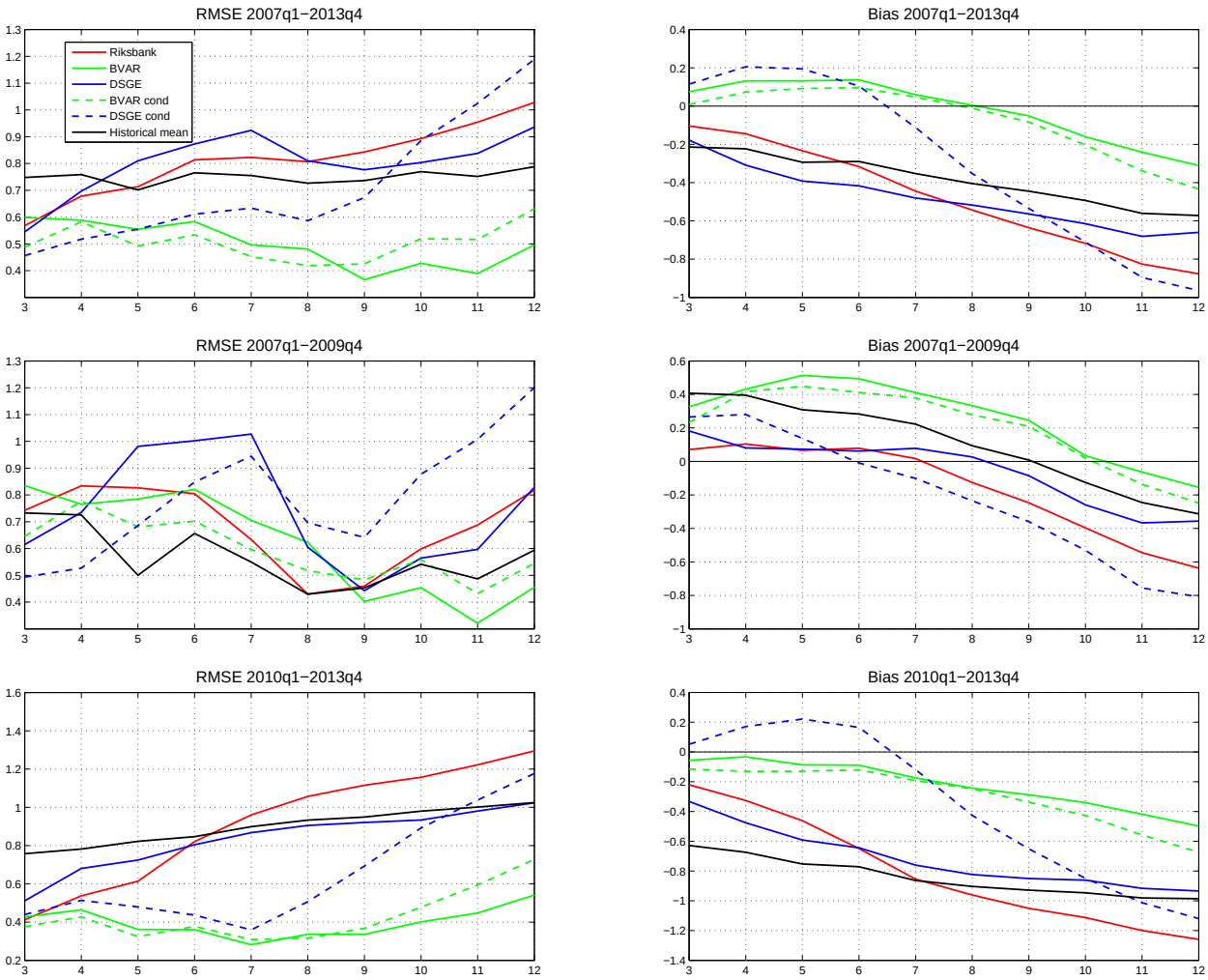
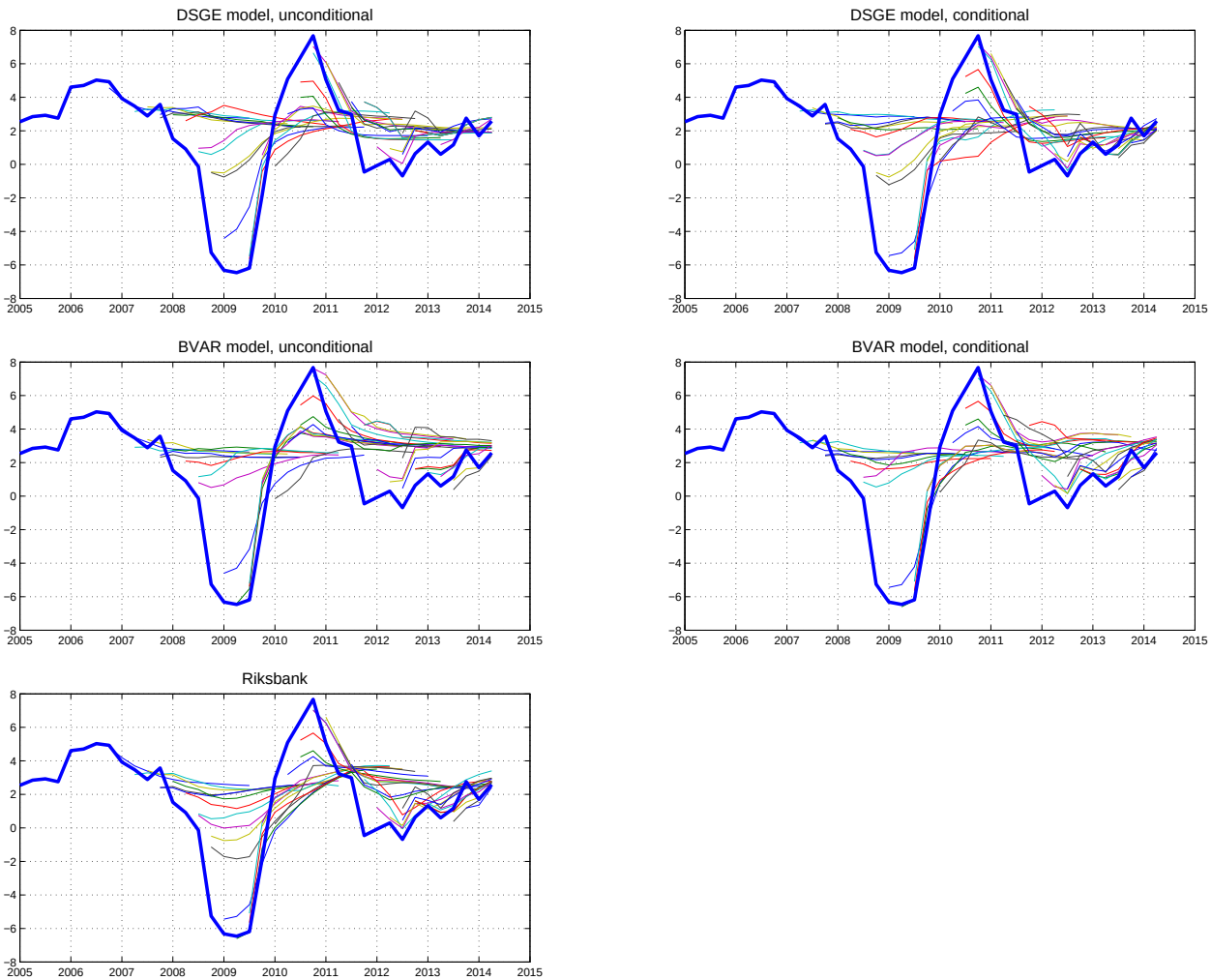


Figure 4: GDP growth and real-time forecasts



Annual percentage change in GDP, seasonally adjusted data. Source: Statistics Sweden and Sveriges Riksbank.

Figure 5: GDP growth forecasts: RMSE and bias

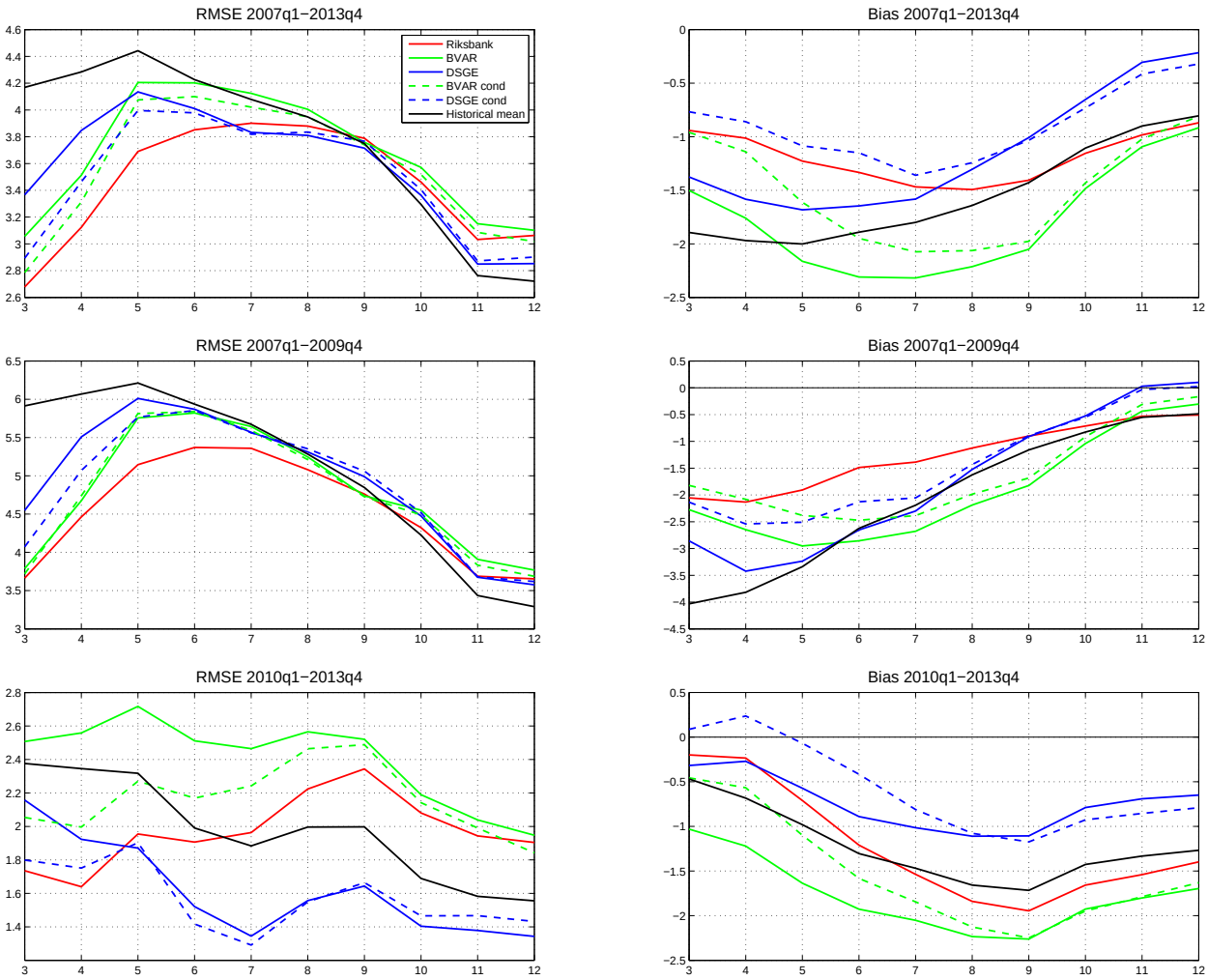
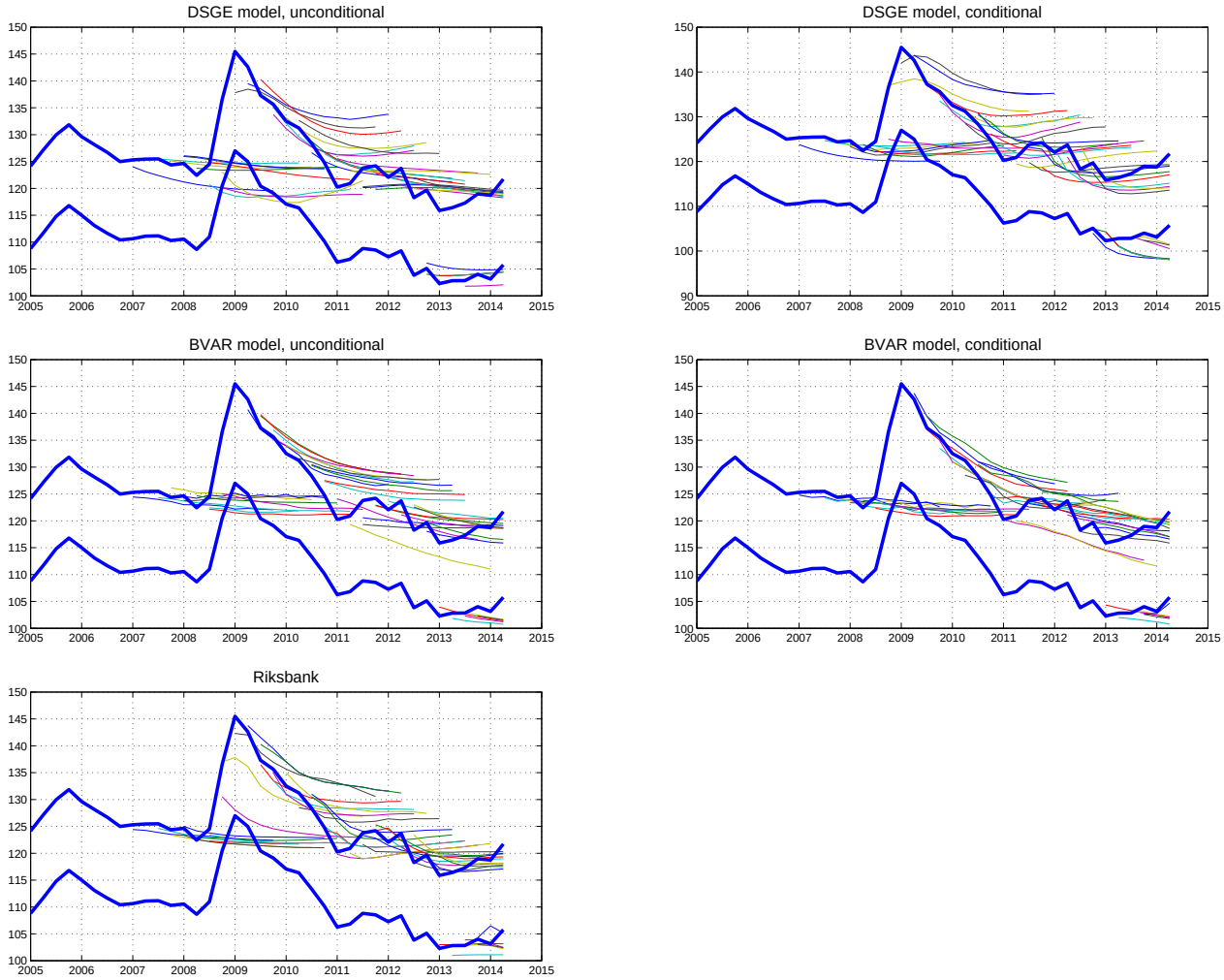


Figure 6: Nominal exchange rate and real-time forecasts



Competition-weighted nominal exchange rate. Upper line and forecasts: TCW index, 1992-11-18 = 100; lower line and forecasts: KIX index, 1992-11-18 = 100. Source: Statistics Sweden and Sveriges Riksbank.

Figure 7: Nominal exchange rate forecasts: RMSE and bias

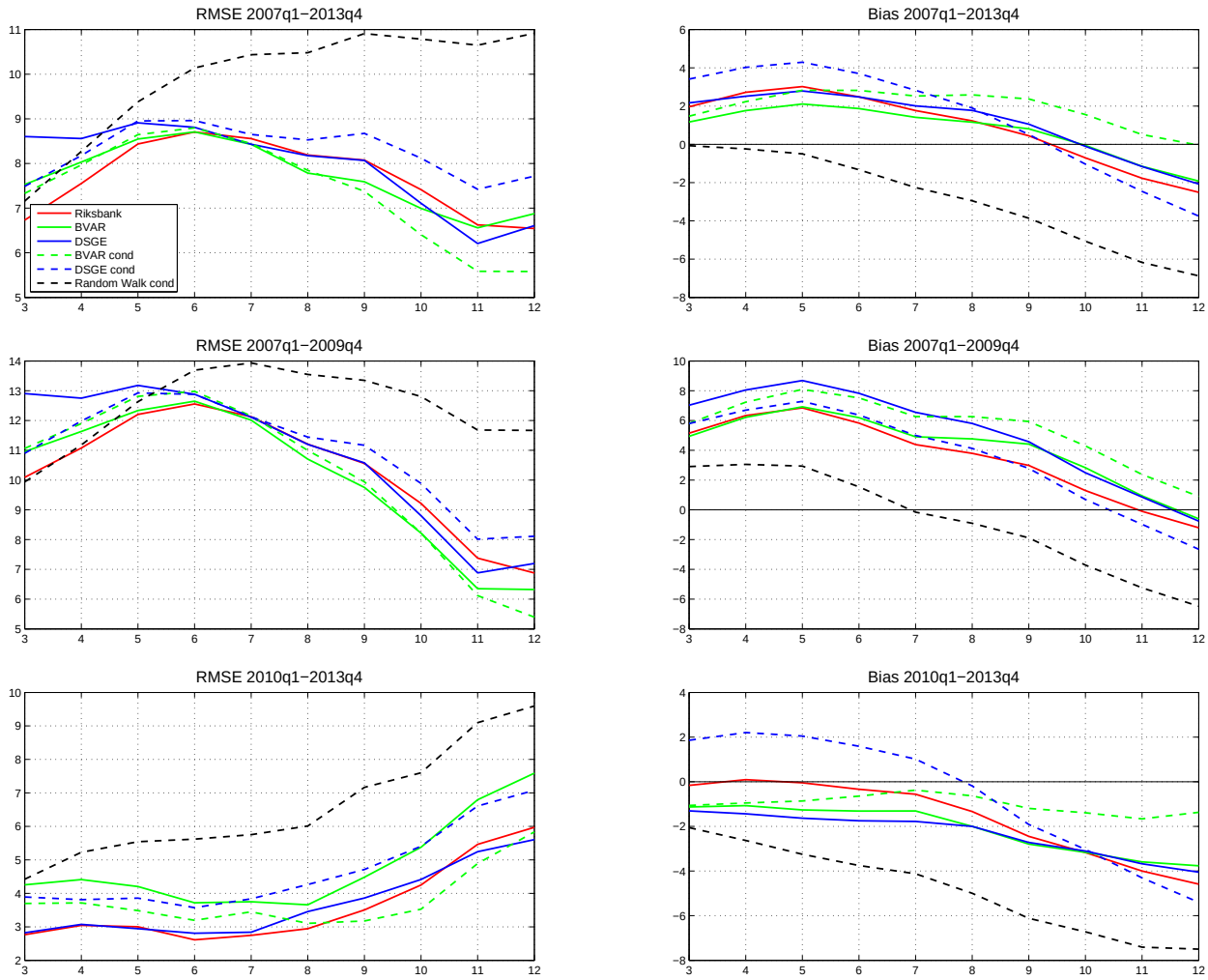
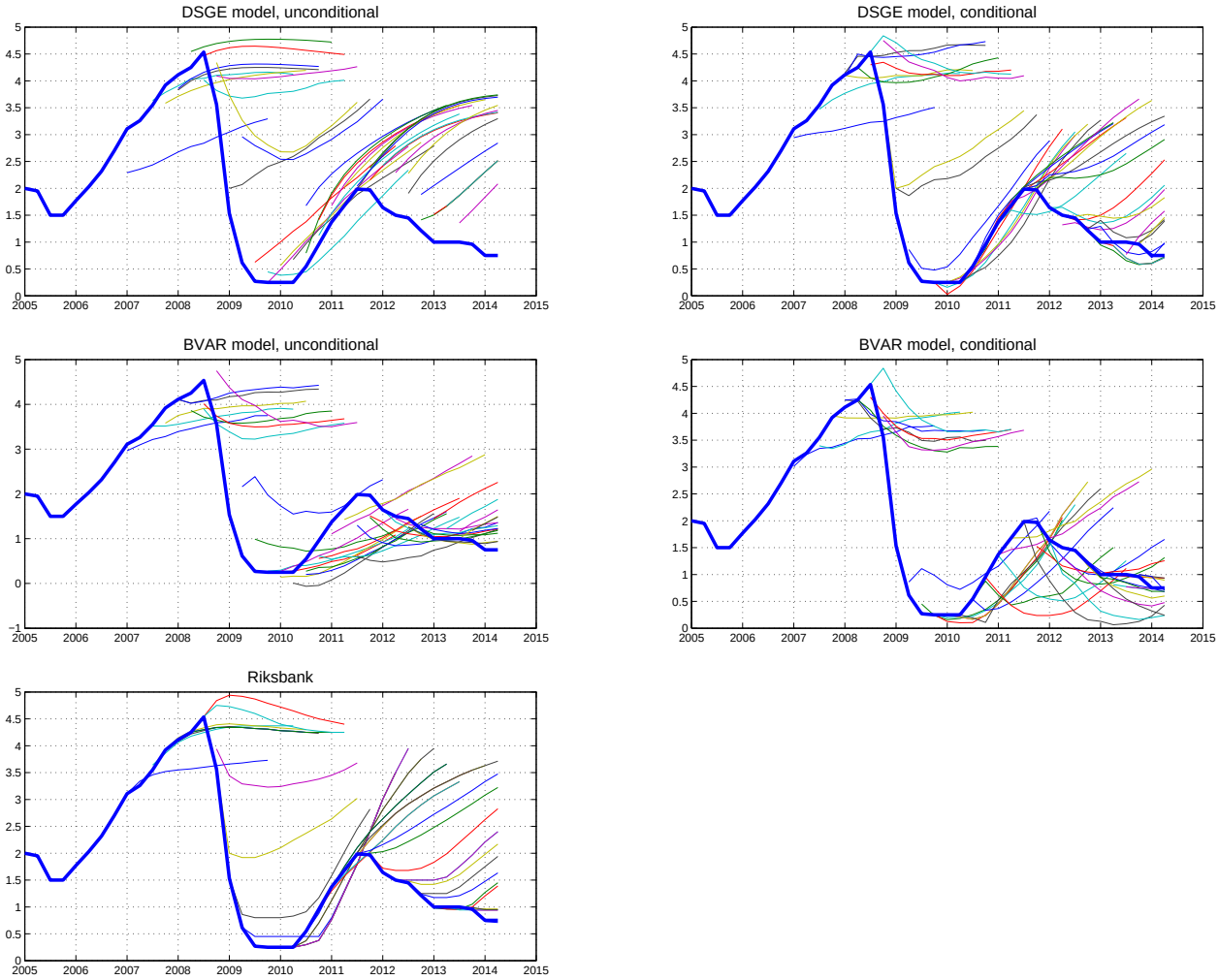


Figure 8: Repo rate and real-time forecasts



Per cent. Source: Sveriges Riksbank.

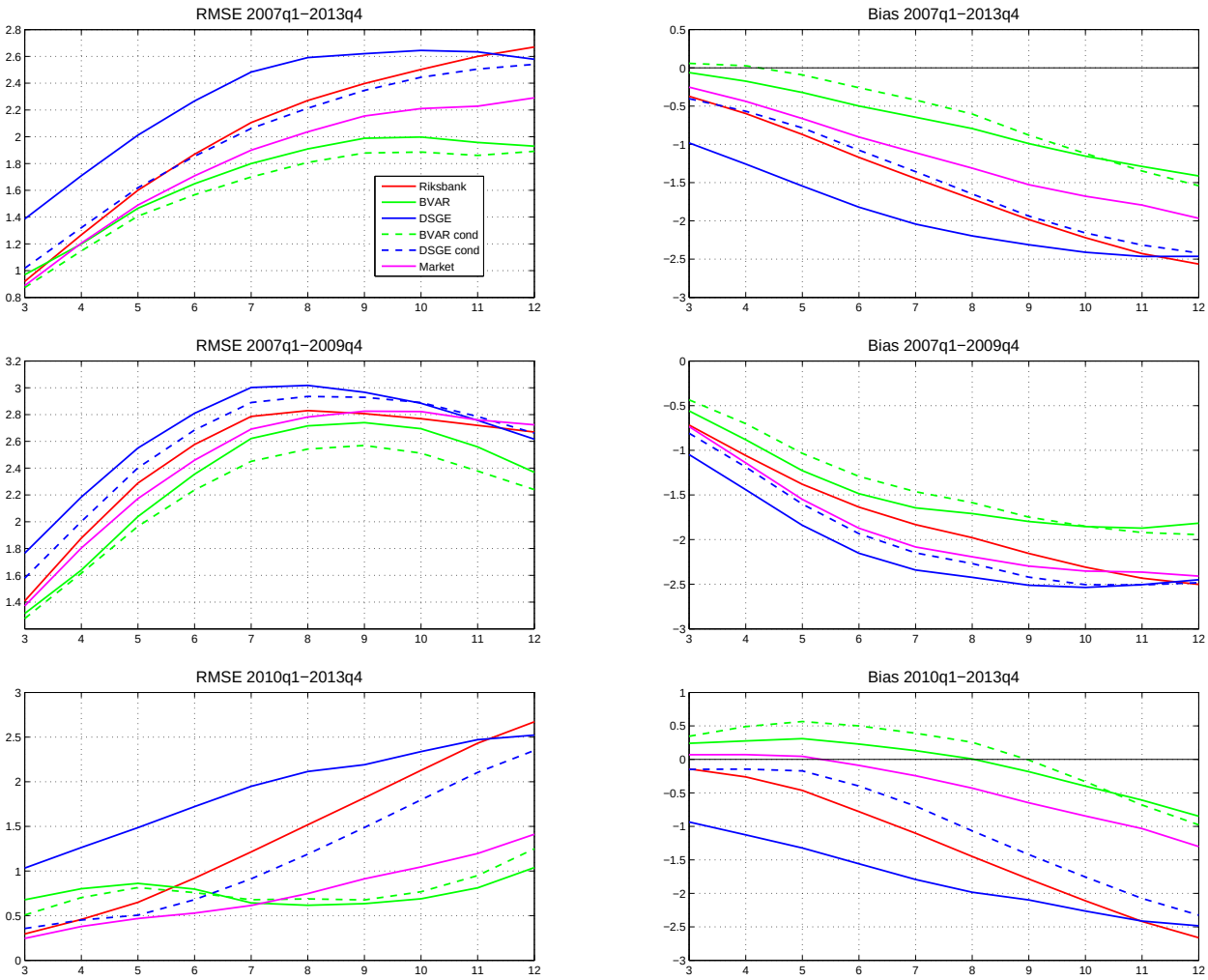



Figure 9: Repo rate forecasts: RMSE and bias