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

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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) from 2007 to 2013. We compare 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.

JEL Classification: E37, E52.

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1 Introduction

Since the introduction of inflation targeting regimes in many countries 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. Some central banks, including Norges Bank and Sveriges Riksbank (the central banks of Norway and Sweden), 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 also include judgemental adjustments. Some of this judgement is motivated by a need to take into account extra-model information. Other judgement may be needed to adjust the predicted path of the monetary policy instruments in order to achieve a well-balanced policy, for instance, to make inflation approach the inflation target at a suitable pace.

The published central bank forecasts are regularly evaluated.[1] Pure model forecasts produced by central banks, however, are rarely made public and are therefore not easily evaluated. In this paper we evaluate published (judgemental) forecasts as well as model-based forecasts produced to support monetary policy decisions at Sveriges Riksbank from 2007 to 2013. 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 judgemental forecasts.[2]

We analyze forecasts made in 2007 to 2013, a period characterized by a deep financial crisis and a global recession, followed by a slow recovery in many parts of the world. Inflation in Sweden fell during these years, and was occasionally lower than the inflation target. Monetary policy was therefore made more expansionary in a series of steps. During these years the Riksbank (like many other forecasters) consistently overestimated

[1] See, for instance, Sveriges Riksbank (2015), Andersson and Palmqvist (2013), or Löf (2015) for Sweden, Falch and Nymoen (2011) for Norway, or Groen, Kapetanios, and Price (2009) for the U.K.

[2] Fawcett, Körber, Masolo, and Waldron (2015) evaluate forecasts from the Bank of England's DSGE model COMPASS estimated using real-time data since 2000. However, these forecasts were not available to policymakers in real time. Alessi, Ghysels, Onorante, Peach, and Potter (2014) evaluate judgemental staff forecasts from the European Central Bank and the Federal Reserve Bank of New York available in real time during the financial crisis.

the rate at which inflation would return to target and also the pace at which the repo rate would be raised towards more normal (long-run) levels. The published inflation and repo rate forecasts thus display a bias. Our evaluation shows that inflation and repo rate forecasts from the DSGE model display a similar bias, whereas forecasts from the BVAR model have a smaller bias. The BVAR model forecasts for inflation and the repo rate perform very well both in absolute terms and relative to the DSGE model forecasts and the published forecasts.

For GDP growth and the exchange rate the pattern is less clear. Which forecast is more accurate depends on the time period and the forecast horizon. But for the exchange rate almost all forecasts in our data set are more accurate than a naive random-walk forecast. This is perhaps surprising, as random-walk forecasts are typically seen as a benchmark that is difficult to beat (see, e.g., Rossi (2013)).

To better understand the role of models in forecasting at the Riksbank, and to evaluate the perceived usefulness of model forecasts, we go on to systematically relate the published forecasts to the forecasts from the two models. Despite the fact that forecasts from the BVAR model were more accurate than the DSGE model forecasts, the published forecasts for inflation and the repo rate are more closely related to the DSGE model forecasts than to 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. For GDP and exchange rate forecasts, the published forecasts are in line with an average of the two model forecasts.

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 the published and the model-based forecasts since 2007, and in Section 4 we relate the model forecasts to the published judgemental forecasts. Finally, we sum up and draw some conclusions for future work in Section 5. An Appendix gives some further details of our data set, which is available from the authors upon request.

2 Monetary policy and macroeconomic modelling at the Riksbank

2.1 The monetary policy framework

Monetary policy at Sveriges Riksbank is guided by an inflation target that was introduced in 1993 and applied from 1995 onwards. The Riksbank has specified this inflation target to 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 partly using the interest costs for owner-occupied housing, monetary policy decisions are also guided by inflation measured by the index CPIF, CPI with a fixed mortgage rate.[3] In addition to stabilizing inflation around the inflation target, monetary policy also strives to stabilize production and employment around long-term sustainable paths, and possibly also takes account of other factors. The Riksbank therefore conducts what is sometimes referred to as "flexible inflation targeting."[4]

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, typically in February, April, July, September, October, and December. After each meeting, the Riksbank publishes 12-quarter forecasts for a large number of variables to motivate the monetary policy decision. 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 full set of forecasts, including the repo rate forecast, or "repo rate path." In February 2015, the Riksbank launched a program to purchase government bonds, and since then the Executive Board has on occasion also voted on the size and design of the purchase program.

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.[5] The forecasting process consists of several steps: First, a forecast is produced for the international (trade-weighted) economy, in terms of GDP growth, consumer price 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

[3]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.

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

[5]Hallsten and Tägtström (2009) provide a more detailed description of the forecasting and decision-making process at the Riksbank.

and high-frequency data. Third, a set of medium-term forecasts is produced for the main variables (including 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 medium-term forecasts for the main variables are "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 assumption on the level and path for the repo rate and possibly other monetary policy tools. The staff policy assumption is informed by various experiments and simulations of the DSGE model "Ramses," as well as other models. Subsequently, after input from the Executive Board and further revisions, the Executive Board takes ownership of the forecasts and these are published in a *Monetary Policy Report* or *Monetary Policy Update* on the day after the monetary policy meeting.[6]

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 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 forecast for the repo rate and to assist Executive Board members in making 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. At the Riksbank, this conditioning is based both on formal analysis and on judgemental adjustments.

2.2 Macroeconomic modelling at Sveriges Riksbank

Since the introduction of inflation targeting in 1993, monetary policy analysis at the Riksbank has been supported by models used to produce forecasts for key variables. The

[6]From February 2007 to February 2015, the Riksbank published three *Monetary Policy Reports* and three *Monetary Policy Updates* per year. Since April 2015, the Riksbank publishes six *Monetary Policy Reports* per year, after each regular monetary policy meeting.

suite of models has developed over time. Currently the Monetary Policy Department uses three macroeconometric models for forecasting and monetary policy analysis.

In the early 2000s, 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 was adapted to the policy environment by 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 is not re-estimated regularly. For a large part of our sample period, the parameters were estimated on 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. Currently (in January 2016) the parameters of the model are estimated using data until 2014Q2.

For monetary policy analysis, 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) (see Jonsson and Moran (2014)), and a small-scale 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 re-estimated in

each policy round using data since 1995.[7] The current version of the model includes three foreign variables (trade-weighted GDP growth, CPI inflation, and monetary policy rate) and six domestic variables (GDP growth, CPIF inflation, hours worked, nominal wages, the repo rate, and the trade-weighted nominal exchange rate).

The third macroeconomic model, Moses, has been 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.[8]

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.

In 2005–07 the Swedish economy was performing fairly well. Average GDP growth in these years was 3.8 percent and unemployment was falling, although inflation was below target, between 1 and 1.5 percent. 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 percent.

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 percent to 4.75 percent.

When the financial crisis escalated in September 2008, export demand plummeted, and exports subsequently fell five quarters in a row. GDP therefore fell dramatically and unemployment increased from 6 percent to close to 9 percent at the end of 2009. Inflation fell from above 3 percent in September to around 2 percent at the end of 2008. Thereafter it kept fairly stable, partly due to a large exchange rate depreciation (the exchange rate weakened by more than 20 percent from July 2008 to March 2009).[9] In response to the dramatic worsening of the economic outlook, the repo rate was reduced

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

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

[9] The effective exchange rate index is set 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. The underlying exchange rates are measured in terms of the domestic currency price of foreign currency. A higher value of the index therefore implies a weaker exchange rate.

rapidly. On October 8, in between scheduled monetary policy meetings, the repo rate was cut to 4.25 percent 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 percent, and at the meeting of December 3 the repo rate was cut by another 175 basis points to 2 percent. Eventually the repo rate reached 0.25 percent 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 percent. 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. Unemployment increased again, partly because of an increase in labor force participation, and inflation fell to levels below 1 percent. The repo rate was therefore reduced from 2 percent to 0.75 percent in December 2013. In 2014 GDP growth picked up, but unemployment remained around 8 percent. Inflation remained low, and also inflation expectations fell gradually. Monetary policy was therefore made more expansionary, and the repo rate was cut in July and October 2014, to a level of 0 percent.

During 2015 the repo rate was cut further to -0.35 percent in three steps in February, March, and July, and the Riksbank has launched a program to purchase government bonds, in order to make inflation increase towards the target of 2 percent.

3 Model forecasts and monetary policy since 2007

Monetary policy decisions are supported by forecasts of a large number of variables. While the published judgemental forecasts are regularly evaluated and compared with forecasts made outside the Riksbank, the model forecasts (which are an important input into the judgemental forecasts) have never previously been published or evaluated. In what follows, we evaluate the judgemental forecasts published by the Riksbank since 2007, as well as the model-based forecasts from the DSGE model and the BVAR model. We focus on forecasts of annual consumer price inflation, annual GDP growth, the effective (trade-weighted) nominal exchange rate, and the repo rate. We evaluate the forecasts over the period from February 2007 to December 2013 against data from 2007Q1 to 2014Q4. In this period, the Riksbank has published forecasts on 40 occasions.[10] 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 inflation and low in-

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

terest rates. In addition to the full sample we therefore also split the sample in two: forecasts made before and after the end of 2010.

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 forecasts, and published judgemental forecasts over the period 2007Q1–2013Q4.[11] The model forecasts are those that were presented 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 (the average forecast error, defined as the difference between outcomes and 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 forecast (typically for the current and next quarter) 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 this 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 the forecasting rounds, by comparing the model forecasts with the published judgemental forecasts.

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.[12] 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 RMSE and bias of each of the five forecast methods.[13]

As benchmarks we also report RMSE and bias for naive forecasts. For inflation and GDP forecasts the naive forecasts are given by their respective historical mean at each forecast date. The naive exchange rate forecasts are given by a random walk, and the naive repo rate forecasts are based on financial market expectations extracted from

[11]The dataset used is available from the authors upon request.

[12]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.

[13]There are a few occasions in our sample where model forecasts are missing or are incorrect, and have therefore been excluded. See the Appendix for more details.

forward rates.[14] 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.

3.1 Inflation forecasts

We begin by studying forecasts of annual consumer price inflation in Figures 2 and 3. Each panel of Figure 2 shows the development of CPIX/CPIF inflation and one set of real-time forecasts in our data set. 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.[15] For much of the sample period since 2010, the exchange rate has been expected to appreciate in the short run. This has led to inflation forecasts in the DSGE model that fall in the short run, after which inflation increases towards the inflation target.

As in the DSGE model the BVAR model has tended to forecast falling inflation in the short run, but in the BVAR model inflation typically remains at the lower level, at least since 2010. The DSGE model forecasts thus have a tendency to approach the inflation target of two percent over time, whereas the BVAR forecasts do not.[16] The published forecasts are less dispersed than the DSGE model forecasts, but more so than the BVAR forecasts. These are also always close to two percent after two years, as monetary policy has been implemented with the objective of returning inflation to the target after two to three years.

Figure 3 reports the RMSE and bias of the inflation forecasts over the full period 2007–14 and the two subperiods 2007–10 and 2011–14. Looking at the full sample,

[14]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 are based on the outcome in 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.

[15]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 produces 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 those with anticipated shocks. Forecasts from April 2013 are therefore conditioned on the international forecasts with unanticipated shocks.

[16]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.

at essentially all horizons the BVAR forecasts (unconditional and conditional on the domestic short-term forecast and the international forecast) have the lowest RMSE. The conditional DSGE model forecasts are competitive with the BVAR forecasts at horizons up to six quarters, but perform considerably worse at longer horizons. The unconditional DSGE forecasts perform well at very short horizons, but worse at longer horizons. The published forecasts show a similar pattern: they perform fairly well at very short horizons, but much less so at longer horizons. And the forecasts based on the recursive historical means do not perform very well at any forecast horizon, at least compared with the BVAR forecasts.

The pattern for the bias is similar to that for the RMSE, so the differences in terms of RMSE are largely driven by differences in bias.[17] The DSGE model and the published forecasts have a negative bias at longer horizons, leading also to larger RMSE. This is due to the tendency of these forecasts to approach two percent after two to three years, leading to a systematic overprediction of inflation since 2011.

For the first subperiod from 2007 to 2010, all models do about equally well for horizons up to eight quarters (except perhaps the unconditional DSGE forecasts), while for longer horizons the BVAR forecasts dominate the other forecasts. The historical mean forecast is also doing well in this period. 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 historical mean forecasts perform much worse in this period, as inflation has steadily decreased since 2011, so the historical mean has not been a good indicator of future inflation.

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 helpful at horizons up to two years, but not for longer horizons, where the unconditional forecasts have performed better than the conditional ones. These findings suggest that the short-term (two-quarter) forecasts for the Swedish economy, as well as the near-term forecasts for the international economy, have been important in forecasting Swedish inflation, while the longer-term international forecasts have not added value for the Swedish inflation forecast produced by the DSGE model.[18]

[17]The mean squared forecast error can be expressed as the sum of the squared bias and the variance of the forecast error.

[18]Whether this latter result arises because the DSGE model is not capturing well the impact of foreign factors on Swedish inflation or because the longer-term international forecasts have not been very accurate would be an interesting question to pursue in future work. Aranki and Reslow (2015) evaluate the Riksbank's forecasts for foreign GDP growth, inflation and policy rates over the period 2007-2015.

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 0.7 over the full sample and 0.6 and 0.4, respectively, for the first and second sub-periods. At many horizons (also longer horizons) the BVAR model forecasts generate a lower RMSE. This is an impressive performance.

One important reason the BVAR forecasts are so dominant relative to the DSGE model and the published forecasts is that the latter tend to approach two percent over time, leading to biased forecasts 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 pattern is also fairly strong in the DSGE model, although these forecasts are not conditioned on an appropriate monetary policy. The conditional forecasts have a weaker tendency than the unconditional forecasts to approach two percent. This is particularly so in the period since 2012, when the forecasts for international interest rates have been very low, leading the exchange rate to strengthen over the forecast period. Nevertheless, the tendency is fairly strong also in these forecasts. These results raise some issues related to inflation forecasting at inflation-targeting central banks to which we will return later.

3.2 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, underestimated the strong recovery in 2010, and then overpredicted GDP growth for much of the period since 2011. As a consequence, over the full sample period all forecasts have high RMSE (especially at medium-term horizons) and a negative bias (on average the forecasts have overpredicted GDP growth).

For the full sample, the published forecasts have the lowest RMSE for horizons up to six quarters. Beyond that there are small differences between the forecasting methods, although there is some indication that the conditional BVAR forecasts are somewhat better than the other methods. When looking at bias the published forecasts

They find that the Riksbank has tended to overestimate foreign GDP growth and policy rates and to underestimate foreign inflation, although this underestimation has been fairly small. Comparing with other analysts they show that the Riksbank's ability to forecast the foreign economy is close to average.

perform well for shorter horizon, whereas the DSGE forecasts have the smallest bias for longer horizons. The results from the first sub-period are similar to those from the full sample. For the more recent sub-period a somewhat different picture emerges: the DSGE forecasts and the published forecasts have the lowest RMSE for all horizons, and the RMSE decrecases as the horizon lengthens, while 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.

These results suggest that judgemental adjustments to model forecasts are useful in volatile times, such as those in 2007–11. This is also visible in Figure 4: the published judgemental forecasts for 2008–09 (and perhaps also 2010) were closer to the outcomes than the model forecasts.

3.3 Exchange rate forecasts

Figures 6 and 7 evaluate forecasts of the nominal exchange rate, a variable that is notoriously difficult to forecast.[19] Again, no forecast captured the dramatic movements in 2008–09. 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.[20]

As with the GDP forecasts, 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, while at medium-term horizons (six to nine quarters) there are no large differences between the forecasting methods, except for the random-walk forecasts which perform poorly. At long horizons the conditional BVAR forecasts perform best. For the second sub-period, the published forecasts perform very well.

Looking at bias over the whole sample the model forecasts and the published forecasts tend to have a positive bias for short horizons, and a small negative bias for long horizons. This pattern is largely driven by the first sub-period, when the exchange rate first weakened dramatically and then strengthened. In the second sub-period, with a persistent strengthening in the exchange rate, all methods except the conditional DSGE model forecasts are approximately unbiased for short horizons and have a positive bias at long horizons.

[19] In October 2012 the Riksbank changed the index for the effective exchange rate used in forecasting, from the TCW ("total competitiveness weights") index with constant weights computed by the IMF to the KIX ("kronindex") with time-varying weights, an index developed by the National Institute of Economic Research.

[20] 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.

Conditioning on external information has improved the BVAR forecasts during the first sub-period, but had a negative impact during the second period. For the DSGE model forecasts, there is a small effect of conditioning during the first period, but conditioning has reduced forecast accuracy during the second period.[21]

A striking result is that the random walk performs so poorly at all horizons beyond four quarters. This is likely driven by the downward (strengthening) trend in the exchange rate over the sample period, which is better captured by the more sophisticated forecasts. But the pattern remains also in the period after 2011. This result goes against many results in the literature, see Meese and Rogoff (1983) and Rossi (2013).

3.4 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 the "repo rate path" can be seen both as a forecast and as an instrument for monetary policy. That is, the published repo rate forecast is chosen to strike a proper balance between returning inflation to target and stabilizing the real economy around long-term sustainable paths (and possibly other factors). Nevertheless, as the published forecasts are intended to be mean forecasts, standard evaluation methods are 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, as with the inflation forecasts.

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 forecasts. For the DSGE model since 2010 the conditioning information has clearly improved on the forecasts. 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 of the repo rate relative to the unconditional forecasts. For the BVAR model forecasts this effect has been smaller.

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

[21]This is partly explained by 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.[22]

3.5 Discussion

Overall, the forecast evaluation suggests that model forecasts perform well compared with judgemental forecasts. Indeed, model forecasts have often been 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, especially during recent years. Using external conditioning information has improved the DSGE forecasts for inflation and the repo rate (confirming the results of Del Negro and Schorfheide (2013)) but not for GDP and the exchange rate.

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, has not been re-estimated each round: the forecasts evaluated here have been based on estimates using data up until 2008Q2, that is, before the financial crisis and the period with low inflation and 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 BVAR model seems more flexible than the DSGE model in letting the forecasts approach steady state very slowly over time.

4 Are model forecasts useful for monetary policy?

An interesting question is how the Riksbank has used the model forecasts to inform the published judgemental forecasts. One way to evaluate the perceived usefulness of model forecasts for the judgemental forecast is to estimate for each variable the regression

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

[22] See also Beechey and Österholm (2014) for an evaluation of the Riksbank's repo rate forecasts and forecasts extracted from financial market participants.

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 $(1 - \alpha_1 - \alpha_2) \in [0, 1]$.

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 forecasts 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 have been judged more useful for story-telling.

Using several different models for forecasting is not always straightforward. On the one hand, forecast accuracy may differ across variables for a given model, so combining forecasts from different models may be a good strategy to produce an optimal set of forecasts. On the other hand, combining model forecasts may hinder building a coherent story.

In addition, for an inflation-targeting central bank the main purpose of the forecasting process is not necessarily to build the most accurate forecast, but to inform policymakers about what is an appropriate monetary policy. That is, the purpose of the forecasting process is to obtain an answer to the question "what monetary policy is likely to make inflation move towards the inflation target at an appropriate pace?" (where an appropriate pace typically is to reach the target within two to three years). Therefore the published inflation forecasts tend always to be close to the inflation target in the medium term.

One approach to find an answer to this question is to use a model to produce a forecast for both inflation and the monetary policy rate, and then study inflation forecasts conditional on different paths for the policy rate in order to find a path that stabilizes inflation around the target. But producing such conditional forecasts is considerably more difficult than just making an unconditional forecast. And using several different models to produce such conditional forecasts may make the process even more complicated.

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. 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) in some cases has 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 use more formal methods than we have used to 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 version of the forecasting models.

Appendix

This appendix documents the forecast data that were used, and the criteria that were used to determine, for each forecasting round and each forecasting method, the first forecast quarter.

The data on forecasts have two different sources. One source is the published, official forecasts of the Riksbank, from February 2007 through December 2013, that are available from the Riksbank webpage (www.riksbank.se). The other source of forecast data is a dataset consisting of real-time forecasts from the Riksbank's two main macroeconomic models (the DSGE model Ramses and the Bayesian VAR model; henceforth, we refer to this second forecast data source as "the forecast data base").[23] The forecast data base also records the offical Riksbank forecasts. During the sample period, official forecasts were published on 40 occasions.

The forecasts are compared to outcomes for the period 2007Q1-2014Q4. For the repo rate, the outcomes refer to quarterly averages of the daily observations (effective date, full-week variant). For the GDP growth rate, the outcomes refer to the fourth (quarterly) difference of the (log of the) final outcome for working day and seasonally adjusted GDP at market prices.

As explained in the main text, the Riksbank has produced forecasts for different subindices of the CPI during the sample period. When computing forecast errors, forecasts of CPIX inflation were evaluated using outcomes for CPIX inflation, and forecasts of CPIF inflation have been evaluated using outcomes for CPIF inflation.[24] Inflation is measured as the quarterly average of the year-on-year change in the relevant index.

During most years included in our sample, from 2007 to late 2012, the Riksbank used the TCW (Total Competitiveness Weights) index to compute and forecast the krona's trade-weighted, effective exchange rate. From October 2012, official forecasts have been based on the index KIX ("kronindex"). For each individual exchange rate forecast, forecast errors were computed using outcomes for the index to which it pertains.

The following procedure was used to determine in what quarter a particular Riksbank forecast begins (i.e., which observations of a particular variable are outcomes, and which observations are forecasts). For each particular forecast round, we consider the date at which the official Riksbank forecast was made public. The quarter to which this date

[23]The forecast dataset is available from the authors upon request.

[24]For the period from May 2009 through April 2010, the outcomes series refer to the original estimate of CPIF inflation as published by Statistics Sweden at the time. This series is different from the official series that is now published by Statistics Sweden as the impact on prices of the subsidy of home repair and maintenance (ROT), which was introduced in 2009, has been revised. For more information of this revision of the CPI, see Statistical News from Statistics Sweden No 2010:364 (Pressmeddelande från SCB nr 2010:364).

belongs is considered to be the first forecast quarter for the repo rate and the exchange rate.[25] Considering the forecasts of inflation and of the growth rate of GDP, we rely on the data on offical forecasts that are published on the Riksbank's webpage, and which contain information concerning the first forecast quarter.

The forecast database contains information regarding the first forecast quarter of the various model forecasts. This information, however, turns out not to be fully reliable. We therefore identify the first forecast quarter as the first quarter where the entries for the model forecast and the official forecast differ.[26]

Some model forecasts were excluded from the sample due to two reasons. First, there are relatively large discrepancies between the data recorded as outcomes in the forecast database and the corresponding outcomes contained in the data files that record the official forecast. We decided to exclude forecasts if the root mean squared difference between the recorded outcomes, over the full sample, was equal to or larger than 5% of the standard deviation of the series. Second, some forecasts was obviously faulty. These reasons lead us to exclude the BVAR forecasts with conditioning information in February, October, and December 2007, February, and December 2008, and February 2009; the unconditional BVAR forecasts in October, and December 2007, December 2008, and February 2009; the unconditional DSGE forecast in July 2009; the conditional DSGE forecast in July 2009.

[25]For the repo rate forecasts, we make an exception to this rule for the first forecast of 2007, which was published on March 29, 2007. Although the Executive Board could in principle have scheduled a new meeting the following day, a new rate decision would not have been implemented until the first days of the following month (i.e., the next quarter). For this forecasting round, we therefore consider 2007Q1 as an outcome for the repo rate. For the exchange rate, we make an exception for all forecasts that were published in the July *Monetary Policy Report*. This report is published in the first few days of the month, so the forecasts were finalized towards the end of the second quarter. We therefore treat the second quarter as a forecast quarter for these forecasts.

[26]As a robustness check, we also computed RMSE for all variables using the information on the first forecast quarter that is recorded in the forecast database, using the full sample. Our main results do not change under this alternative timing assumption.

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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	

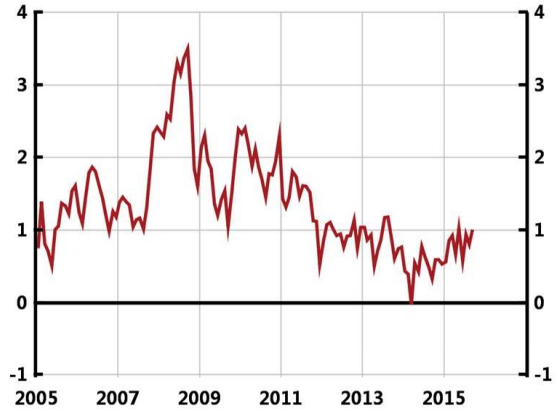
The table shows the estimated weights α_1, α_2, and $(1-\alpha_1-\alpha_2)$ that minimize the mean squared error of the regression

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

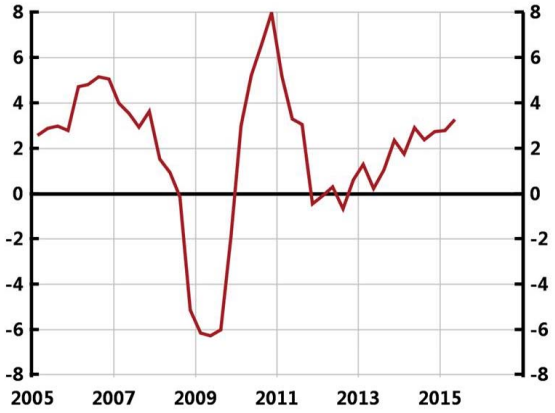
where α_1, α_2, $(1-\alpha_1-\alpha_2) \in [0,1]$, and where $Y_{j,t}$ is a vector containing the published forecasts for variable j at policy round t, $X_{j,t}^{\text{DSGE}}$ and $X_{j,t}^{\text{BVAR}}$ are vectors containing the corresponding conditional DSGE model forecast and conditional BVAR forecasts, respectively, and $Y_{j,t-1}$ is a vector containing the published forecasts at the previous policy round $t-1$.

Figure 1: Macroeconomic developments in Sweden, 2005–2015

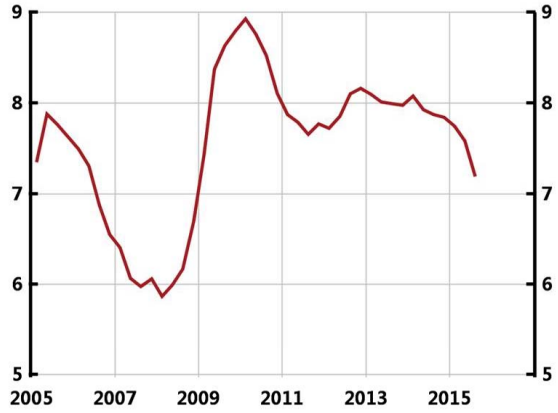
(a) CPIX/CPIF inflation



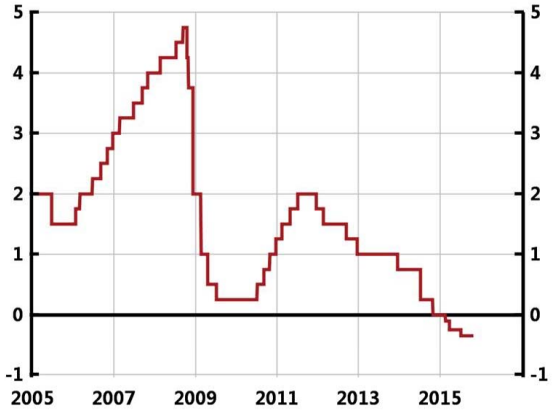
(b) GDP growth



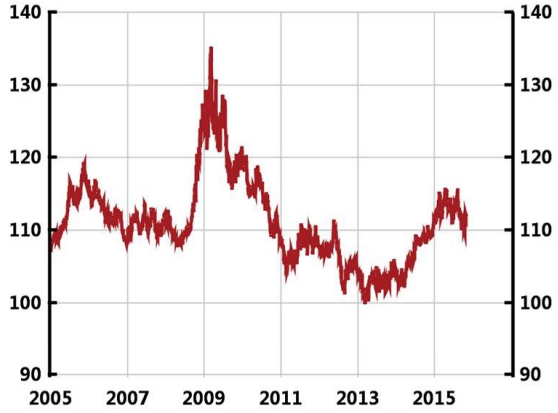
(c) Unemployment



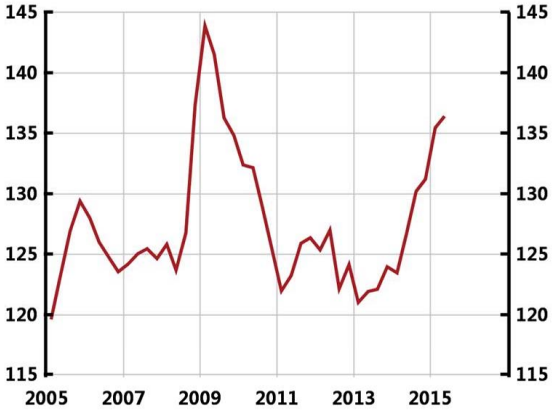
(d) Repo rate



(e) Nominal exchange rate

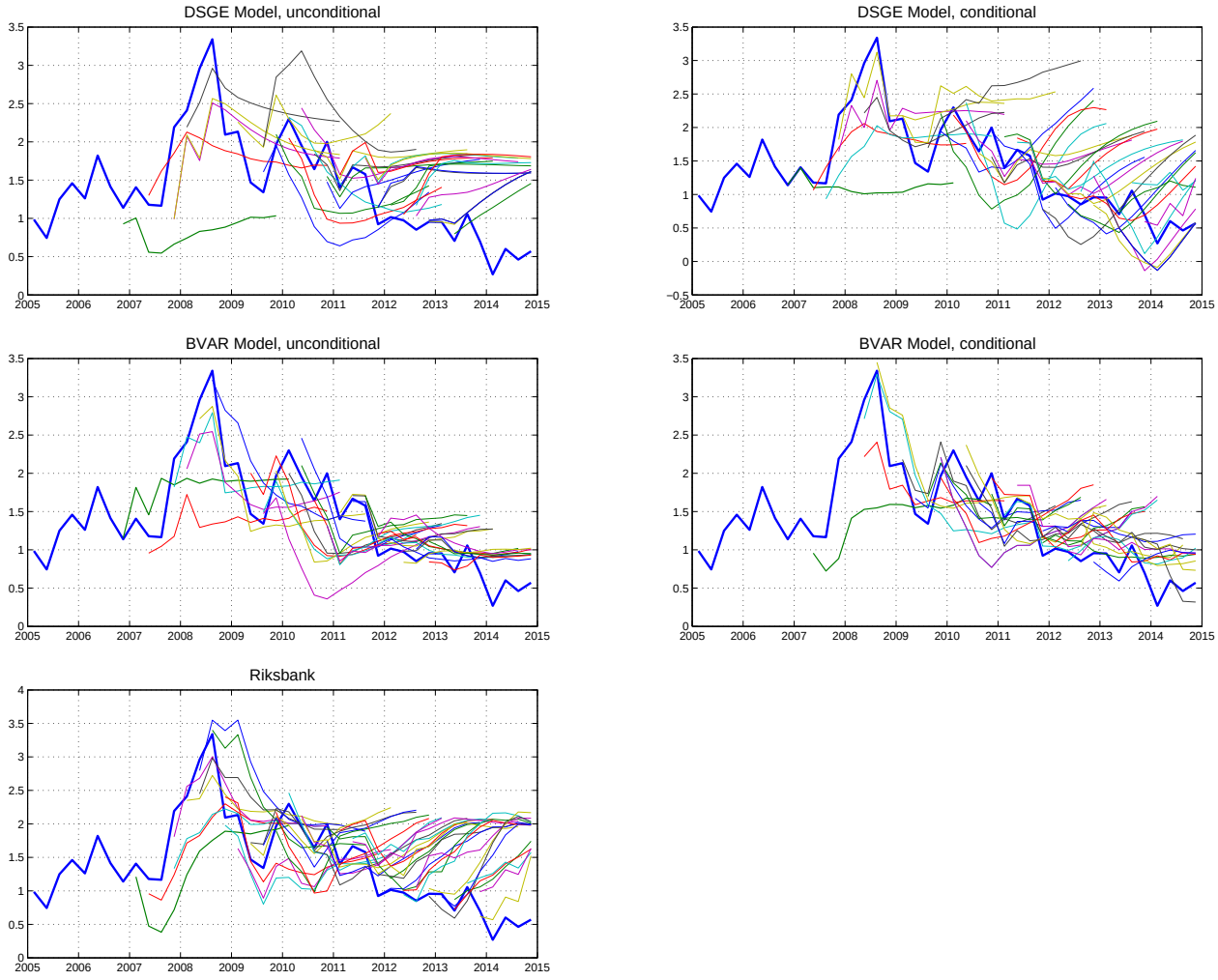


(f) Real exchange rate



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

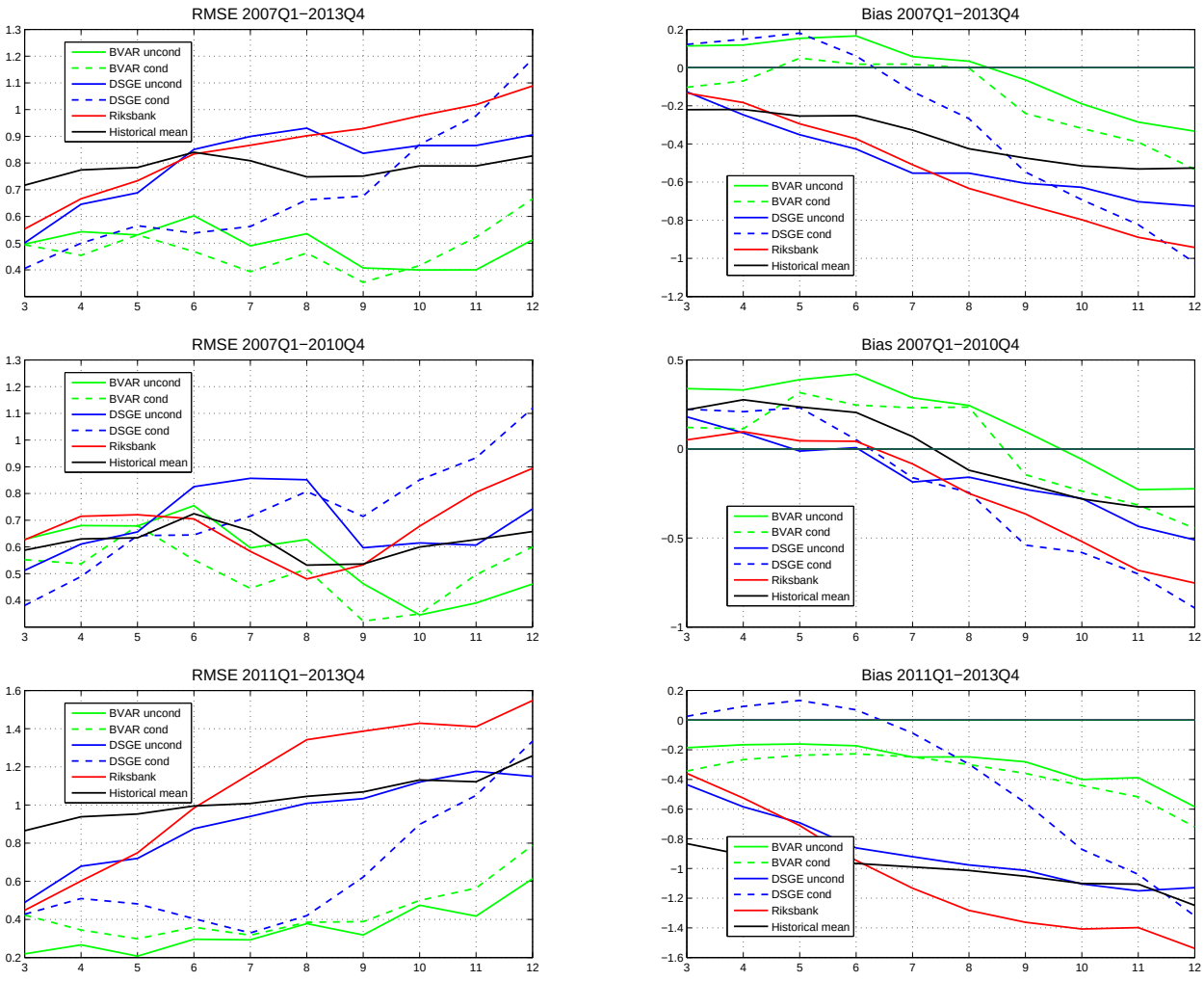
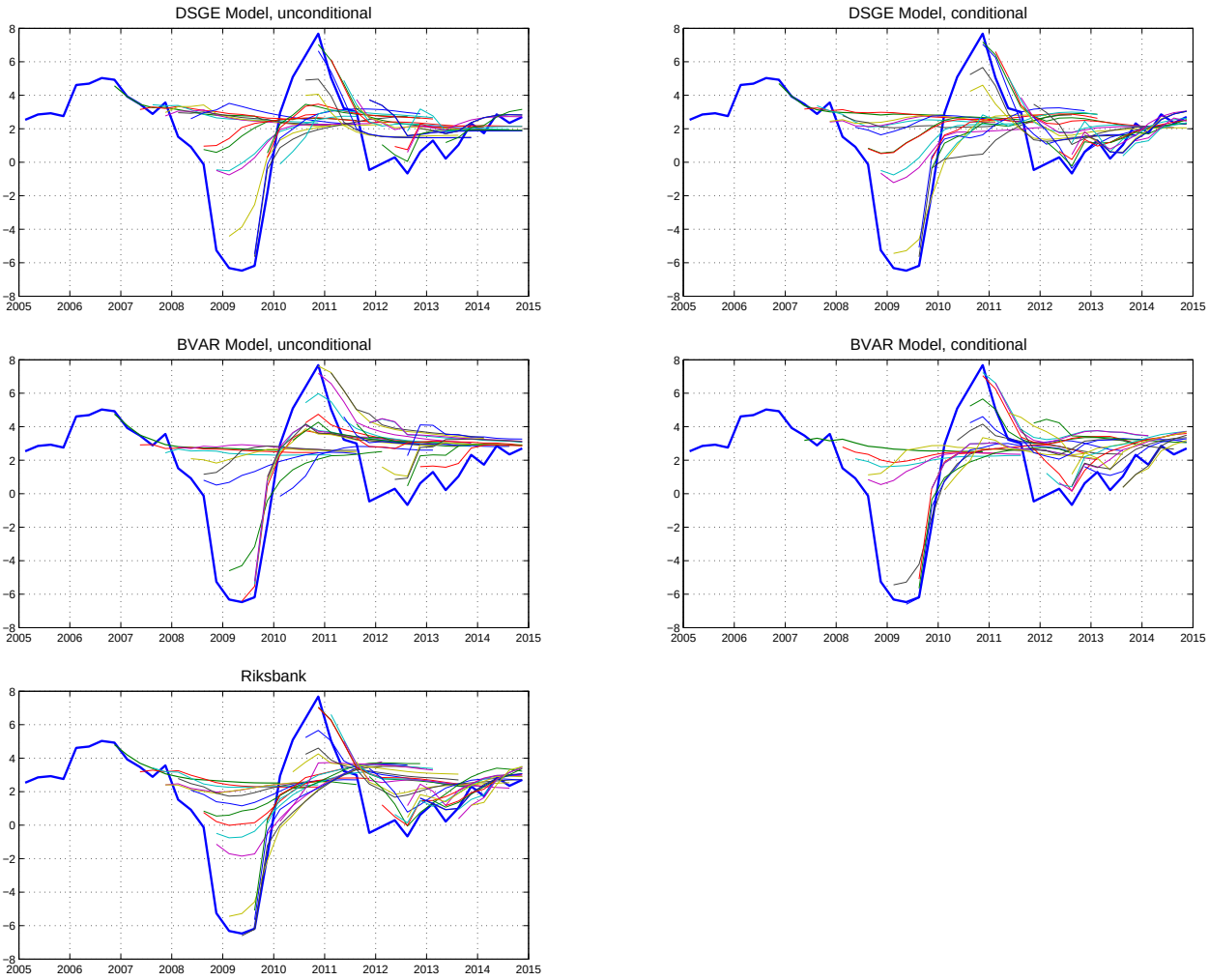


Figure 4: GDP growth and real-time forecasts



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

Figure 5: GDP growth forecasts: RMSE and bias

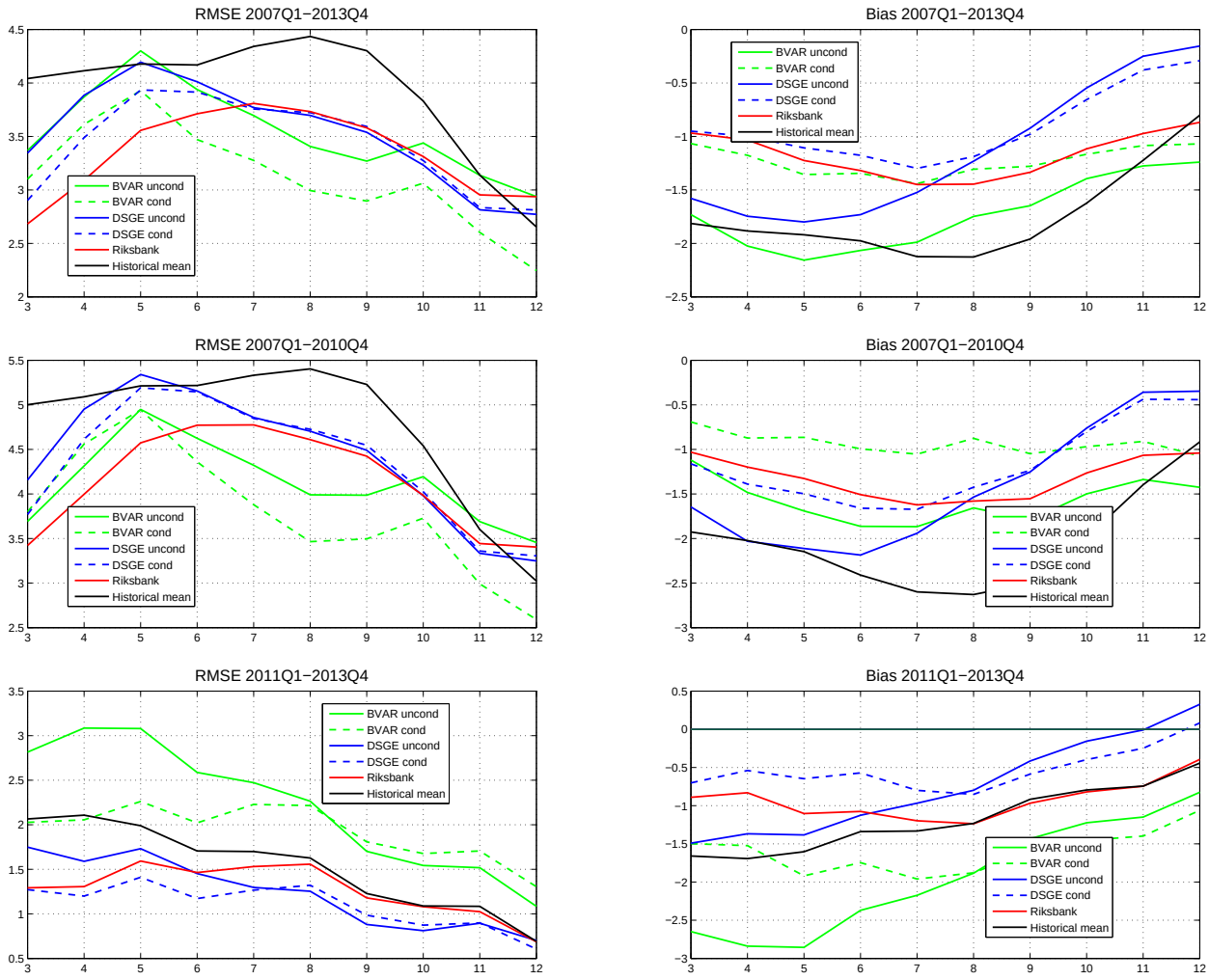
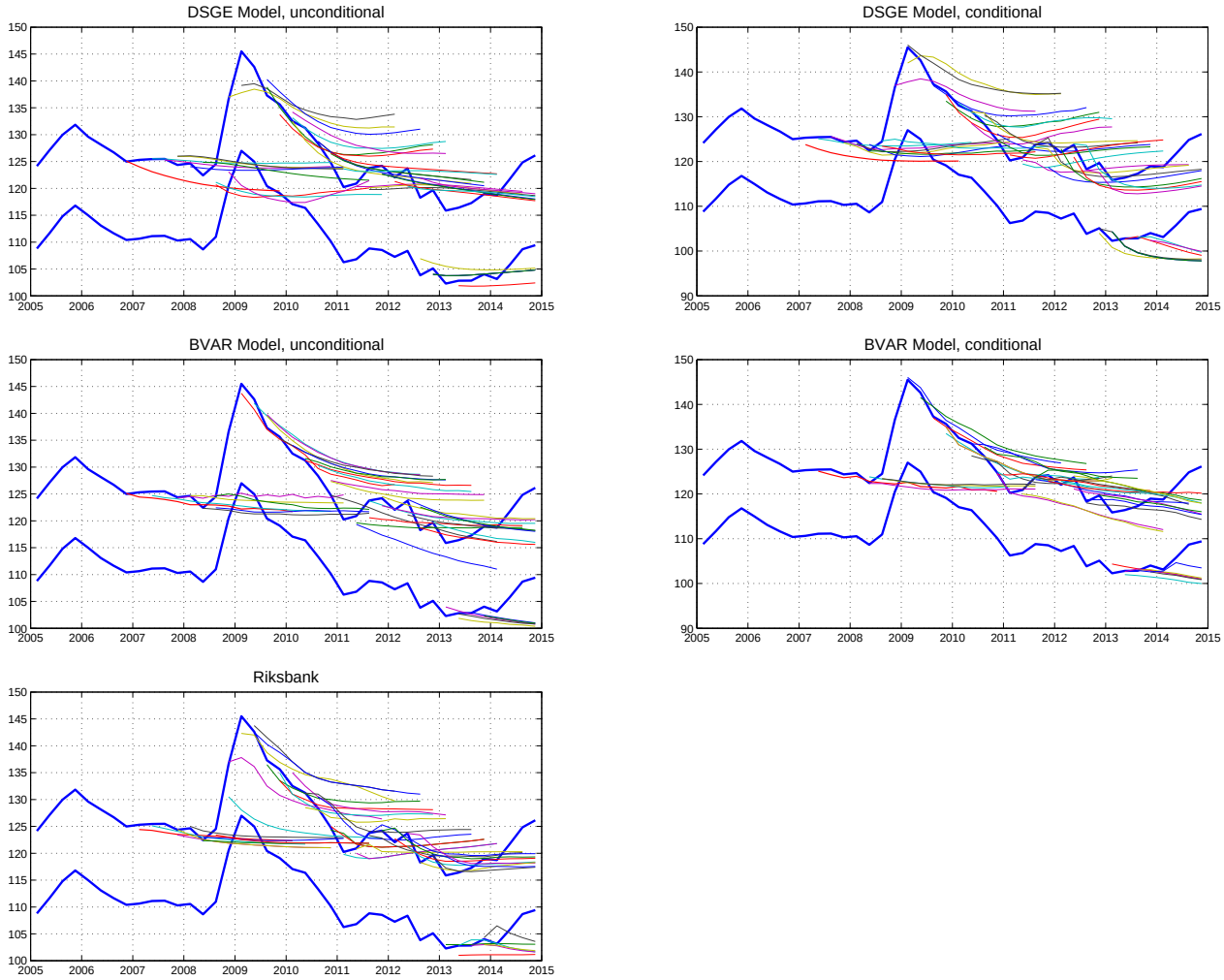


Figure 6: Nominal exchange rate and real-time forecasts



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

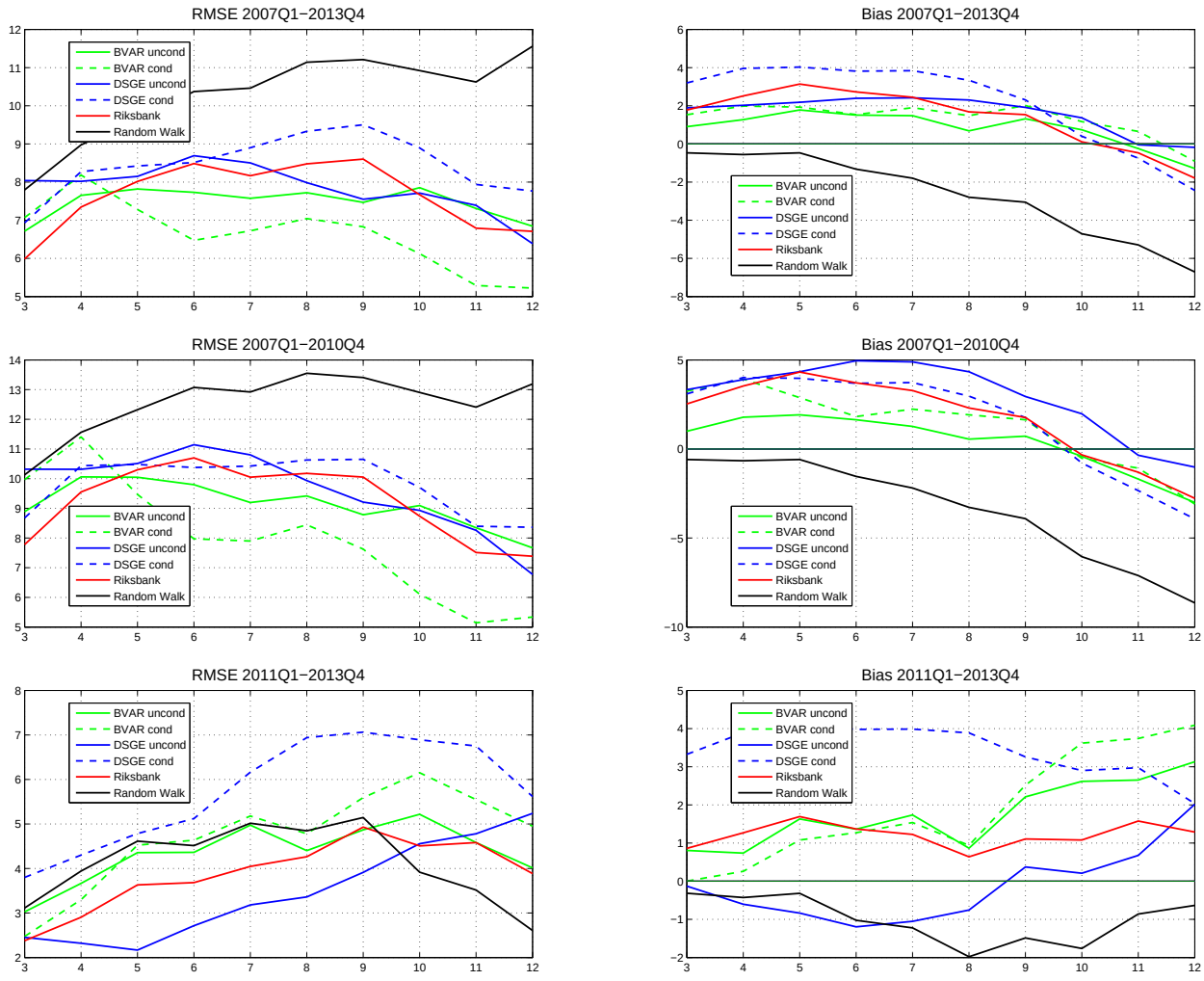
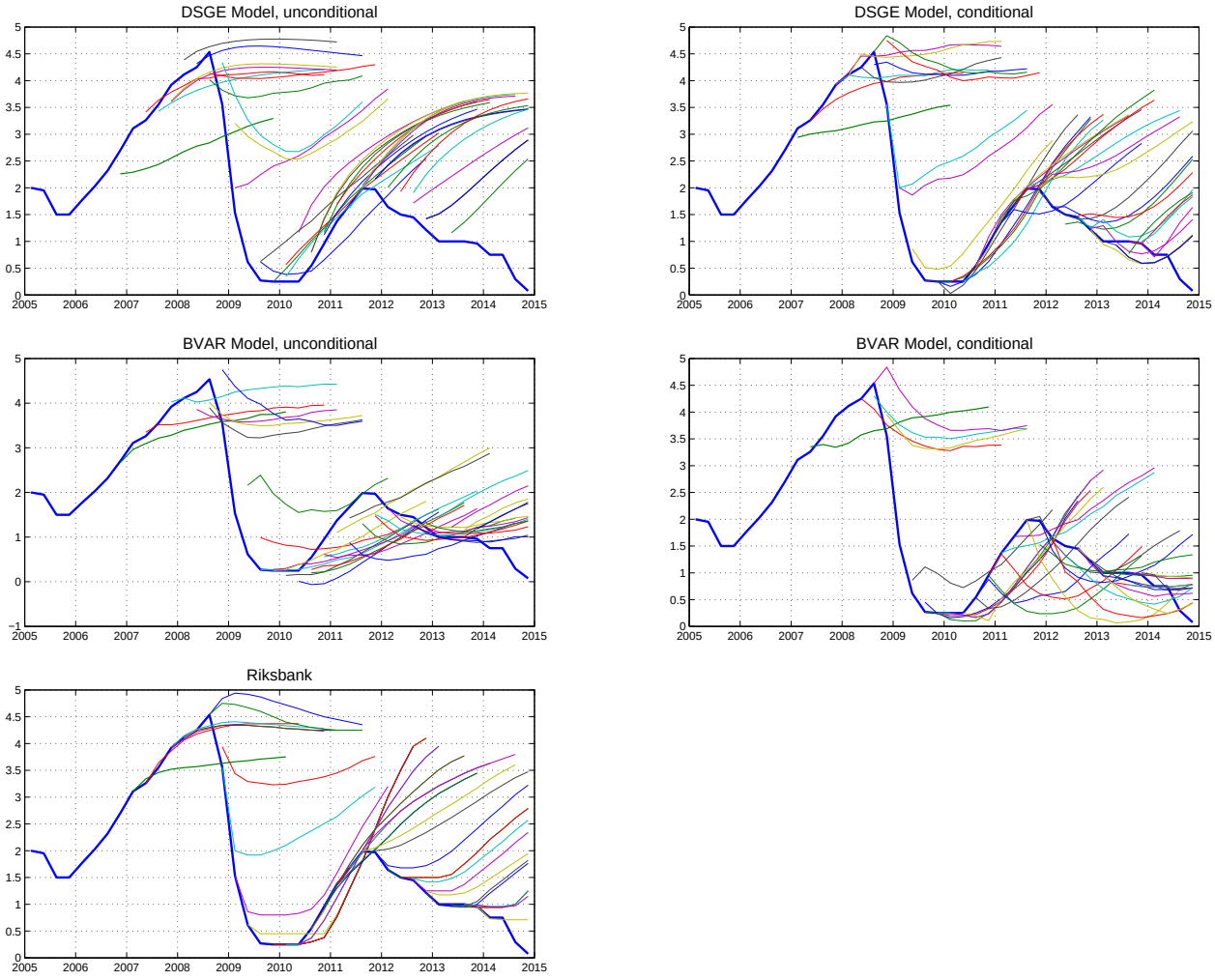
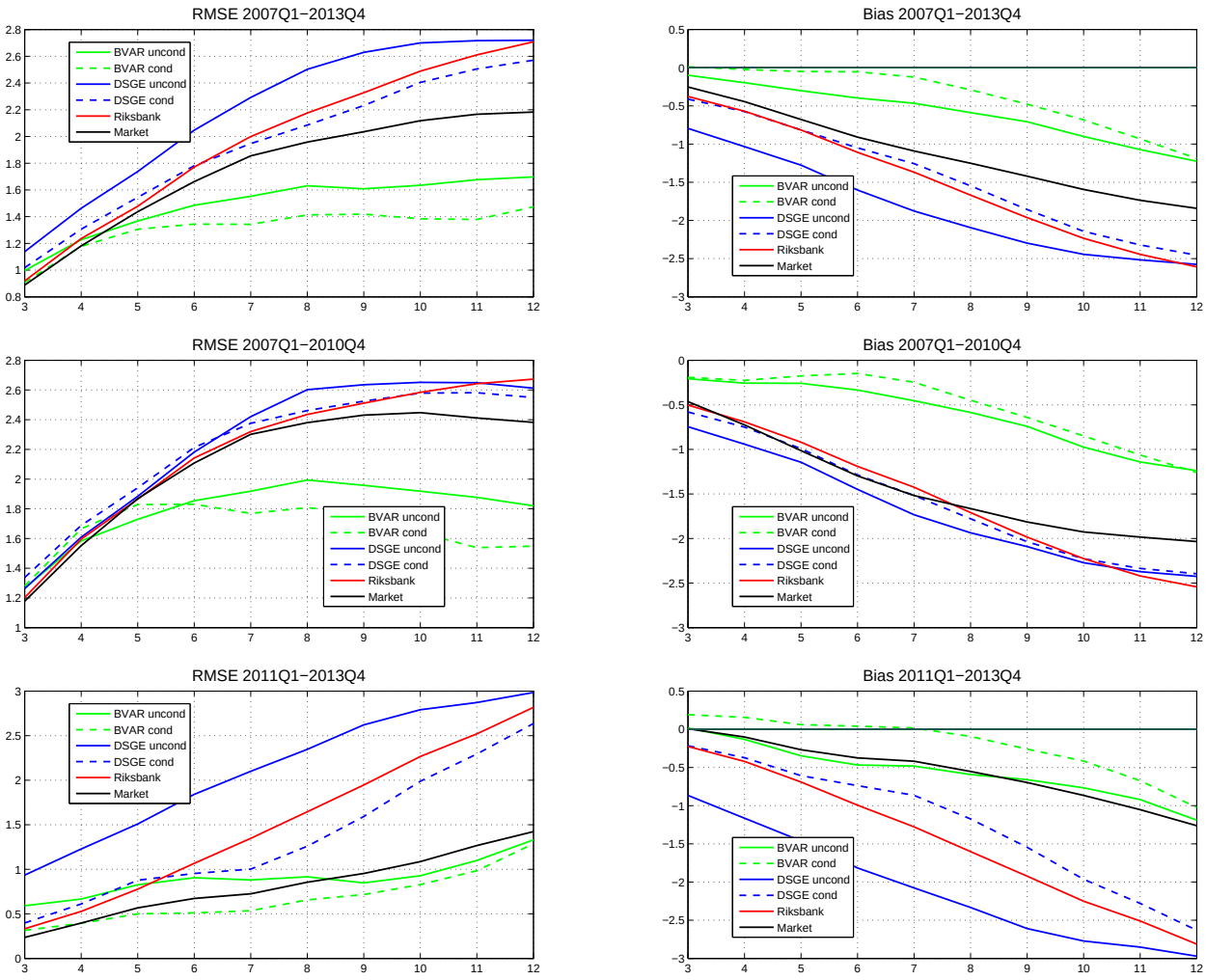


Figure 8: Repo rate and real-time forecasts



Per cent. Source: Sveriges Riksbank.

Figure 9: Repo rate forecasts: RMSE and bias



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Bayesian Estimation of an Open Economy DSGE Model with Incomplete Pass-Through by Malin Adolfson, Stefan Laséen, Jesper Lindé and Mattias Villani	2005:179
Are Constant Interest Rate Forecasts Modest Interventions? Evidence from an Estimated Open Economy DSGE Model of the Euro Area *by Malin Adolfson, Stefan Laséen, Jesper Lindé and Mattias Villani*	2005:180
Inference in Vector Autoregressive Models with an Informative Prior on the Steady State *by Mattias Villani*	2005:181
Bank Mergers, Competition and Liquidity *by Elena Carletti, Philipp Hartmann and Giancarlo Spagnolo*	2005:182
Testing Near-Rationality using Detailed Survey Data *by Michael F. Bryan and Stefan Palmqvist*	2005:183
Exploring Interactions between Real Activity and the Financial Stance *by Tor Jacobson, Jesper Lindé and Kasper Roszbach*	2005:184
Two-Sided Network Effects, Bank Interchange Fees, and the Allocation of Fixed Costs *by Mats A. Bergman*	2005:185
Trade Deficits in the Baltic States: How Long Will the Party Last? *by Rudolfs Bems and Kristian Jönsson*	2005:186
Real Exchange Rate and Consumption Fluctuations follwing Trade Liberalization *by Kristian Jönsson*	2005:187
Modern Forecasting Models in Action: Improving Macroeconomic Analyses at Central Banks *by Malin Adolfson, Michael K. Andersson, Jesper Lindé, Mattias Villani and Anders Vredin*	2005:188
Bayesian Inference of General Linear Restrictions on the Cointegration Space *by Mattias Villani*	2005:189
Forecasting Performance of an Open Economy Dynamic Stochastic General Equilibrium Model *by Malin Adolfson, Stefan Laséen, Jesper Lindé and Mattias Villani*	2005:190
Forecast Combination and Model Averaging using Predictive Measures *by Jana Eklund and Sune Karlsson*	2005:191
Swedish Intervention and the Krona Float, 1993-2002 *by Owen F. Humpage and Javiera Ragnartz*	2006:192
A Simultaneous Model of the Swedish Krona, the US Dollar and the Euro *by Hans Lindblad and Peter Sellin*	2006:193
Testing Theories of Job Creation: Does Supply Create Its Own Demand? *by Mikael Carlsson, Stefan Eriksson and Nils Gottfries*	2006:194
Down or Out: Assessing The Welfare Costs of Household Investment Mistakes *by Laurent E. Calvet, John Y. Campbell and Paolo Sodini*	2006:195
Efficient Bayesian Inference for Multiple Change-Point and Mixture Innovation Models *by Paolo Giordani and Robert Kohn*	2006:196
Derivation and Estimation of a New Keynesian Phillips Curve in a Small Open Economy *by Karolina Holmberg*	2006:197
Technology Shocks and the Labour-Input Response: Evidence from Firm-Level Data *by Mikael Carlsson and Jon Smedsaas*	2006:198
Monetary Policy and Staggered Wage Bargaining when Prices are Sticky *by Mikael Carlsson and Andreas Westermark*	2006:199
The Swedish External Position and the Krona *by Philip R. Lane*	2006:200

Price Setting Transactions and the Role of Denominating Currency in FX Markets *by Richard Friberg and Fredrik Wilander*	2007:201
The geography of asset holdings: Evidence from Sweden *by Nicolas Coeurdacier and Philippe Martin*	2007:202
Evaluating An Estimated New Keynesian Small Open Economy Model *by Malin Adolfson, Stefan Laséen, Jesper Lindé and Mattias Villani*	2007:203
The Use of Cash and the Size of the Shadow Economy in Sweden *by Gabriela Guibourg and Björn Segendorf*	2007:204
Bank supervision Russian style: Evidence of conflicts between micro- and macro-prudential concerns *by Sophie Claeys and Koen Schoors*	2007:205
Optimal Monetary Policy under Downward Nominal Wage Rigidity *by Mikael Carlsson and Andreas Westermark*	2007:206
Financial Structure, Managerial Compensation and Monitoring *by Vittoria Cerasi and Sonja Daltung*	2007:207
Financial Frictions, Investment and Tobin's q *by Guido Lorenzoni and Karl Walentin*	2007:208
Sticky Information vs Sticky Prices: A Horse Race in a DSGE Framework *by Mathias Trabandt*	2007:209
Acquisition versus greenfield: The impact of the mode of foreign bank entry on information and bank lending rates *by Sophie Claeys and Christa Hainz*	2007:210
Nonparametric Regression Density Estimation Using Smoothly Varying Normal Mixtures *by Mattias Villani, Robert Kohn and Paolo Giordani*	2007:211
The Costs of Paying – Private and Social Costs of Cash and Card *by Mats Bergman, Gabriella Guibourg and Björn Segendorf*	2007:212
Using a New Open Economy Macroeconomics model to make real nominal exchange rate forecasts *by Peter Sellin*	2007:213
Introducing Financial Frictions and Unemployment into a Small Open Economy Model *by Lawrence J. Christiano, Mathias Trabandt and Karl Walentin*	2007:214
Earnings Inequality and the Equity Premium *by Karl Walentin*	2007:215
Bayesian forecast combination for VAR models *by Michael K. Andersson and Sune Karlsson*	2007:216
Do Central Banks React to House Prices? *by Daria Finocchiaro and Virginia Queijo von Heideken*	2007:217
The Riksbank's Forecasting Performance *by Michael K. Andersson, Gustav Karlsson and Josef Svensson*	2007:218
Macroeconomic Impact on Expected Default Freqency *by Per Åsberg and Hovick Shahnazarian*	2008:219
Monetary Policy Regimes and the Volatility of Long-Term Interest Rates *by Virginia Queijo von Heideken*	2008:220
Governing the Governors: A Clinical Study of Central Banks *by Lars Frisell, Kasper Roszbach and Giancarlo Spagnolo*	2008:221
The Monetary Policy Decision-Making Process and the Term Structure of Interest Rates *by Hans Dillén*	2008:222
How Important are Financial Frictions in the U S and the Euro Area *by Virginia Queijo von Heideken*	2008:223
Block Kalman filtering for large-scale DSGE models *by Ingvar Strid and Karl Walentin*	2008:224
Optimal Monetary Policy in an Operational Medium-Sized DSGE Model *by Malin Adolfson, Stefan Laséen, Jesper Lindé and Lars E. O. Svensson*	2008:225
Firm Default and Aggregate Fluctuations *by Tor Jacobson, Rikard Kindell, Jesper Lindé and Kasper Roszbach*	2008:226

Re-Evaluating Swedish Membership in EMU: Evidence from an Estimated Model *by Ulf Söderström*	2008:227
The Effect of Cash Flow on Investment: An Empirical Test of the Balance Sheet Channel *by Ola Melander*	2009:228
Expectation Driven Business Cycles with Limited Enforcement *by Karl Walentin*	2009:229
Effects of Organizational Change on Firm Productivity *by Christina Håkanson*	2009:230
Evaluating Microfoundations for Aggregate Price Rigidities: Evidence from Matched Firm-Level Data on Product Prices and Unit Labor Cost *by Mikael Carlsson and Oskar Nordström Skans*	2009:231
Monetary Policy Trade-Offs in an Estimated Open-Economy DSGE Model *by Malin Adolfson, Stefan Laséen, Jesper Lindé and Lars E. O. Svensson*	2009:232
Flexible Modeling of Conditional Distributions Using Smooth Mixtures of Asymmetric Student T Densities *by Feng Li, Mattias Villani and Robert Kohn*	2009:233
Forecasting Macroeconomic Time Series with Locally Adaptive Signal Extraction *by Paolo Giordani and Mattias Villani*	2009:234
Evaluating Monetary Policy *by Lars E. O. Svensson*	2009:235
Risk Premiums and Macroeconomic Dynamics in a Heterogeneous Agent Model *by Ferre De Graeve, Maarten Dossche, Marina Emiris, Henri Sneessens and Raf Wouters*	2010:236
Picking the Brains of MPC Members *by Mikael Apel, Carl Andreas Claussen and Petra Lennartsdotter*	2010:237
Involuntary Unemployment and the Business Cycle *by Lawrence J. Christiano, Mathias Trabandt and Karl Walentin*	2010:238
Housing collateral and the monetary transmission mechanism *by Karl Walentin and Peter Sellin*	2010:239
The Discursive Dilemma in Monetary Policy *by Carl Andreas Claussen and Øistein Røisland*	2010:240
Monetary Regime Change and Business Cycles *by Vasco Cúrdia and Daria Finocchiaro*	2010:241
Bayesian Inference in Structural Second-Price common Value Auctions *by Bertil Wegmann and Mattias Villani*	2010:242
Equilibrium asset prices and the wealth distribution with inattentive consumers *by Daria Finocchiaro*	2010:243
Identifying VARs through Heterogeneity: An Application to Bank Runs *by Ferre De Graeve and Alexei Karas*	2010:244
Modeling Conditional Densities Using Finite Smooth Mixtures *by Feng Li, Mattias Villani and Robert Kohn*	2010:245
The Output Gap, the Labor Wedge, and the Dynamic Behavior of Hours *by Luca Sala, Ulf Söderström and Antonella Trigari*	2010:246
Density-Conditional Forecasts in Dynamic Multivariate Models *by Michael K. Andersson, Stefan Palmqvist and Daniel F. Waggoner*	2010:247
Anticipated Alternative Policy-Rate Paths in Policy Simulations *by Stefan Laséen and Lars E. O. Svensson*	2010:248
MOSES: Model of Swedish Economic Studies *by Gunnar Bårdsen, Ard den Reijer, Patrik Jonasson and Ragnar Nymoen*	2011:249
The Effects of Endogenuos Firm Exit on Business Cycle Dynamics and Optimal Fiscal Policy *by Lauri Vilmi*	2011:250
Parameter Identification in a Estimated New Keynesian Open Economy Model *by Malin Adolfson and Jesper Lindé*	2011:251
Up for count? Central bank words and financial stress *by Marianna Blix Grimaldi*	2011:252

Wage Adjustment and Productivity Shocks *by Mikael Carlsson, Julián Messina and Oskar Nordström Skans*	2011:253
Stylized (Arte) Facts on Sectoral Inflation *by Ferre De Graeve and Karl Walentin*	2011:254
Hedging Labor Income Risk *by Sebastien Betermier, Thomas Jansson, Christine A. Parlour and Johan Walden*	2011:255
Taking the Twists into Account: Predicting Firm Bankruptcy Risk with Splines of Financial Ratios *by Paolo Giordani, Tor Jacobson, Erik von Schedvin and Mattias Villani*	2011:256
Collateralization, Bank Loan Rates and Monitoring: Evidence from a Natural Experiment *by Geraldo Cerqueiro, Steven Ongena and Kasper Roszbach*	2012:257
On the Non-Exclusivity of Loan Contracts: An Empirical Investigation *by Hans Degryse, Vasso Ioannidou and Erik von Schedvin*	2012:258
Labor-Market Frictions and Optimal Inflation *by Mikael Carlsson and Andreas Westermark*	2012:259
Output Gaps and Robust Monetary Policy Rules *by Roberto M. Billi*	2012:260
The Information Content of Central Bank Minutes *by Mikael Apel and Marianna Blix Grimaldi*	2012:261
The Cost of Consumer Payments in Sweden *by Björn Segendorf and Thomas Jansson*	2012:262
Trade Credit and the Propagation of Corporate Failure: An Empirical Analysis *by Tor Jacobson and Erik von Schedvin*	2012:263
Structural and Cyclical Forces in the Labor Market During the Great Recession: Cross-Country Evidence *by Luca Sala, Ulf Söderström and AntonellaTrigari*	2012:264
Pension Wealth and Household Savings in Europe: Evidence from SHARELIFE *by Rob Alessie, Viola Angelini and Peter van Santen*	2013:265
Long-Term Relationship Bargaining *by Andreas Westermark*	2013:266
Using Financial Markets To Estimate the Macro Effects of Monetary Policy: An Impact-Identified FAVAR* *by Stefan Pitschner*	2013:267
DYNAMIC MIXTURE-OF-EXPERTS MODELS FOR LONGITUDINAL AND DISCRETE-TIME SURVIVAL DATA *by Matias Quiroz and Mattias Villani*	2013:268
Conditional euro area sovereign default risk *by André Lucas, Bernd Schwaab and Xin Zhang*	2013:269
Nominal GDP Targeting and the Zero Lower Bound: Should We Abandon Inflation Targeting?* *by Roberto M. Billi*	2013:270
Un-truncating VARs* *by Ferre De Graeve and Andreas Westermark*	2013:271
Housing Choices and Labor Income Risk *by Thomas Jansson*	2013:272
Identifying Fiscal Inflation* *by Ferre De Graeve and Virginia Queijo von Heideken*	2013:273
On the Redistributive Effects of Inflation: an International Perspective* *by Paola Boel*	2013:274
Business Cycle Implications of Mortgage Spreads* *by Karl Walentin*	2013:275
Approximate dynamic programming with post-decision states as a solution method for dynamic economic models *by Isaiah Hull*	2013:276
A detrimental feedback loop: deleveraging and adverse selection *by Christoph Bertsch*	2013:277
Distortionary Fiscal Policy and Monetary Policy Goals *by Klaus Adam and Roberto M. Billi*	2013:278
Predicting the Spread of Financial Innovations: An Epidemiological Approach *by Isaiah Hull*	2013:279

Firm-Level Evidence of Shifts in the Supply of Credit *by Karolina Holmberg*	2013:280
Lines of Credit and Investment: Firm-Level Evidence of Real Effects of the Financial Crisis *by Karolina Holmberg*	2013:281
A wake-up call: information contagion and strategic uncertainty *by Toni Ahnert and Christoph Bertsch*	2013:282
Debt Dynamics and Monetary Policy: A Note *by Stefan Laséen and Ingvar Strid*	2013:283
Optimal taxation with home production *by Conny Olovsson*	2014:284
Incompatible European Partners? Cultural Predispositions and Household Financial Behavior *by Michael Haliassos, Thomas Jansson and Yigitcan Karabulut*	2014:285
How Subprime Borrowers and Mortgage Brokers Shared the Piecial Behavior *by Antje Berndt, Burton Hollifield and Patrik Sandås*	2014:286
The Macro-Financial Implications of House Price-Indexed Mortgage Contracts *by Isaiah Hull*	2014:287
Does Trading Anonymously Enhance Liquidity? *by Patrick J. Dennis and Patrik Sandås*	2014:288
Systematic bailout guarantees and tacit coordination *by Christoph Bertsch, Claudio Calcagno and Mark Le Quement*	2014:289
Selection Effects in Producer-Price Setting *by Mikael Carlsson*	2014:290
Dynamic Demand Adjustment and Exchange Rate Volatility *by Vesna Corbo*	2014:291
Forward Guidance and Long Term Interest Rates: Inspecting the Mechanism *by Ferre De Graeve, Pelin Ilbas & Raf Wouters*	2014:292
Firm-Level Shocks and Labor Adjustments *by Mikael Carlsson, Julián Messina and Oskar Nordström Skans*	2014:293
A wake-up call theory of contagion *by Toni Ahnert and Christoph Bertsch*	2015:294
Risks in macroeconomic fundamentals and excess bond returns predictability *by Rafael B. De Rezende*	2015:295
The Importance of Reallocation for Productivity Growth: Evidence from European and US Banking *by Jaap W.B. Bos and Peter C. van Santen*	2015:296
SPEEDING UP MCMC BY EFFICIENT DATA SUBSAMPLING *by Matias Quiroz, Mattias Villani and Robert Kohn*	2015:297
Amortization Requirements and Household Indebtedness: An Application to Swedish-Style Mortgages *by Isaiah Hull*	2015:298
Fuel for Economic Growth? *by Johan Gars and Conny Olovsson*	2015:299
Searching for Information *by Jungsuk Han and Francesco Sangiorgi*	2015:300
What Broke First? Characterizing Sources of Structural Change Prior to the Great Recession *by Isaiah Hull*	2015:301
Price Level Targeting and Risk Management *by Roberto Billi*	2015:302
Central bank policy paths and market forward rates: A simple model *by Ferre De Graeve and Jens Iversen*	2015:303
Jump-Starting the Euro Area Recovery: Would a Rise in Core Fiscal Spending Help the Periphery? *by Olivier Blanchard, Christopher J. Erceg and Jesper Lindé*	2015:304
Bringing Financial Stability into Monetary Policy* *by Eric M. Leeper and James M. Nason*	2015:305

SCALABLE MCMC FOR LARGE DATA PROBLEMS USING DATA SUBSAMPLING AND THE DIFFERENCE ESTIMATOR *by MATIAS QUIROZ, MATTIAS VILLANI AND ROBERT KOHN*	2015:306
SPEEDING UP MCMC BY DELAYED ACCEPTANCE AND DATA SUBSAMPLING *by MATIAS QUIROZ*	2015:307
Modeling financial sector joint tail risk in the euro area *by André Lucas, Bernd Schwaab and Xin Zhang*	2015:308
Score Driven Exponentially Weighted Moving Averages and Value-at-Risk Forecasting *by André Lucas and Xin Zhang*	2015:309
On the Theoretical Efficacy of Quantitative Easing at the Zero Lower Bound *by Paola Boel and Christopher J. Waller*	2015:310
Optimal Inflation with Corporate Taxation and Financial Constraints *by Daria Finocchiaro, Giovanni Lombardo, Caterina Mendicino and Philippe Weil*	2015:311
Fire Sale Bank Recapitalizations *by Christoph Bertsch and Mike Mariathasan*	2015:312
Since you're so rich, you must be really smart: Talent and the Finance Wage Premium *by Michael Böhm, Daniel Metzger and Per Strömberg*	2015:313
Debt, equity and the equity price puzzle *by Daria Finocchiaro and Caterina Mendicino*	2015:314
Trade Credit: Contract-Level Evidence Contradicts Current Theories *by Tore Ellingsen, Tor Jacobson and Erik von Schedvin*	2016:315
Double Liability in a Branch Banking System: Historical Evidence from Canada *by Anna Grodecka and Antonis Kotidis*	2016:316
Subprime Borrowers, Securitization and the Transmission of Business Cycles *by Anna Grodecka*	2016:317

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