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Economic Commentaries

Forecasting the krona

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For the central bank of a small open economy with an inflation target, like the Riksbank, the movements of the exchange rate are important. However, compared to other macroeconomic variables, the exchange rate is difficult to forecast, because it is only weakly connected to economic fundamentals. This Economic Commentary provides a comparison and evaluation of different forecasting methodologies for the krona exchange rate in the short and medium term. In the short term, the best forecast is its level at forecast date. In the medium term, economic models that are based on the convergence of the exchange rate to an equilibrium long-run level perform well. The Riksbank has recently adopted a forecasting methodology based on the results of this analysis as baseline for forecasting the krona's effective exchange rate. The convergence to the assessed long-run equilibrium is now assumed to happen at a considerably slower pace than in earlier forecasts.

"*Overall, our analysis of the literature and the data suggests that the answer to the question 'Are exchange rates predictable?' is, 'It depends.'* " (Rossi, 2013)

Since 1993 Sweden has had a floating exchange rate and an inflation targeting regime. The new monetary policy framework became operative from 1995, with a target of 2 per cent inflation. Sweden is a small open economy with extensive trade with the rest of the world. Hence, the krona exchange rate is important for the Swedish economic activity and inflation. The exchange rate has a direct impact on inflation, through import prices. It also has an indirect impact, through its effects on the real economy, for example the demand for Swedish goods abroad.[3] Given the tight link between the exchange rate and inflation, it is important for an inflation targeting central bank such as Sveriges Riksbank to have a well-informed view about the likely future development of the exchange rate. However, it is very difficult to forecast the exchange rate compared to other macroeconomic variables, as recognized in the academic literature.[4] For example, over the last five years, Sveriges Riksbank and the respondents of the Prospera survey have often predicted an appreciation of the krona. Instead, outcomes have shown a depreciation of the krona.

In this commentary, we discuss and compare different methodologies to forecast the exchange rate, and we show which methodology performs best for the krona effective exchange rate, measured using the KIX index.[5] We focus the analysis on a subset of the KIX index, which includes only the most important trading partners, the euro area and the United States, and represents more than 50 percent of the full KIX index. The narrow KIX index assigns a weight of roughly 85 percent to the euro area and roughly 15 percent to the United States. Its variation at short to medium frequencies is similar to the full index (with a correlation above 0.9), as shown in Figure 1, because the variation in the bilateral exchange rates EUR/SEK and USD/SEK captures almost all the variation in the bilateral exchange rates of the other relevant currencies.[6] Moreover, the narrow KIX index is the preferred choice of exchange rate index for the macroeconomic models with a large set of foreign variables used at Sveriges Riksbank, due to

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[3] How the exchange rate affects the economy more specifically depends on the causes of its fluctuations. See Sveriges Riksbank (2016), Corbo and Di Casola (2018) and further references therein.

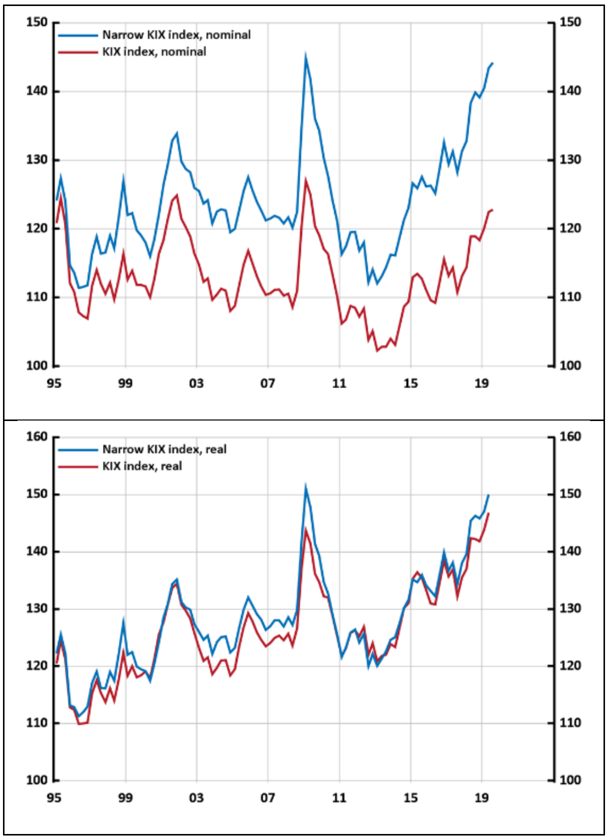
[4] The attempts made in the economic literature to forecast the exchange rate, and their failures are reviewed in Rossi (2013) and Cheung et al. (2019).

[5] The KIX index refers to Sweden's 32 main trading partners. The KIX index is a geometric index of bilateral exchange rates of the Swedish currency with respect to other currencies, where the weights are based on total flows of processed goods and commodities and take into account exports and imports, as well as third-country effects. These competition-based weights are updated each year and computed by Sveriges Riksbank.

[6] The different level of the real versus the nominal effective exchange rate with the full and the narrow index is due to the fact that the full KIX index also contains emerging economies, which have higher inflation, on average, than the advanced economies included in both the full and the narrow index.

better data availability of the macroeconomic variables of the euro area and the United States, alongside their high weight in the KIX index. Indeed, in the following analysis the foreign variables we consider are weighted averages of the variables for the euro area and the United States, with the same weights as in the narrow KIX index. Given the high correlation between the full and the narrow index, the broad conclusions from our analysis should be valid also for the full KIX index.

Figure 1. Nominal and real effective krona exchange rate, narrow and full KIX index (18-11-1992=100).



Note. An increase in the exchange rate corresponds to a depreciation of the Swedish currency.

As emphasized by Rossi (2013), which methodology performs better at forecasting the exchange rate depends on many factors, such as the forecast horizon and the sample period used for the analysis. For this reason, we divide our analysis into two parts. The first part covers the short-term horizon, up to one year ahead, and focuses on the nominal effective krona exchange rate, that is the relative price of the Swedish currency with respect to other currencies. The second part covers the medium-term horizon, from one to three years ahead, and focuses on the real effective exchange rate, that is the relative price of consumer goods and services in Sweden compared to other countries, expressed in the same currency. In each part, we discuss how results differ when the forecasting period includes or excludes the financial crisis. Before discussing our results, we describe the criteria used to evaluate the forecasting methodologies.

How to evaluate forecasts?

When alternative methodologies are used to forecast a variable, their relative performance can be evaluated based on forecast errors, i.e. the difference between the forecasts and the outcomes. There are many different criteria to evaluate how far the forecasts are from the outcomes. The choice of the appropriate criteria depends on what is the objective of the comparison. Here we focus on two criteria: the root mean squared error (RMSE) and the mean error, also called bias. The RMSE measures the deviations of the forecasts from the outcomes and assigns a larger weight to larger deviations. The lower the RMSE, the more accurate is the forecasting methodology. The RMSE entails no information about whether the deviation is systematic, i.e. whether forecasts are consistently above or consistently below realized outcomes. The bias measures the systematic components of the forecast errors. For example, one forecasting method can yield large forecast errors and hence a high RMSE. However, if the forecasts are equally likely to be higher and lower than the outcomes, the errors may cancel out and the bias may be close to zero.

For most of the forecasting methodologies used in the analysis, the forecasts are produced “out-of-sample”, meaning that all the data up to a particular date are used to estimate the relationship between the exchange rate and its explanatory variables. Then, the forecasts are made for the subsequent periods.[7] Note, however, that future realized values of the explanatory variables are used in the forecasting exercise. This means that our exercise does not fully replicate the forecasting process happening at any given point in time, since future values of the explanatory variables are not available when actual forecasts are produced. Our exercise allows us to compare the forecast of the exchange rate using different methodologies, while not being affected by possible forecasting errors of the explanatory variables. This type of exercise is appropriate for comparisons of the relative forecasting accuracy of different methodologies, but there is a caveat. If a complex model that contains many explanatory variables performs better than a smaller one, one needs to evaluate the gain in performance against the additional complexity involved in the effective forecasting process. The reason is that even the explanatory variables have to be forecast, and their forecast accuracy will matter as well.

Forecasting at different horizons

The forecasting process at Sveriges Riksbank is in two steps: 1) evaluating where the economy is at present and 2) projecting where the economy will be in the coming years. In fact, due to the time it takes before new outcomes for the current economic situation are available, the forecaster needs first to assess the starting point for the forecast, which is usually referred to as “nowcasting”.[8] The forecasts for the current period and near-time future are based on a large number of variables, using indicator models and high-frequency data. The forecasts for the medium term are based on macroeconomic models, often based on economic theory.

For this reason, the forecasting process of the exchange rate at the Riksbank is divided into short-term and medium-term forecasting. The short-term forecast for the nominal effective exchange rate is computed using data at high frequency. Since prices of goods and services do not adjust quickly to changing economic conditions, fluctuations in the nominal exchange rate translate almost one-to-one into fluctuations of the real exchange rate in the short term. The medium-term forecast, instead, is computed for the real effective exchange rate at quarterly frequency, using the short-term forecast as initial point. The choice of forecasting the real effective exchange rate is due to the fact that economic theory provides guidance for where the real effective exchange rate should converge in the long term under

[7] One exception is the forecast produced with the DSGE model, discussed in the section ”Medium-term forecasts”. Due to the complexity of the estimation of the DSGE model, we perform the analysis with the parameters estimated only once, over the full sample period. Hence, for DSGE models we carry out a so-called “in-sample” exercise.

[8] For more details on how the nowcasting process is connected to the forecasting process at Sveriges Riksbank, see Andersson and den Reijer (2015).

the inflation targeting regime, while the nominal exchange rate does not have a long-term anchor.[9]

Short-term forecasts

The analysis of the performance of different exchange rate forecast methodologies in the short run is based on the nominal krona effective exchange rate at monthly frequency.[10] We consider various relationships and economic models to forecast the krona exchange rate. The models are estimated on an initial sample from January 1999 until December 2006, and the forecasts for the subsequent twelve months are computed. After that, the models are re-estimated, each time adding one additional month and repeating the forecast exercise twelve months ahead, until December 2018.

The benchmark relationship is the so-called "random walk" (RW). The RW implies that in the future the exchange rate is expected to remain at its level at forecast date. The reason why we choose the random walk as the benchmark for our analysis is related to the common finding in the economic literature that the best forecast for the exchange rate in the short run is usually based on the random walk (see Meese and Rogoff, 1983). Even "out-of-sample" forecasts produced with macroeconomic models conditioned on the future realized values of explanatory variables are found to be further away from the outcomes of the exchange rate than the forecasts based on an unchanged level.[11]

A commonly used relationship to forecast the exchange rate is the "uncovered interest rate parity condition" (UIP), which connects the exchange rate between the domestic and foreign currencies to the interest rate differential between the domestic and foreign economies. According to this condition, a positive interest rate differential between the domestic and foreign economy translates one-to-one into an expected depreciation of the domestic currency in the periods ahead. However, many empirical studies find that this theoretical relation does not hold in the data.[12] Therefore, we also consider a model inspired by the UIP condition, where the parameters governing the relationship between the interest rate differential and the exchange rate are estimated on data.

Due to the lack of empirical support for the UIP, many studies have proposed alternative models to explain the movements in the exchange rate. One such model is the "uncovered return parity" (URP), which is based on the idea that financial flows in and out of an economy affect its exchange rate.[13] Investors require a premium for holding assets in one currency or another. The URP assumes that movements in exchange rate left unexplained by the UIP condition can be explained by the relative returns of investing in the stock market in the domestic and foreign economy. We also consider an augmented URP model (URP-YC) that takes into account the information contained in the yield curves of the domestic and the foreign economies. The yield curve, or term structure of interest rates, describes the relationship between yields on assets and their time to maturity. It moves through time, based on markets' expectations about the future developments in the economy.[14] Our

[9] The most used concept to define the long-term or equilibrium value of the real exchange rate is the Purchasing Power Parity, implying that goods and services are expected to cost the same in different countries, after conversion to the same currency. See Rogoff (1996) and Taylor (2006) for reference. Sveriges Riksbank (2018) contains a discussion of the long-run equilibrium value of the krona exchange rate.

[10] The monthly data correspond to end-of-month daily data.

[11] Since their seminal work, the fact that it is very difficult to forecast exchange rates in the short term with economic models is known as "the Meese and Rogoff forecasting puzzle" (Obstfeld and Rogoff, 2001). Other studies followed the seminal paper by Meese and Rogoff (1983), as reviewed in Rossi (2013), but could not fully modify their conclusions. However, more recent work argues that some economic models actually imply that the exchange rate is "nearly" a random walk, meaning that its changes are not predictable (Engel et al., 2008). At longer horizons, though, macroeconomic models are able to outperform the random walk.

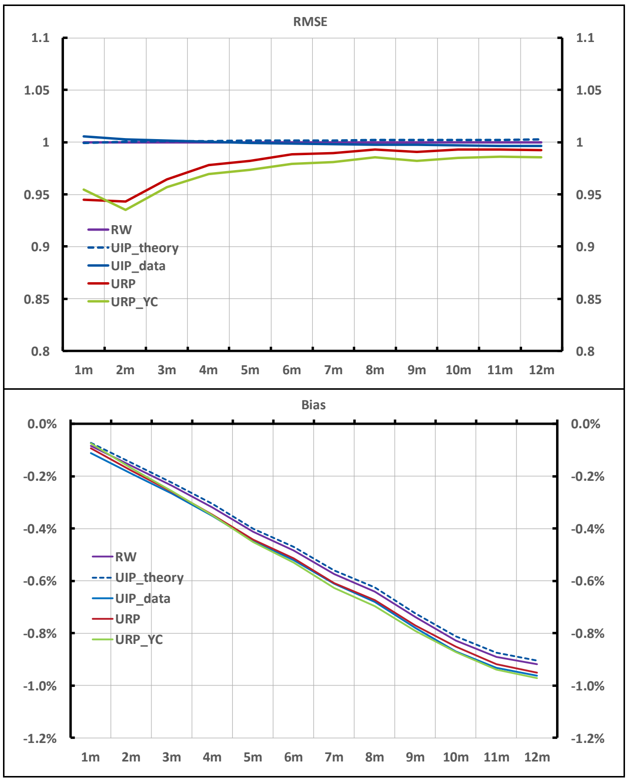
[12] The UIP holds under the following conditions: risk neutrality of the investors, lack of trading costs or barriers in financial markets, and equal liquidity, maturity and default risk of the assets traded. See Engel (2014) for a review of the papers that do not find evidence of the uncovered interest rate parity condition in the data.

[13] See Hau and Rey (2006), Cappiello and De Santis (2007) and Djeutem and Dunbar (2018).

[14] In our specification of the URP, we include the three factors that best summarize a yield curve, namely the level factor, usually connected to agents' long-term expectations, and the slope and curvature of the curve, usually connected to the business cycle and the

forecasts of the exchange rate based on URP models will be conditional on the realized values of the financial variables included.

Figure 2. Root mean squared error relative to the random walk and bias of forecasting models for the short term, forecasting sample over 2007-2018.



Note. RMSE (with respect to random walk) and bias for forecasts of the nominal effective krona exchange rate against the Euro and the US dollar one to twelve months ahead. Realized values are used for future values of the explanatory variables.

Figure 2 reports the RMSE and the bias of the forecasting relationships and models described above. Tables with the underlying data for this and the subsequent figures are reported in the appendix. Only the models based on the uncovered return parity condition perform slightly better than the random walk in terms of RMSE, but the differences are not statistically significant.[15] Therefore, we conclude that the random walk performs well in terms of forecast accuracy in the short term. We note also that all the relationships and models considered, including the random walk, perform poorly in terms of bias. On average, they underestimate the exchange rate, meaning that they have systematically forecast a stronger exchange rate over our sample period. This result is related to the specific features of the sample period considered, when depreciations of the exchange rate were more frequent than appreciations.

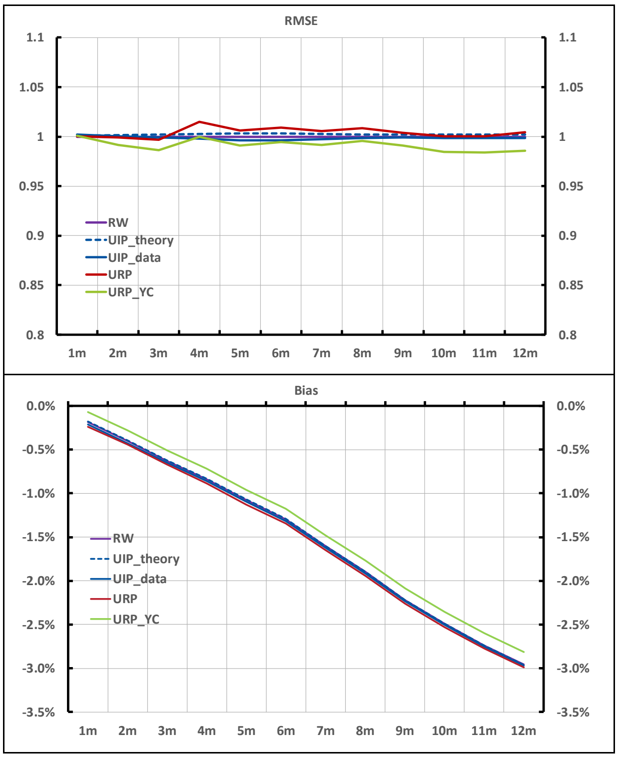
An additional factor determining the success of forecasting models for the exchange rate is the sample used to estimate the models, as discussed in Rossi (2013). If we replicate our forecasting exercise over a shorter sample period, starting in 2012, so that the financial crisis

monetary stance of the central bank. Litterman and Scheinkman (1991) and Diebold and Li (2006) are among the first studies to interpret the main factors summarizing the yield curve as level, slope and curvature factors, while Dewachter and Lyrio (2006) and Rudebush and Wu (2007, 2008) identify their economic content. More technical details on yield curves and how this information is used in a central bank can be found in De Rezende (2017). Chen and Tsang (2013) find a connection between the three factors of the yield curve and the exchange rate predictability.

[15] To test the statistical significance of the difference in the RMSE of different models and relationships, we used a variant of the test first proposed in Diebold and Mariano (1995).

and the European sovereign debt crisis are not forecast, the results are slightly different. Comparing Figure 2 and Figure 3, we can see that the small gain in RMSE of the URP models disappears with a shorter forecasting sample period and the superiority of the random walk is even stronger. In fact, the URP model performs well at forecasting the strengthening of the krona after the financial crisis, but these results rely on using information about the future realized values of its financial explanatory variables during a period of financial turmoil. In terms of bias, we still obtain that all the relationships and models forecast a stronger exchange rate than the outcome, on average. Note, though, that the size of the bias (in absolute terms) is three times larger than what we obtain when the financial crisis is part of the forecast period. This is due to the exclusion of the large appreciation of the krona directly after the financial crisis in the shorter sample.

Figure 3. Root mean squared error and bias of forecasting models for the short term, forecasting sample over 2012-2018.



Note. RMSE (with respect to random walk) and bias for forecasts of the nominal effective krona exchange rate against the Euro and the US dollar one to twelve months ahead. Realized values are used for future values of the explanatory variables.

In conclusion, we do not find a relationship or model that can forecast the exchange rate more accurately than the random walk at short horizons. The random walk is also the simplest relationship, requiring no additional information or explanatory variable. Some models may improve the forecast of the exchange rate by using information about key financial variables. However, using these models for forecasting the exchange rate requires informative forecasts of these key financial variables.

Medium-term forecasts

The analysis of the medium-term forecasts is based on quarterly data of the real krona effective exchange rate. The real exchange rate is forecast up to twelve quarters ahead. The models presented below are first estimated on a sample from 1995 until 2006, and then re-estimated by recursively adding one additional quarter until the last quarter of 2018. The only exception is the DSGE model, which is estimated only once, over the full sample period 1995-2018, due to the complexity of its estimation.

The benchmark relationship for this analysis, too, is the random walk. Then, we use a Bayesian Vector Autoregressive (BVAR) model containing six domestic variables (repo rate, CPIF inflation, GDP growth, employment growth, wage growth, and real effective exchange rate) and three foreign variables (policy rate, inflation rate and GDP growth).[16] We consider endogenous and conditional forecasts. Endogenous forecasts are produced by the model when it generates predictions for domestic and foreign variables, while conditional forecasts are produced by the model when it takes foreign economic developments as given. Furthermore, we use a Dynamic Stochastic General Equilibrium (DSGE) model of the Swedish economy developed at the Riksbank, and building on the Ramses II model.[17] It is a structural model of Sweden and the rest of the world, relying on the assumption that the foreign economy can affect Sweden but the reverse is not possible. The exchange rate is determined by the UIP condition, modified to allow for movements in the exchange rate to reflect the risk premium required by investors in order to hold Swedish assets. We consider endogenous forecasts and forecasts conditioned on outcomes of the foreign policy rate, inflation rate and GDP growth.

Finally, we use several autoregressive (AR) models, built on the assumption that at any point in time the real exchange rate gradually returns to its long-run equilibrium value. These models do not rely on additional information about other variables, but depend only on the long-run equilibrium value and the speed of convergence to it. For the long-run value of the real exchange rate, we use the Riksbank's estimate, which is time-varying.[18] One way to quantify the speed of adjustment is to measure the half-life of the exchange rate, i.e. the time it takes for the forecast to halve the distance between its starting point and the long-run value. We have considered different values of the speed of adjustment, but here we only report the results from the models that feature the best forecasting performance. The models differ in the values of half-life: a) a half-life of 9 quarters (AR data), obtained from estimating the historical speed of convergence to the long run in Swedish data; b) a half-life of 20 quarters (AR theory), which is the upper bound of the interval of estimated half-lives in the academic literature.[19]

Figure 4 reports the RMSE and the bias of the forecasting models and relationships described above. In terms of RMSE, the DSGE model conditional on foreign variables is the best forecasting model and performs better than the random walk at any horizon. The second best performing model in the first six quarters is BVAR conditional on foreign variables, while the AR models and unconditional BVAR perform better from six to twelve quarters ahead. Note, that conditional forecasts from the DSGE and BVAR models are based on realized values of the foreign variables. Their forecasting performance may be lower in the actual forecasting process, when also foreign variables are forecast.

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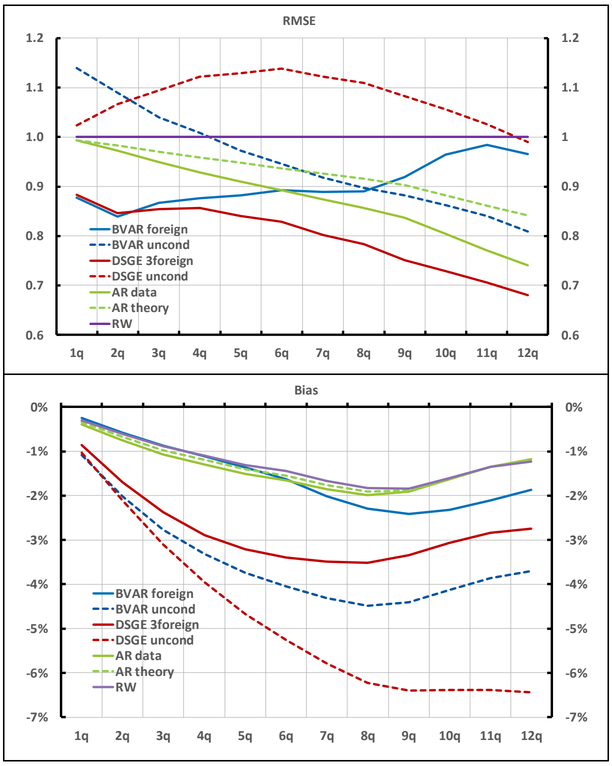
[16] The BVAR model is written in deviation from its steady state, following Villani (2009). Also the choice of prior distribution is based on Villani (2009). The model contains four lags. Since Sweden is a small open economy, it is assumed that domestic shocks cannot affect the foreign economy, while foreign shocks may affect domestic variables.

[17] See Christiano et al. (2011) and Adolfson et al. (2013) for details on Ramses II.

[18] See Sveriges Riksbank (2018, 2019) for a discussion on the long-run value of the real krona effective exchange rate and the Riksbank's current assessment for the KIX index, based on different types of models. To assess the long-run value for the narrow KIX index, used in this analysis, Sveriges Riksbank uses similar models to the ones used to assess the long-run value of the full KIX index.

[19] Rogoff (1996) provides an overview of the empirical studies on the half-life of the exchange rate and finds an agreement on the range between 3 to 5 years for the exchange rate to halve the distance to its long-run value. However, Kilian and Zha (2002) find no strong support for this range and conclude that there is large uncertainty on the estimates. Kilian and Taylor (2003) show that the speed of adjustment is nonlinear, being higher, the further is the exchange rate from its long-run level.

Figure 4. Root mean squared error and bias of forecasting models for the medium term, forecasting sample over 2007-2018.

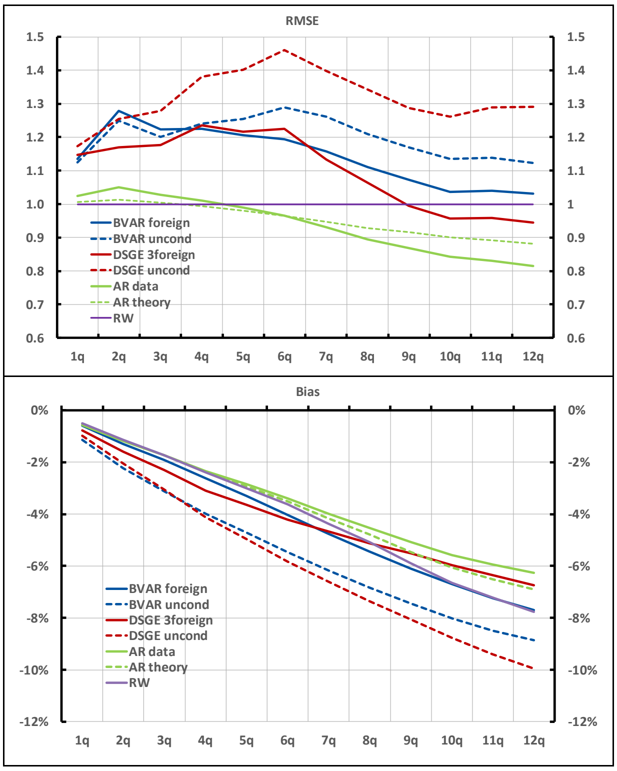


Note. RMSE (with respect to random walk) and bias for forecasts of the nominal effective krona exchange rate against the Euro and the US dollar one to twelve quarters ahead. Realized values of selected foreign variables are used for conditional forecasts.

All the models, including the random walk, feature a negative bias, since they systematically forecast a stronger exchange rate than the outcome. The negative bias overlaps with the analysis for the short-term forecasts, but in the medium-term case it becomes less severe with the forecast horizon. The random walk, together with the AR models, produces the smallest bias (in absolute terms) at any horizon. Overall, the BVAR and DSGE models perform better once additional information on the foreign variables is used. The ability of macroeconomic models to outperform the random walk in the medium term is in line with the findings in the economic literature.[20] It is also in line with the analysis with real-time forecast data for the foreign variables by Iversen et al. (2016). The authors conduct an evaluation of the forecast of the nominal effective krona exchange rate for the period 2007-2013 and find that the BVAR and the DSGE models used at the Riksbank perform better than the random walk in the medium term, even with real-time forecasts for the foreign variables.[21] In particular, the BVAR model conditional on foreign variables performs best.

[20] See, for example, Ca' Zorzi et al. (2017) for results from DSGE, BVAR and AR models.
[21] The BVAR model considered in Iversen et al. (2016) was very similar to the one used in this analysis. The DSGE models used are Ramses I and Ramses II, described in detail in Adolfson et al. (2008), Christiano et al. (2011) and Adolfson et al. (2013).

Figure 5. Root mean squared error and bias of forecasting models for the medium term, forecasting sample over 2012-2018.



Note. RMSE (with respect to random walk) and bias for forecasts of the nominal effective krona exchange rate against the Euro and the US dollar one to twelve quarters ahead. Realized values of selected foreign variables are used for conditional forecasts.

As discussed for the case of short-term forecasts, we have redone our analysis, starting the forecast evaluation in the period after the financial crisis (Figure 5). We find that the AR models are the best performers both in terms of RMSE and bias, if we start the analysis from 2012.[22] None of the macroeconomic models can produce an RMSE smaller or in line with the random walk, while the AR models outperform the random walk two to three years ahead. The models feature a negative bias also for this sample period, but the bias is more severe than in the previous case. The fact that the results are sensitive to the sample period is not new in the studies on exchange rate forecasting, especially when the financial crisis period is considered.[23] This result confirms that the good performance of the conditional forecasts of the DSGE and BVAR models is strongly dependent on the period of analysis, due to the importance of conditioning on foreign variables. We conclude that the AR models provide the best forecasts for the medium term.

Concluding remarks

As anticipated at the beginning of our analysis, the success of different methodologies at forecasting the exchange rate depends, among other things, on the horizon and the sample period used. Our analysis shows that there is no relationship or model performing better than the random walk to forecast the nominal effective krona exchange rate in the short term. The random walk is also the simplest relationship, requiring no additional information or

[22] Ca' Zorzi et al. (2016) is another study that confirms the good forecasting performance of AR models for the exchange rate.
[23] See Bussiere et al. (2018), Engel and Wu (2018) and Lilley et al. (2019) for examples of studies that find different results, depending on whether the sample includes the financial crisis or not.

explanatory variable. The performance of the DSGE and BVAR models, both in the short and medium term, depends on the knowledge of the future values of the foreign variables and also on the specific period of analysis. Instead, AR models outperform the random walk in medium-term forecasting, independently of the sample period used. All the methodologies considered feature a systematic bias, producing a stronger krona exchange rate than the outcome, especially if the forecast period excludes the financial crisis. This is also in line with the forecasts produced by Sveriges Riksbank and the average responses in the Prospera survey and relates to the surprising weakening of the krona exchange rate over the last five years.

Based on the above presented analysis, we conclude that a good strategy to forecast the krona exchange rate is to assign horizon-varying weights to the random walk and the estimated AR model. In the initial quarters, a larger weight is assigned to the random walk, which is used to forecast the nominal krona effective exchange rate. For the subsequent quarters, the AR models should have a larger weight to forecast the real effective exchange rate. This methodology has recently been adopted by Sveriges Riksbank as a baseline for forecasting the krona effective exchange rate. With respect to the methods previously used, the convergence to the assessed long-run equilibrium is now assumed to happen at a considerably slower pace. The final forecast of the exchange rate published in the Monetary Policy Report, however, may be subject to judgement, taking into account factors that are not captured in the models.

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Appendix

Short-term forecasts

Note. The long forecasting sample refers to an initial estimation of the models over the period January 1999–December 2006, after which the estimation is repeated by recursively adding one additional month until December 2018 and the forecasts start from January 2007. The short forecasting sample refers to an initial estimation of the models over the period January 1999–December 2011, after which the estimation is repeated by recursively adding one additional month until December 2018 and the forecasts start from January 2012.

Table A 1. Root mean squared error (with respect to random walk) of forecasting models for the short term, long forecasting sample.

Month	RW	UIP_theory	UIP_data	URP	URP_YC
1	1	1.00	1.01	0.95	0.95
3	1	1.00	1.00	0.96	0.96
6	1	1.00	1.00	0.99	0.98
12	1	1.00	1.00	0.99	0.99

Table A 2. Bias (in percentage) of forecasting models for the short term, long forecasting sample.

Month	RW	UIP_theory	UIP_data	URP	URP_YC
1	-0.08	-0.07	-0.11	-0.09	-0.08
3	-0.24	-0.22	-0.27	-0.26	-0.26
6	-0.48	-0.47	-0.52	-0.51	-0.53
12	-0.92	-0.90	-0.96	-0.95	-0.97

Table A 3. Root mean squared error (with respect to random walk) of forecasting models for the short term, short forecasting sample.

Month	RW	UIP_theory	UIP_data	URP	URP_YC
1	1	1.00	1.00	1.00	1.00
3	1	1.00	1.00	1.00	0.99
6	1	1.00	1.00	1.01	0.99
12	1	1.00	1.00	1.00	0.99

Table A 4. Bias (in percentage) of forecasting models for the short term, short forecasting sample.

Month	RW	UIP_theory	UIP_data	URP	URP_YC
1	-0.19%	-0.18%	-0.21%	-0.24%	-0.07%
3	-0.63%	-0.62%	-0.65%	-0.67%	-0.51%
6	-1.29%	-1.29%	-1.31%	-1.35%	-1.18%
12	-2.96%	-2.96%	-2.97%	-2.99%	-2.81%

Medium-term forecasts

Note. The long forecasting sample refers to an initial estimation of the models over the period 1995-2006, after which the estimation is repeated by recursively adding one additional quarter until the end of 2018 and the forecasts start from 2007. The short forecasting sample refers to an initial estimation of the models over the period 1995-2011, after which the estimation is repeated by recursively adding one additional quarter until the end of 2018 and the forecasts start from 2012. The DSGE model is an exception, since it is estimated over the full sample 1995 – 2018.

Table A 5. Root mean squared error (with respect to random walk) of forecasting models for the medium term, long forecasting sample.

Quarter	RW	BVAR foreign	BVAR uncond	DSGE 3foreign	DSGE uncond	AR data	AR theory
1	1	0.88	1.14	0.88	1.02	0.99	0.99
4	1	0.88	1.01	0.86	1.12	0.93	0.96
8	1	0.89	0.90	0.78	1.11	0.86	0.92
12	1	0.97	0.81	0.68	0.99	0.74	0.84

Table A 6. Bias (in percentage) of forecasting models for the medium term, long forecasting sample.

Quarter	RW	BVAR foreign	BVAR uncond	DSGE 3foreign	DSGE uncond	AR data	AR theory
1	1	-0.25	-1.09	-0.86	-1.03	-0.39	-0.34
4	1	-1.10	-3.32	-2.89	-3.96	-1.29	-1.19
8	1	-2.29	-4.48	-3.52	-6.22	-1.98	-1.91
12	1	-1.87	-3.70	-2.75	-6.45	-1.17	-1.19

Table A 7. Root mean squared error (with respect to random walk) of forecasting models for the medium term, short forecasting sample.

Quarter	RW	BVAR foreign	BVAR uncond	DSGE 3foreign	DSGE uncond	AR data	AR theory
1	1	1.13	1.12	1.15	1.17	1.02	1.01
4	1	1.23	1.24	1.24	1.38	1.01	0.99
8	1	1.11	1.21	1.06	1.34	0.89	0.93
12	1	1.03	1.12	0.95	1.29	0.81	0.88

Table A 8. Bias (in percentage) of forecasting models for the medium term, short forecasting sample.

Quarter	RW	BVAR foreign	BVAR uncond	DSGE 3foreign	DSGE uncond	AR data	AR theory
1	1	-0.59	-1.13	-0.78	-0.97	-0.56	-0.53
4	1	-2.62	-3.99	-3.09	-4.12	-2.34	-2.37
8	1	-5.45	-6.83	-5.13	-7.36	-4.52	-4.79
12	1	-7.70	-8.85	-6.75	-9.95	-6.25	-6.91