STAFF MEMO

Norges Bank's BEER models for the Norwegian effective exchange rate

NORGES BANK

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Kjetil Martinsen[1], September 4, 2017

I revisit Norges Bank's Behavioural Equilibrium Exchange Rate (BEER) models for the Norwegian effective exchange rate first introduced in Flatner et al. (2010) and extend the model framework in several directions. Two medium-term BEER models are estimated using both short- and long-term interest rate differentials, where the latter intends to capture the effects of unconventional monetary policy. Both models include the oil price, relative consumer prices and a measure for the Norwegian "basic balance", an approximation of Mainland Norway's current account. Moreover, the short-term BEER model is extended with a long-term interest rate differential and a measure of Norwegian specific foreign exchange volatility. I show that the movements in the effective exchange rate can be explained quite well by the fundamental explanatory variables in the model framework.

1 Introduction

Being a small open economy, the exchange rate is important for both Norwegian inflation and production. Since 2001, Norges Bank has been a flexible inflation targeting central bank with a mandate of stabilizing inflation around 2.5 percent over time, but also stabilizing the production around its potential. Hence, the exchange rate is important in Norges Bank's conduct of monetary policy.

Over the past years, Norges Bank has developed a broad set of models to analyze the movements in the Norwegian nominal effective exchange rate (I-44). Flatner et al. (2010) give an overview of the model toolbox, with emphasis on econometric models where the theories of purchasing power parity and uncovered interest rate parity are central. Moreover, ter Ellen and Martinsen (2016) develop an SVAR model to study the effects of oil price shocks on the Norwegian krone. In addition, ter Ellen (2016) investigates the nonlinearities in the relationship between oil price changes and movements in the Norwegian krone.

Following Flatner et al. (2010), in this note I revisit the BEER[2] model framework and present the current state of the BEER models for the Norwegian effective exchange rate which are currently in use at Norges Bank. These BEER models are used as simple crosschecks for the developments in the I-44 based on historical co-movements between the Norwegian krone and other economic variables. The purpose of these models is to get an indication of whether the I-44 has evolved in line with what fundamental drivers would suggest, based on historical relationships. I introduce two versions of the medium-term BEER model, one estimated using real variables and one version using nominal variables. Moreover, as an extension to Flatner et al. (2010), 10 year interest rate differentials are included to encompass the effect of unconventional monetary policy among foreign central banks. In addition, I include the basic balance as an explanatory variable for the I-44. The basic balance, which is an approximation of Mainland Norway's current account, is included as a variable for gauging the actual currency transactions stemming from

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[2] Behavioural Equilibrium Exchange Rate models, see MacDonald (2007) for a review of the BEER model framework.

households and businesses. Finally, I also introduce an updated version of the short-term BEER model, where a variable for the Norwegian specific foreign exchange volatility is included, in addition to 10 year interest rate differentials.

The structure of this memo is as follows. Section 2 introduces the data. Section 3 outlines the structure and results of the various BEER models. Section 4 concludes.

2 Data

In order to assess whether the I-44 has been in line with the movements in other fundamental economic variables, I have developed two different BEER models, a medium-term BEER and a short-term BEER, where the differences between the models are mainly due to estimation period, frequency of the data and also the variables included. Both the medium- and short-term models take interest rate differentials and the oil price as a starting point. The oil price works as a proxy for the risk premium in Norwegian kroner, but could also, more generally, serve as a measure of Norway's terms of trade, that in turn is likely to affect the equilibrium exchange rate. In the medium-term BEER model, variables such as relative consumer prices, interest rates differentials, oil price and the Norwegian basic balance are included. This model is estimated on quarterly data and the sample period ranges from the first quarter of 1999 to the fourth quarter of 2016. In the short-term BEER model, the interest rate differential, the oil price and a measure of Norwegian Specific Volatility (NOKVOL) are included as explanatory variables. This short-term model is estimated on weekly data from the first week of 2009 to the last week of 2016.

Table 1: Overview of included variables in the various BEER models

Model	**Real medium-term BEER**[1]	**Nominal medium-term BEER**	**Nominal short-term BEER**
	Quarterly frequency, 1999 Q1 – 2016 Q4	Quarterly frequency, 1999 Q1 – 2016 Q4	Weekly frequency, 2009 W1 – 2016 W52
Included variables			
I-44	Yes, deflated	Yes	Yes
Relative prices	No	Yes	No
12 month interest rate differential	Yes, deflated	Yes	Yes
10 year interest rate differential	Yes, deflated	Yes	Yes
Oil price	Yes, deflated	Yes	Yes
Basic balance	Yes, deflated	Yes	No
NOKVOL	No	No	Yes

1) Note: the variables are deflated using actual consumer price indices. For 12 month and 10 year interest rate differentials deflating using expected inflation would be recommended. However, these inflation expectations are not available for Norway.

Figure 1: Overview of model variables. I-44, relative consumer prices (Norway minus trading partners) and NOKVOL measured in index points, 12 month and 10 year interest rate differentials (Norway minus trading partners) measured in percentage points, the oil price measured in USD per barrel and the basic balance measured in billions of NOK.
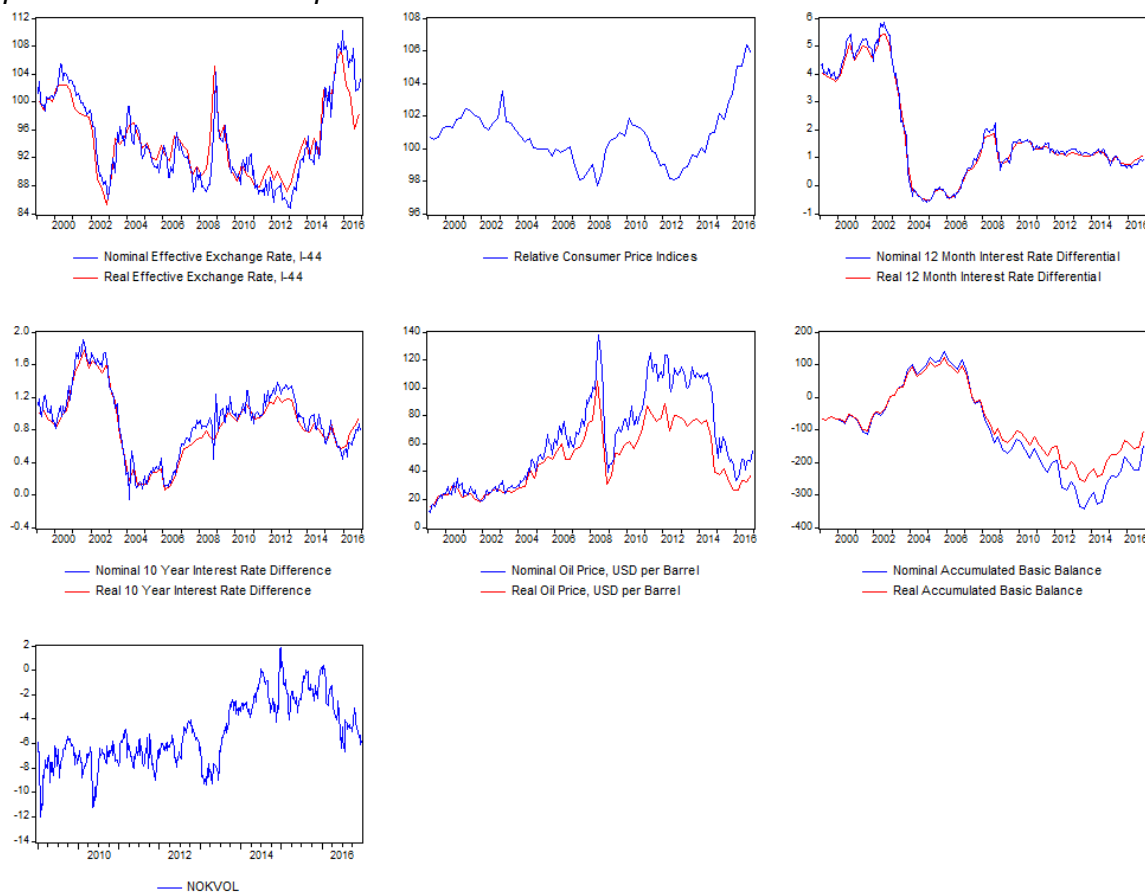
The variable of interest, the nominal effective exchange rate (I-44), is a weighted index of the Norwegian krone against the currencies of Norway's most important trading partners.[3] The I-44 is calculated as a weighted average of the exchange rates of 44 countries (following the introduction of the euro, there are now 31 unique currencies making up the index), of which the euro, Swedish krone, Chinese yuan, British pound and US dollar make up about 70 percent of the basket. The I-44 is calculated as an inverted index, meaning that a higher value of the I-44 implies a depreciation of the Norwegian krone.

In our analysis, I use two different sets of interest rate differentials. Our short term interest rates are measured as the 12 month swap interest rates for Norway and a computed average of the trading partners' 12 month swap interest rates. 12 month interest rates are chosen rather than 3 month, as the 12 month interest rates to a larger degree capture expectations of future monetary policy. The trading partners' swap interest rate is made up as an average of the interest rates of Norway's seven biggest trading partners. Ideally, the computed average should contain the same countries and weights as in the I-44. Due to data unavailability, however, this is not possible. The seven countries included in the trading partners' swap interest rate make up approximately 75 percent of the weights in I-44.

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[3] See Norges Bank's webpage for more information on calculation of the I-44: http://www.norges-bank.no/en/Statistics/exchange_rates/Calculated-rates---explanation/

Following the global financial crisis in 2008-09, some of Norway's trading partners started to use unconventional monetary policy tools, often referred to as quantitative easing (QE), with the aim of lowering longer term interest rates. These measures have most often been implemented when key interest rates has been at (its perceived) lower bound. To encompass the effect of longer term interest rates on the I-44, I therefore include the 10 year swap interest rate differential as an explanatory variable in our BEER models. For the medium-term BEER, though, which has a sample ranging from 1999 Q1 until 2016 Q4, I add a dummy variable to the long-term interest rate differential which takes the value of zero in the quarters up until 2008 Q4 and the value of 1 thereafter. The motive for choosing 2009 Q1 as the starting point for including 10 year swap interest rate differential is owing to the fact that Federal Reserve started their first QE-program in late 2008. Since the short-term BEER is estimated from 2009 W1, there is no need for a dummy variable in this model.

The oil price is often classified as an important driver for the exchange rate, see for example Bjørnland and Hungnes (2005). The oil price could affect the exchange rate through various channels. The oil price is to a large degree correlated with Norwegian terms of trade, since oil is the country's single largest export good. A higher oil price is likely to increase the nation's wealth and hence raise demand. The oil price could be seen as an indicator of the state of the Norwegian economy, where one can assume that a high oil price increases activity in the oil sector and have positive spillover effects into other sectors of the Norwegian economy. In that sense, changes in the oil price could affect the equilibrium exchange rate. The oil price may affect the level of the key interest rate in Norway and among Norway's trading partners, and thus through the interest rate differential. Furthermore, oil price fluctuations could lead to risk premiums in financial markets. A low oil price could lead to higher uncertainty about economic developments in Norway, and thereby cause investors to require a higher expected return for investing in Norwegian kroner.

For the oil price, I use Brent blend 1st contract, measured in US dollars per barrel. Brent blend is deemed to be the most appropriate oil price to use, as this is the type of oil which is extracted from the Norwegian continental shelf.

Relative consumer prices, which are related to the concept of purchasing power parity (PPP), are included in the medium-term BEER models. In the nominal setup, relative consumer prices are included directly as an explanatory variable, whereas in the real setup I use consumer prices to deflate the other variables. For Norway, I use seasonally adjusted CPI in levels, while I use a weighted seasonally adjusted consumer price index for 25 of Norway's most important trading partners' as foreign prices. Ideally, price level data might be preferable; however, these series are hard to obtain across countries. CPI series, on the other hand, are often similarly defined and easily obtainable. Thus, the relative CPI variable included in the BEER models should be considered a proxy for the true relative price levels.

The current account is often put forward as a key driver for the exchange rate. Clark and MacDonald (1998) include the cumulative current account, or the country's net foreign assets, as an explanatory variable in models for the level of the effective exchange rate of the US dollar, German mark and Japanese yen.

High exports of oil and gas has given Norway substantial current account surpluses over many years. An increase in the current account will normally lead to increased demand for NOK and a stronger domestic nominal exchange rate. The share of the petroleum revenues that are invested directly abroad through the Norwegian Government Pension Fund Global (GPFG), however, has no direct effect on the Norwegian exchange rate. The

same argument applies to the currency surpluses of the oil companies operating on the Norwegian continental shelf. This currency surplus is admittedly a relatively modest size compared with transfers to the GPFG, and is also difficult to estimate. The current account adjusted for transactions related to petroleum activities, which do not directly affect the demand for NOK, is referred to as the "basic balance", see Lund (2009).

Regarding the supply of and demand for foreign currency, the basic balance plays the same role as the current account in countries without a similar fund mechanism. The basic balance could therefore be seen as a proxy for the current account for Mainland Norway.

In the medium-term BEER model, the basic balance is approximated by the current account minus government net lending, see figure 2. Government net lending is by and large the government net transfers to the GPFG, and hence, the basic balance could be seen as the current account minus the net transfers to the GPFG. Since I estimate a model of the exchange rate in levels, the basic balance is included as a cumulative series measured in billion NOK, i.e. an approximation of Mainland Norway's net foreign assets. In isolation, one would expect a decline in the cumulated basic balance to yield a depreciating pressure on the NOK, and conversely, an increase in the basic balance could make the NOK appreciate. Both the current account and government net lending are only available at a quarterly frequency, constraining the medium-term BEER model to be estimated on quarterly data.

Figure 2: The building blocks of the basic balance. The current account, government net lending, basic balance and cumulated basic balance in billions of NOK. 1999 Q1 – 2016 Q4

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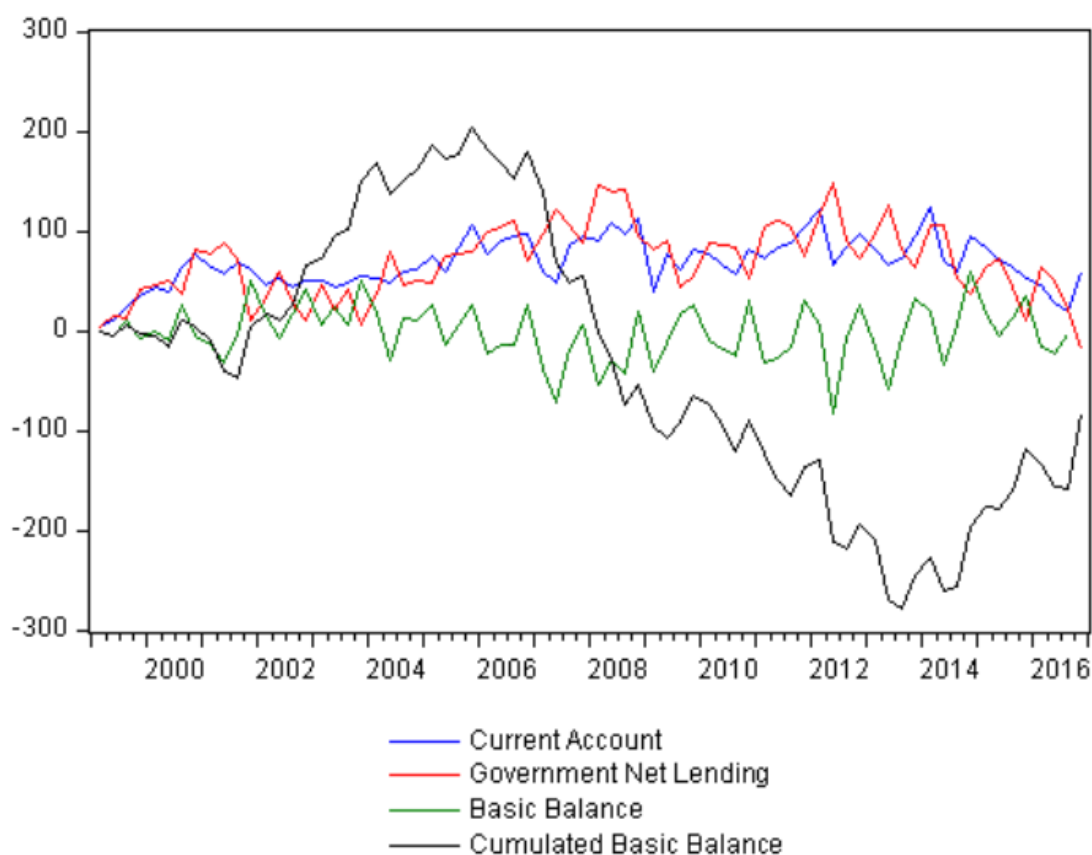
In line with ter Ellen and Martinsen (2016), I also include a measure of Norwegian-specific volatility (NOKVOL) in the short-term BEER model. NOKVOL is assumed to approximate the NOK risk premium relative to other major currencies, such as euro, US dollars and Japanese yen. The idea is that Norway's risk premium in the FX market is related to uncertainty about the outlook for the Norwegian economy and Norges Bank's monetary policy. This uncertainty probably increased following the drop in the oil price from the autumn of 2014. The NOKVOL indicator is created by taking the difference between implied volatility in the Norwegian and the international foreign exchange market.[4]

3 Model specification and results

3.1 Medium-term BEER

3.1.1 Real model

Following the BEER literature, see MacDonald (2007) and references therein, the BEER approach is regarded as a very general approach to modelling equilibrium exchange rates. It takes as a starting point the proposition that real factors are a key explanation for the slow reversion to PPP observed in the data. I model the real effective exchange rate, q_t, as a function of real interest rate differentials, real oil price and the real basic balance as motivated above:

$$q_t = c + \beta_1\left(r_{12m,t} - r^*_{12m,t}\right) + \beta_2\left(r_{10y,t} - r^*_{10y,t}\right) * d_{09q1,t} + \beta_3\, rpoil_t + \beta_4 rBB_t + \varepsilon_t, \quad (1)$$

where $r_{12m,t}$ and $r^*_{12m,t}$ are real domestic and foreign 12-month interest rates, respectively, and $r_{10y,t}$ and $r^*_{10y,t}$ are the corresponding 10 year interest rates. The interest rates are deflated by actual domestic and foreign annual CPI inflation, respectively. $rpoil_t$ is the log of the Brent blend oil price measured in US dollars, deflated by US CPI and rBB_t is the real Norwegian basic balance in billions NOK deflated by domestic CPI. c is a constant. In order to have interpretable coefficients, the real variables included are rebased to 1999 Q1 to the same level as their nominal counterparts. One reason for this is because I am using price indices as deflators, rather than the actual price level. Hence, I am achieving economic inference by rebasing all variables to the same reference year, and also making the estimation results for the real exchange rate more comparable to that of the nominal exchange rate.

Estimation[5] of equation (1) for the real effective exchange rate on a quarterly frequency using data from 1999 Q1 to 2016 Q4 yields the following results, with t-statistics reported in parenthesis:

$$q_t = \underset{(95.76)}{5.031} - \underset{(-6.14)}{0.025} \left(r_{12m,t} - r^*_{12m,t}\right) - \underset{(-3.83)}{0.080} \left(r_{10y,t} - r^*_{10y,t}\right) * d_{09q1,t}$$
$$- \underset{(-8.77)}{0.118}\; rpoil_t - \underset{(-5.64)}{0.0005}\, rBB_t \tag{2}$$

The estimation results in equation (2) show that all coefficients are statistically significant with expected sign. According to the model, a ten basis point increase in the 12 month

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[4] To be precise, Norwegian implied volatility is proxied to be EURNOK 3 month implied volatility, while global implied volatility is an equally weighted measure of EURUSD, USDJPY and EURJPY 3 month implied volatilities.

[5] I estimate the equations in this paper using Fully Modified OLS (FMOLS) from the Eviews package.

real interest rate differential leads to an appreciation of the real I-44 of about 0.3 percent. Similarly, a ten basis point increase in the 10 year real interest rate differential leads to an appreciation of the real I-44 of 0.9 percent. Given that the 10 year real interest differential was only included from 2009 Q1, when short term interest rates already was close to the lower bound, this could explain why the 10 year real interest rate differential has a bigger impact on the I-44 that the 12 month real interest rate differential. As shown in the results in the short-term BEER model, an estimation period from 2009 Q1 until 2016Q4 yields more equal coefficients for the two interest rate differentials.

An increase in the real oil price of 10 percent leads to an appreciation of the real I-44 of about 1.2 percent. This is consistent with results from ter Ellen and Martinsen (2016), although using nominal data. Moreover, an increase in the level of the basic balance will also lead to an appreciation of the real I-44. The coefficient implies that if the basic balance increases by 1 billion Norwegian kroner, the krone will appreciate by 0.05 percent. Given that the cumulated basic balance has increased by more than 100 billion NOK from 2013 until the end of 2016, the estimated isolated effect on the I-44 would be close to 5 percent.

Figure 3 depicts the coefficients of the model based on a 12 quarter rolling regression from 1999 Q1 to 2016 Q4. The figure shows that the coefficients are broadly stable; however, it is also clear that there have been periods where the coefficients have changed sign or not been significantly different from zero. These periods are often linked to unprecedented events, like the build-up to the financial crisis for the 12 month real interest rate differential (upper left chart), the debt crisis in the euro area in 2012 for the 10 year real interest rate differential (upper right chart) or the large changes in the oil price in 2014 (lower left chart). Given that these are estimates using a 12 quarter rolling regression, the standard errors are inflated due to the short data sample. Figure 3 also clearly indicates that the oil price, together with the 10 year interest rate differential, have been the most important drivers behind the changes in the real exchange rate for the past couple of years, since the coefficients of the other explanatory variables have not been significantly different from zero. One reason that the 12 month real interest rate differential has had little impact on the I-44 over the recent years could be that this interest differential has remained more or less unchanged for several years, as depicted in figure 2. Both Norwegian and foreign 12 month interest rates have declined somewhat over the latest years. The 12 month interest rate differential has been stable at around 1 percentage point since 2010. This very stable period for the short interest rate differential is in stark contrast to the pre-financial crisis levels where the 12 month interest rate differential dropped from 5 percentage points to roughly zero in 2004, before increasing to 2 percentage points in 2008.

Figure 4 shows the actual real effective exchange rate, measured by I-44 adjusted by domestic and foreign CPI, and the estimated real exchange rate from the equation above. The real exchange rate has generally followed the movements that the fundamental explanatory variables would suggest. One exception is in the beginning of the 2000s, where the model less well explains the developments in the real I-44. However, the model captures the krone depreciation during the financial crisis well. The same applies to the depreciation of the NOK from the autumn of 2014, when the oil price fell sharply. It also seems that the model has captured the turning point in the exchange rate from the first half of 2016, when the NOK started to appreciate again.

Figure 3: Reported coefficients from a 12 quarter rolling regression of the real medium-term BEER model. 2002 Q1 – 2016 Q4. Note that the coefficient of the 10 year interest rate differential is zero until 2008 Q4 by construction
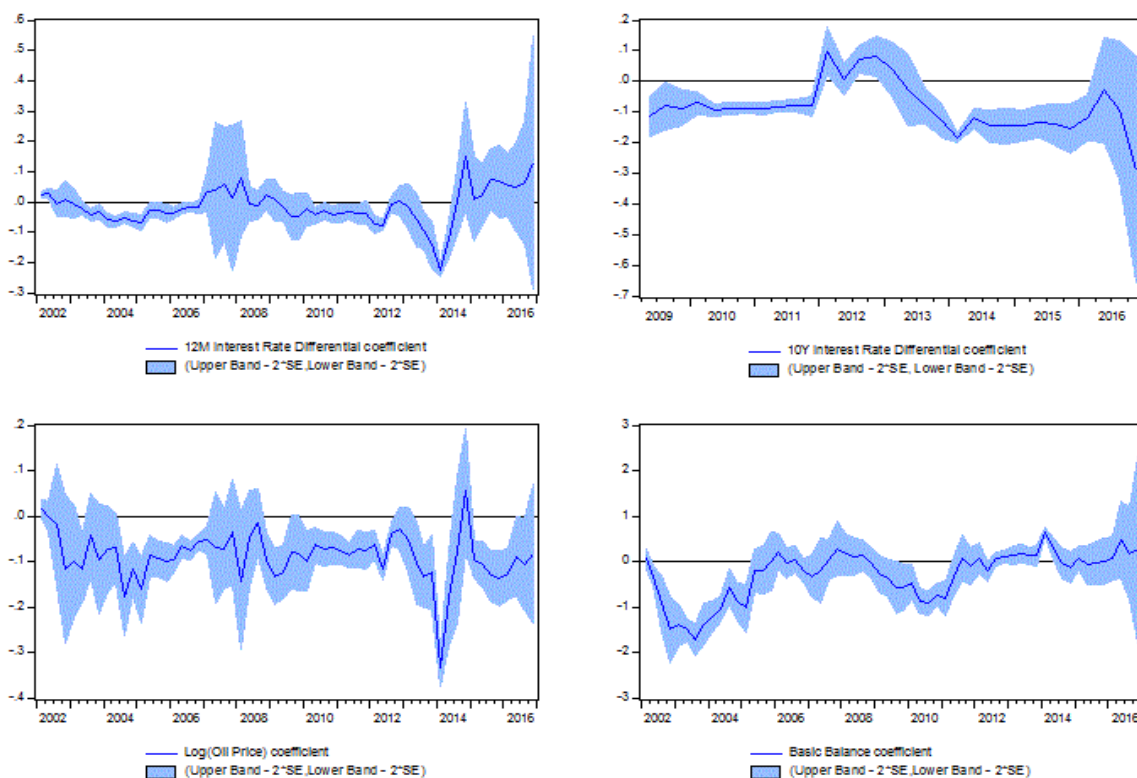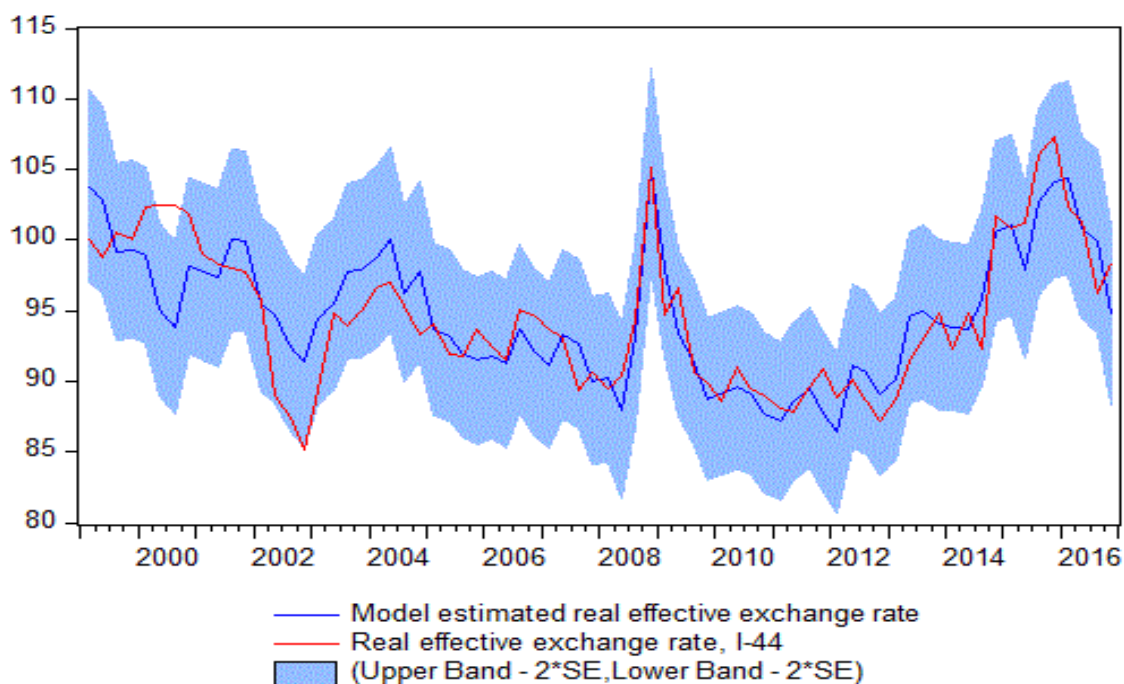

Figure 4: Real effective exchange rate, real I-44, and model estimated real effective exchange rate with uncertainty bands. Medium-term BEER. Estimation period 1999 Q1 – 2016 Q4

3.1.2 Nominal model

I also propose a nominal version of the medium-term BEER model. Although fundamental model applications most often are estimated using real variables, the inclusion of a nominal model is justified for at least four reasons. First, the nominal medium-term model would be directly comparable to the short-term model, introduced below. Since the short-term model is estimated on weekly data, it is most appropriate to estimate this model using nominal data without interpolating consumer price indices to match this frequency. Second, the nominal medium-term model would also be directly comparable to the financial variables observed daily in the financial markets, whereas real variables would have to be converted into approximated nominal variables. Third, inflation in Norway and among its most important trade partners has been low and stable over the sample period considered. Hence one could ask whether agents in financial markets really have paid much attention to inflation differentials in their pricing of financial assets. Fourth and last, it is not trivial to deflate variables with the correct measure of inflation. For instance, one could argue that 12 month and 10 year swap interest rates should be deflated using the 12 month and 10 year inflation expectations, respectively, rather than actual inflation. However, at least for Norway, there are no market based indicators for inflation expectations that would be suitable for this purpose.

Following Bjørnland and Hungnes (2005), I combine the concepts of PPP and UIP to have an expression for the nominal effective exchange rate as:

$$s_t = p_t - p_t^* - v(i_t - i_t^*) - \delta poil_t \tag{3}$$

where s_t is the log of the nominal exchange rate, p_t is the log of the domestic price level and p_t^* is the log of the foreign price level. i_t is the domestic nominal interest rate and i_t^* is the nominal foreign interest rate. As discussed above, and as argued by Bjørnland and Hungnes, given that Norway is an oil exporter, the oil price should be included to encompass that the NOK is a "petrocurrency". This feature is captured in the term $poil_t$.

As already elaborated upon for the real version of the medium-term BEER, I also include the basic balance as an explanatory variable to capture the actual transactions stemming from mainland Norway's exports and imports. Thus, I postulate a similar model as the real medium-term BEER, with the exception that all variables are nominal, while I include a log PPP-term, $(p_t - p_t^*)$, directly:

$$s_t = c + \beta_1(p_t - p_t^*) + \beta_2(i_{12m,t} - i_{12m,t}^*) + \beta_3(i_{10y,t} - i_{10y,t}^*) * d_{09q1,t} + \beta_4\, poil_t + \beta_5 BB_t + \varepsilon_t, \tag{4}$$

where $i_{12m,t}$ and $i_{12m,t}^*$ are nominal domestic and foreign 12-month interest rates, respectively, and $i_{10y,t}$ and $i_{10y,t}^*$ are the corresponding 10 year interest rates. $poil_t$ is the log of the Brent blend oil price measured in US dollars and BB_t is the Norwegian basic balance measured in billions NOK.

Using the same sample period as for the real version of the model, estimation of the nominal model yields the following results:

$$
\begin{aligned}
s_t = \;& 4.935 \; + 1.196\,(p_t - p_t^*) \; - \; 0.020\,\left(i_{12m,t} - i_{12m,t}^*\right) - \; 0.076\,\left(i_{10y,t} - i_{10y,t}^*\right) * d_{09q1,t} \\
& \;(68.87)\quad (3.17)\qquad\qquad\quad (-5.25)\qquad\qquad\qquad\qquad (-3.84) \\
& \quad - \; 0.093\; poil_t - \; 0.0004\, BB_t \\
& \qquad (-5.84)\qquad\quad (-5.41)
\end{aligned} \tag{5}
$$

The estimation results are in line with those from the real model. All coefficients have the sign expected from theory and all are significantly different from zero at a five percent significance level. A ten basis point increase in the 12 month interest rate differential leads to an appreciation of the I-44 of about 0.2 percent, whereas a ten basis point increase in the 10 year interest rate differential leads to an appreciation of the I-44 of 0.8 percent. This is in line with results of the real model, which could indicate that changes in the nominal interest rate differential are perceived as changes in the real interest rate differential. The impact on the I-44 from the oil price and the basic balance are slightly more muted than in the real model. However, the impact on the I-44 from an oil price increase of 10 percent hovers around 1 percent, broadly in line with previous results.

The coefficients from a rolling regression of the nominal medium-term BEER model are reported in figure 5 below. The coefficients are very much in line with the coefficients reported from the real version of the model. However, a couple of results are worth highlighting. First, the coefficient of the relative prices (upper left chart), capturing the purchasing power parity condition, is substantial and volatile in the beginning of the sample. This is the period when Norges Bank adopted inflation targeting regime where the economies were in a transitional phase with a focus on lowering consumer price inflation. Second, the 10 year interest rate differential (middle left chart), alongside the oil price (middle right chart), seems to be somewhat more important for the development in the I-44 than in the real version of the model.

Figure 6 shows the actual nominal effective exchange rate, I-44, and the estimated nominal exchange rate from the equation above. From the figure, we see that the I-44 has a good fit with the nominal model, as in the real version of the model. Again, in the period following the introduction of the inflation target in Norway the model cannot to the same extent explain the developments in the I-44. However, this is the only period where the I-44 is outside the error bands of the model. From 2004 onwards, the model fits the development of the actual exchange rate reasonably well.

Figure 5: Reported coefficients from a 12 quarter rolling regression of the nominal medium-term BEER model. 2002 Q1 – 2016 Q4. Note that the coefficient of the 10 year interest rate differential is zero until 2008 Q4 by construction
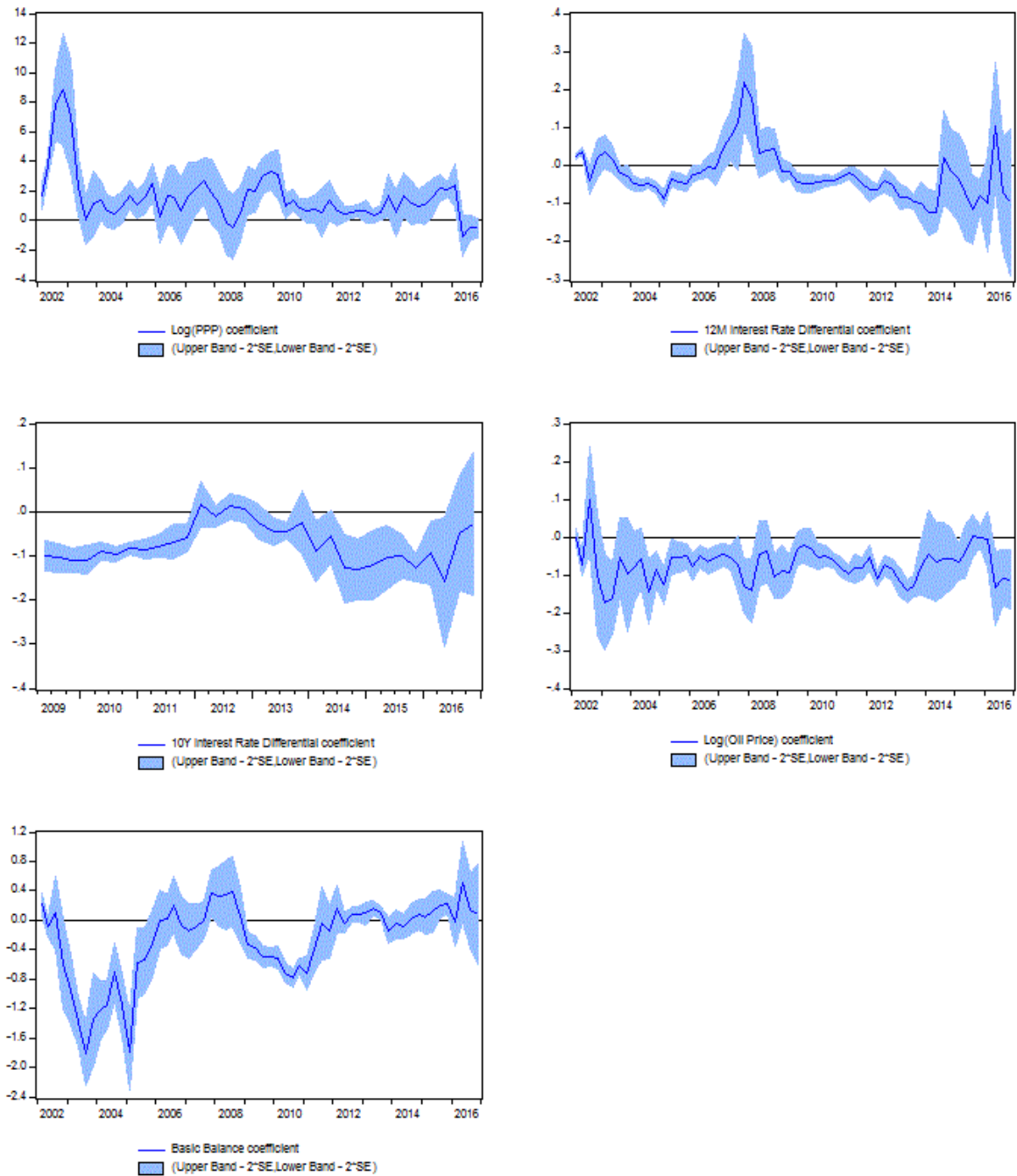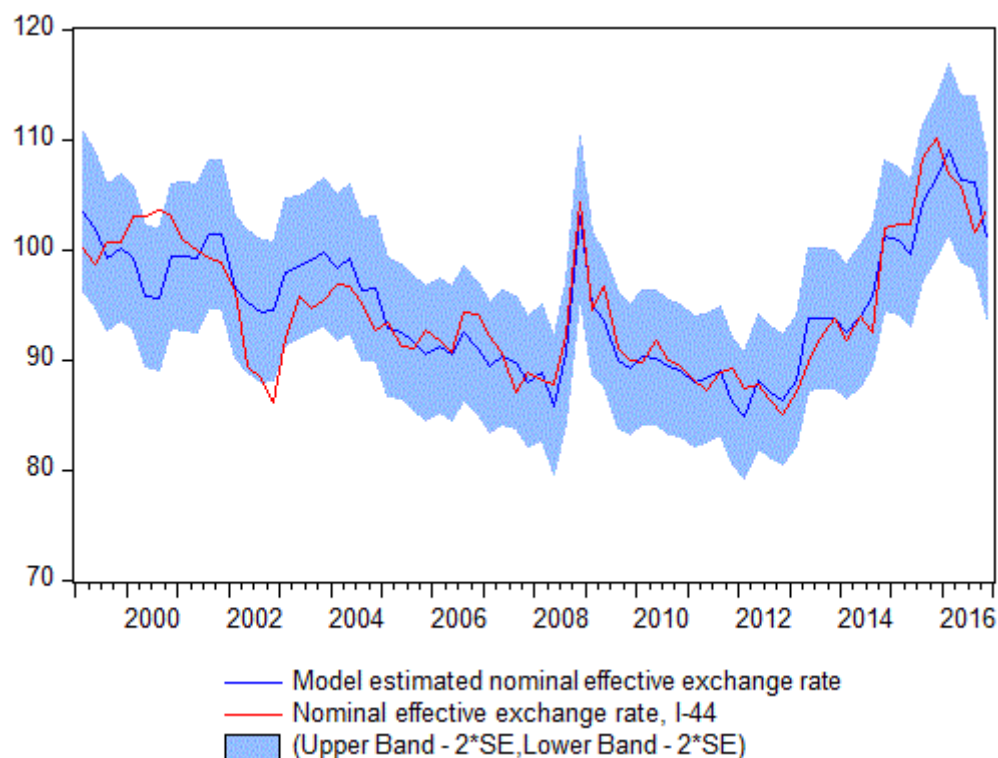
Figure 6: Nominal effective exchange rate, I-44, and model estimated nominal effective exchange rate with uncertainty bands. Medium-term BEER. Estimation period 1999 Q1 – 2016 Q4

3.2 Short-term BEER

The medium-term BEER model is developed to gauge whether the I-44 has been in line with the developments in fundamental variables over the past two decades. The quarterly frequency of the model enables us to use national accounts data as explanatory variables. However, a short-term BEER model with a weekly data frequency allow us to update the model more often and hence evaluate the model fit almost in real time. The weekly frequency, on the other hand, prevents us from using national accounts data and the monthly CPI variables. In other words, the short-term BEER model is solely based on financial and commodity variables in nominal terms, which are available on a daily frequency. In addition to the financial and commodity variables included in the medium-term BEER model, I include the NOKVOL variable stemming from the foreign exchange options market, as introduced above. The short-term BEER model is therefore set up as follows:

$$s_t = c + \beta_1\left(i_{12m,t} - i^*_{12m,t}\right) + \beta_2\left(i_{10y,t} - i^*_{10y,t}\right) + \beta_3\, poil_t + \beta_4\, NOKVOL_t + \varepsilon_t, \qquad (6)$$

where the variables are as described above. I estimate this model using a sample ranging from the first week of 2009 until the last week of 2016. Hence, I do not have to include a dummy for the 10 year swap interest rate differential, as this dummy took the value of 1 from 2009 and onwards. Estimation of this model yields the following results:

$$
\begin{aligned}
s_t = \;& 5.120 \;-\; 0.054 \left(i_{12m,t} - i^*_{12m,t}\right) \;-\; 0.097 \left(i_{10y,t} - i^*_{10y,t}\right) \;-\; 0.093 \;\; poil_t \\
& {\scriptstyle(241.36)} \quad {\scriptstyle(-6.33)} \qquad\qquad\qquad {\scriptstyle(-7.97)} \qquad\qquad\qquad\qquad {\scriptstyle(-13.87)} \\
& +\; 0.004\; NOKVOL_t \\
& \quad {\scriptstyle(4.98)}
\end{aligned}
\qquad (7)
$$

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The results of the short-term BEER in equation (7) is broadly in line with the results from the nominal medium-term BEER. Again, all coefficients have the expected signs and are significantly different from zero at a five percent significance level. A marginal difference, however, is that the 12 month swap interest rate differential has a larger coefficient, in absolute terms, compared to the medium-term BEER. This effect could be owing to the fact that exchange rates have, for several countries, become more sensitive to changes in interest rates over time, see for example Ferrari et al. (2016). Moreover, the estimation results convey a positive coefficient for the NOKVOL variable. This implies that investors demand a higher expected return to invest in Norwegian kroner when there are Norwegian specific uncertainties present in the foreign exchange market.

Figure 7 below depicts the coefficients of the short-term model based on a 52 week rolling regression from 2009 W1 to 2016 W52. Although broadly well defined, the coefficients of the weekly model seem to be somewhat more volatile than the coefficients of the quarterly models. This could be because financial markets inherit short term volatility and omitted variables could be affecting the I-44 in the short run. Moreover, it is clear from the figure that in the periods when the oil price (lower left chart) has a relatively large (negative) and significant coefficient, the estimated effects of the other explanatory variables are more muted. The same pattern is seen for the other variables and hence, one conclusion that could be drawn from this is that financial markets are "topic driven" and that there are nonlinearities in the relationship between movements in I-44 and the included explanatory variables. ter Ellen (2016) notes indeed that this could be the case for movements in the oil price and I-44.

Figure 7: Reported coefficients from a 52 week rolling regression of the short-term BEER model. 2010 W1 – 2016 W52
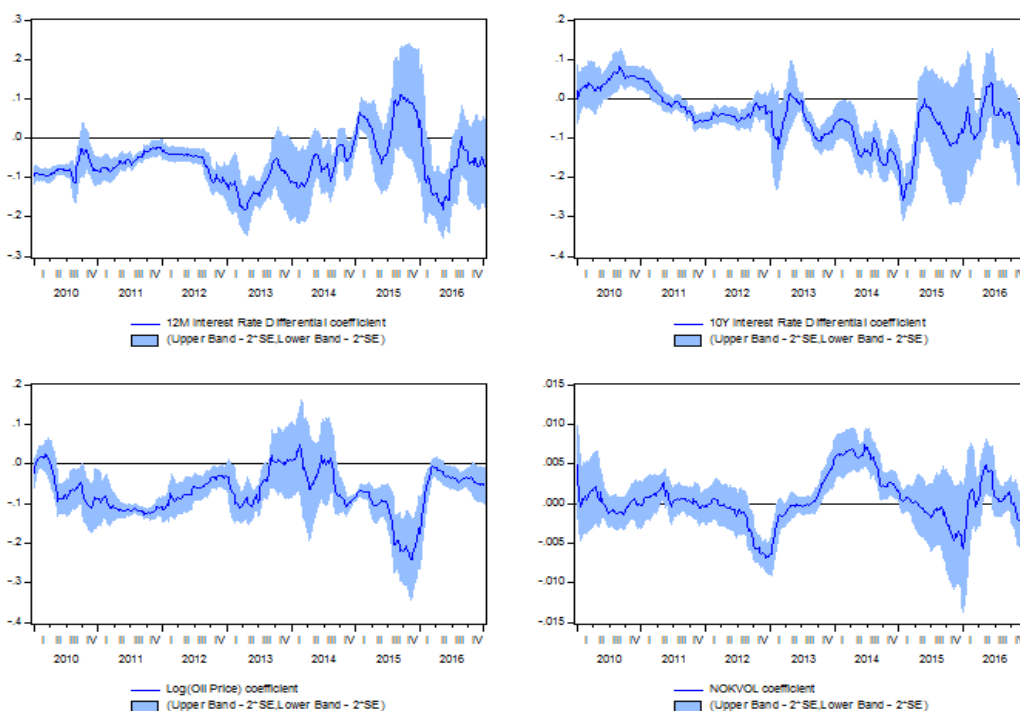

Figure 8 below shows that the I-44 estimated by the model tracks the actual developments of the I-44 well. In the months after the large drop in the oil price in the second half of 2014 and the beginning of 2015 the model predicted a weaker currency than actual. Moreover, the model predicted a much sharper depreciation of the I-44 around year-end 2015 when I-44 was at its weakest ever recorded levels. Throughout

2016, however, the short-term BEER model estimates a somewhat stronger currency than what has been the case. These results are in contrast to the results from the nominal medium-term BEER model, where the model estimated a somewhat stronger I-44 than actually observed following the drop in the oil price in 2014 and a slightly weaker I-44 during 2016.

Figure 8: Nominal effective exchange rate, I-44, and model estimated nominal effective exchange rate with uncertainty bands. Short-term BEER. Estimation period 2009 W1 – 2016 W52
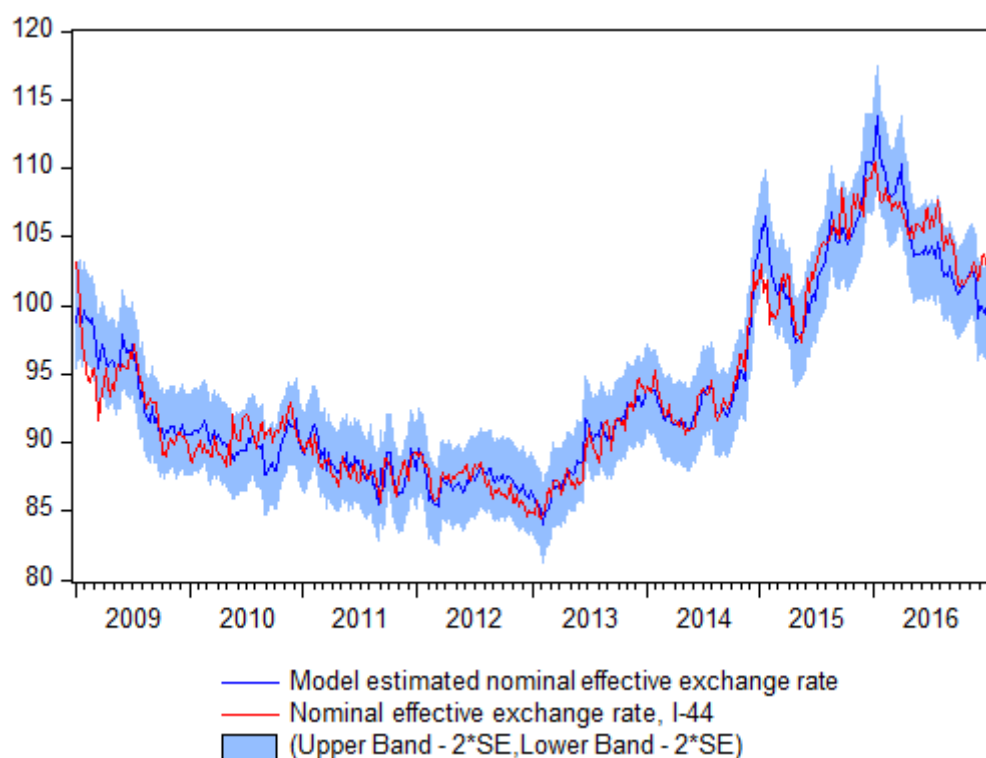
4 Conclusion

In this paper, I revisit Norges Bank's BEER models as introduced in Flatner et al. (2010). I propose both a real and a nominal version of a medium-term BEER model to estimate the Norwegian effective exchange rate (I-44). Following the introduction of unconventional monetary policy by several of Norway's trading partners, I extend the model in Flatner et al. (2010) by including a long term interest rate differential to account for QE effects aiming to lower long-term interest rates. The 10 year interest rate differential proves to be an important variable for explaining the movements in the I-44 following the financial crisis. Moreover, I also extend previous model specifications by adding a measure for mainland Norway's current account, the basic balance. The basic balance is included as an explanatory variable as the current account is often put forward as a key driver for the exchange rate. However, the share of the petroleum revenues that are invested directly abroad through the Norwegian Government Pension Fund Global has no direct effect on the Norwegian exchange rate. The basic balance could, in the same way as the current account in countries without a similar stock of net foreign assets, be the result of businesses' and households' supply and demand for foreign currency.

Moreover, I revisit a short-term BEER model estimated over a shorter sample on weekly data. This model is extended from Flatner et al. (2010) by the inclusion of the 10 year interest rate differential, as in the medium-term models, as well as a variable of Norwegian specific foreign exchange volatility to account for the increased risk premium in the I-44 following the recent drop in the oil price.

The coefficients in all model specifications are significantly different from zero and have the signs suggested by theory. Estimation of the medium- and short-term BEER models show that the development of the I-44 in broad terms can be understood based on fundamental economic variables. Also the depreciation of the I-44 in the last couple of years, following the large drop in the oil price in the autumn of 2014, is well explained by the models proposed. Moreover, the coefficients for the 12 month interest rate differential and the oil price are in line with previous studies by Norges Bank on these relationships. The results, however, also indicate that the 10 year interest rate differential has been an important driver behind the changes in the exchange rate for the last couple of years. Additionally, I measure the effect on the I-44 to be about 0.05 percent from an increase in the basic balance of 1 billion NOK. This is consistent in both the real and nominal medium-term BEER model, and these results suggest that the basic balance should indeed enter as a fundamental economic explanatory variable in the medium-term BEER models.

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