Why is the Norwegian krone exchange rate so weak? An analysis utilizing a fully simultaneous approach[*†]

Andreas Benedictow[‡]
Roger Hammersland[§]

October 19, 2021

Abstract

In this paper, we seek to draw attention to some of the factors that may contribute to explaining why the Norwegian krone euro exchange rate suddenly started to weaken from 2013 onwards. In addition to building on an expanded understanding of what must be said to represent a set of fundamental explanatory variables, including interest rate differentials and relative prices, this is done by considering non-traditional explanatory factors related to the potential existence of an exchange rate premium and the micro structure. By resorting to a fully simultaneous and endogenous understanding of the underlying process driving the krone-euro exchange rate, we find support for several claims to insights made from market participants. Hence, in addition to oil prices the recent weakening of the krone exchange rate seems to some extent to be driven by uncertainty, be it uncertainty related to the global business cycle in general or more specific kinds of uncertainty related to the future of oil in Norway. However, there is still little to suggest that the underlying process is not also driven by fundamentals.

Keywords: Exchange rate, Foreign exchange rate premium, Cointegration, VAR-analysis, COVID-19.

JEL Codes: F31,F41,G15

[*] Very preliminary paper version. Please do not quote.

[†] The authors are grateful to Kjetil Martinsen for interesting discussions and procurement of FDI data.

[‡] Housing Lab, Oslo Metropolitan University
[§] Statistics Norway, Bjørknes University College

1 Introduction

After inflation targeting was formally introduced in Norway in 2001, there are three periods in particular that stand out with a marked weakening of the krone exchange rate, see Figure 1. From the first two, it quickly regained its strength, but from the third, it has not recovered to this very day.

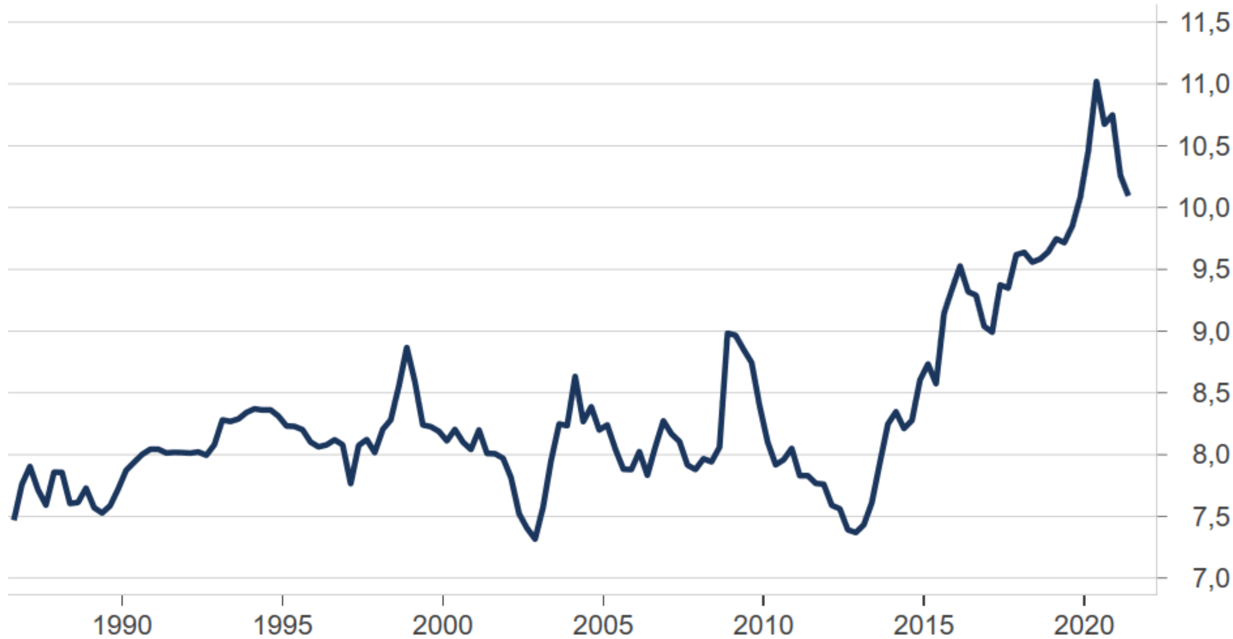
In 2001-2002, the krone strengthened markedly, which can probably largely be attributed to an increased interest rate differential with other countries, cf. for example Naug (2003). The following weakening probably overshot, after which the NOK rapidly reverted to what for many years had seemed to be a long term equilibrium just above 8 NOK for a euro, and more in line with a partial closing of the interest rate differential.

There were particularly large fluctuations in the krone exchange rate also in 2008-2010. The krone weakened sharply as a result of a flight to large, "safe haven" currencies such as the US dollar and the Swiss franc while the international financial crisis was in the acute phase in the autumn of 2008, before the krone regained its strength through 2009 and into 2010.

It appears that the krone exchange rate had a strong tendency to return to just over NOK 8 for one euro from the late 1980s and throughout the two following decades. However, from 2013 and into 2015, the krone weakened to previously unseen levels against the euro, first due to a general strengthening of the euro which may have been caused by improved prospects for the European economy, but, especially from the summer of 2014, also as a result of the steep fall in oil prices. Since 2016 the development in the euro-krone exchange rate (NOKEUR) has not been in line with the oil price development and other fundamentals. This paper investigates what factors may have caused the prolonged period of a weak NOK.

The euro is by far the most important currency for Norwegian trade in goods and services. In 2020, close to 35 per cent of Norwegian exports of goods went to the euro area. To quantify what influences the krone exchange rate, we take as our starting point the classic hypothesis of uncovered interest parity (UIP) or rather deviations from it, the latter in terms of the

Figure 1: NOKEUR



Source: Macrobond

existence of a foreign exchange risk premium, see for example Juselius et al. (1992), Juselius and MacDonald (2006) and Rashid et al. (2009). Like Bjørnland and Hungnes (2006) and Bjørnstad and Jansen (2007), we are open to the effects of oil prices. However, in order to better intercept the existence of an exchange rate premium and in this context to take into account potential effects related to market dynamics and micro structure, we include a number of additional variables in our information set. First, this implies looking at the explanatory power of the oil price when it is scaled against the Norwegian economy, as represented by the value of oil and gas exports as a share of the value of total Norwegian exports. To capture the effects of different types of investor behavior and in that context effects that potentially stem from circumstances such as expectations of an imminent green shift, increased focus on ESG-related investments[1], poor international prospects and global turbulence, we have, in addition to a number of uncertainty and volatility indices, also chosen

[1]ESG (Environmental, Social and Governance) investing refers to a class of investing that is also known as "sustainable investing." This is an umbrella term for investments seeking positive returns and long-term impact on society, environment and the performance of business.

to include an industry-specific oil equity index and a variable intercepting the development in the net holding of capital across national borders between Norway and the countries in the euro area.

We find a well-specified model for the NOKEUR, providing support for a theoretical model based on the deviation from UIP, as represented by the existence of a foreign exchange rate risk premium. Hence, in the long run, the krone exchange rate depends on relative prices and the real interest rate differential vis-à-vis the euro area, as well as a number of variables that may be taken to represent a foreign exchange risk premium. These include a variable that is intended to capture the relative importance of oil and gas in the Norwegian economy (v), but also variables that are intended to capture the effects of investor behavior more directly, i.e. the net flow of foreign capital between Norway and the euro countries as well as an industry-specific share price index related to the production of oil and gas in Norway. In addition, we do find more direct evidence of safe-haven behavior, as reflected by a significant effect of changes to the volatility of the US S&P equity index (VIX).

In the short term, the krone exchange rate is to a large degree driven by changes to the US dollar oil price and interest rates, although eigen dynamics and some additional variables related to the risk premium are found to be significant too. However, with the exception of the VIX volatility index and in contrast to what applies to the long term, the effect of these additional variables primarily appears to be valid from 2016 onwards. We do also identify a seasonal effect related to the last quarter of each year, as there is a general tendency for less krone trading at Christmas due to holidays.

The VAR pertaining to the long-run cointegration analysis is estimated by utilizing the probability maximization method (full information maximum likelihood, hereinafter referred to as FIML) while the design and estimation of the dynamic contingent krone-euro specification has been undertaken by resorting to a combination of an automatic model reduction scheme and hands-on design utilizing a single equation ordinary least square (OLS) procedure.

The theoretical background is explained in Chapter 2, where we briefly explain the key concepts of international purchasing power parity, uncovered interest rate parity and rational expectations, and argue briefly for including variables that intercept a foreign exchange premium as explanatory variables in the empirical analysis. Chapter 3 presents data and identifies possible long-term relationships between a set of different variables in our information set. Finally, Chapter 4 presents the results of the empirical analysis, including simulations aimed at illustrating the model's in-sample prediction and ex ante forecast properties. To illustrate the effects on the krone exchange rate of changes to some of the exogenous variables in this chapter we also undertake some shift calculations. Chapter 5 summarizes.

2 Theoretical background

The hypothesis of purchasing power parity (PPP) in its most restrictive form is based on the law of one price, which states that (in the long run, or in equilibrium) the cost of a commodity or a commodity group is the same regardless of which currency (or country) you buy it in, see for example Sarno and Taylor (2002).[2] Then the bilateral exchange rate between two countries can be expressed as the relative price ratio between the two countries,

$$S_t = P_t/P_t^*, \tag{1}$$

where S is the nominal, bilateral exchange rate, and P_t and P_t^* are the price levels in the two countries in period t, let us for simplicity call them home and abroad, respectively, where the latter is marked with an asterisk (*). PPP must be considered as an equilibrium, and thus (1) as an equilibrium condition. In practice, there will be deviations from PPP for a number of reasons. There may be data problems, such as a weak connection between the price measures used, typically the consumer price index (CPI), and the price you actually want

[2] An extension of the PPP hypothesis, known as *relative* PPP, relates changes in (expected) inflation in two countries to (expected) changes in the bilateral exchange rate. This implies that the prices (of the same product) may be different in different countries, but that the price difference is (or varies around a) constant over time. The real exchange rate must be stationary for PPP to hold in the long term.

to measure. There may also be more fundamental factors, such as the existence of shielded goods and services, trade barriers, price movements driven by speculation, differences in productivity, long-term fiscal imbalances, long cycles in commodity prices and interest rate differentials, which we will return to shortly.

If we multiply by P_t^*/P_t on both sides in (1) and take the logarithm, we get that $q_t = s_t + p_t^* - p_t = 0$ in equilibrium, where Q is the real exchange rate and lowercase letters indicate logarithmic form. As we see from (2), the real exchange rate can be interpreted as a deviation from PPP,

$$q_t = s_t - p_t + p_t^*. \tag{2}$$

There is little empirical support for PPP in the short term, but on long time series there are several studies that find support in the long term. Fair et al. (2009) finds support for PPP for 8 out of 22 countries with time series of 50 years in his global macroeconometric model. Akram (2006) finds support for PPP between Norway and its trading partners over long time series. As mentioned above, there can be many reasons for slow convergence towards PPP.

Uncovered interest parity (UIP) states that the interest rate differential between two countries shall be equal to the expected change in the exchange rate between the countries, and can be expressed approximately by

$$E_t \Delta s_{t,T} = I_{t,T} - I_{t,T}^*, \tag{3}$$

where E_t is the expectation operator, $E_t \Delta s_{t,T} \equiv E_t s_T - s_t$ is expected (at time t) percentage change in the exchange rate in the period from time t to T and $I_{t,T}$ and $I_{t,T}^*$ is the nominal interest rate at home and abroad with maturity T-t. UIP applies in an efficient market, and then it does not matter for the return in which country one invests money in interest-bearing securities, since an interest rate difference between two countries will correspond to an opposing change in the bilateral exchange rate in the same period. The hypothesis of efficient markets is consistent with risk-neutral market participants (on average) with rational expectations, see Sarno (2005).

If we express UIP in real terms and allow for a risk premium, z_t, (3) can be rewritten as

$$q_t = E_t q_T - (E_t R_{t,T} - E_t R^*_{t,T}) + z_t, \tag{4}$$

where $E_t q_T$ is the expected real exchange rate in period T, $E_t R_{t,T} = I_{t,T} - [E_t p_T - p_t]$ is the ex ante expected real interest rate and $E_t p_T - p_t$ is expected domestic inflation in the period t to T. $E_t R^*_{t,T}$ is the corresponding expected real interest rate abroad.

We may combine PPP and UIP, represented by equations (1) and (4), respectively, by inserting for q_t, and get

$$s_t = p_t - p^*_t + E_t q_T - (E_t R_{t,T} - E_t R^*_{t,T}) + z_t. \tag{5}$$

According to 5, the nominal exchange rate is determined by the current price difference between two countries, the expected future real interest rate differential and the expected long-term real exchange rate plus a risk premium. This equation forms the basis for our empirical analysis, in which we also try to capture the effects of risk premiums through a number of indicators, as explained in Section 4. We also test explicitly for the effects of forward-looking expectations both in terms of inflation and exchange rates.

3 Data

The exchange rate relationship is estimated on quarterly data. The estimation period runs from 2001, when an inflation target for monetary policy was introduced, to 2020.

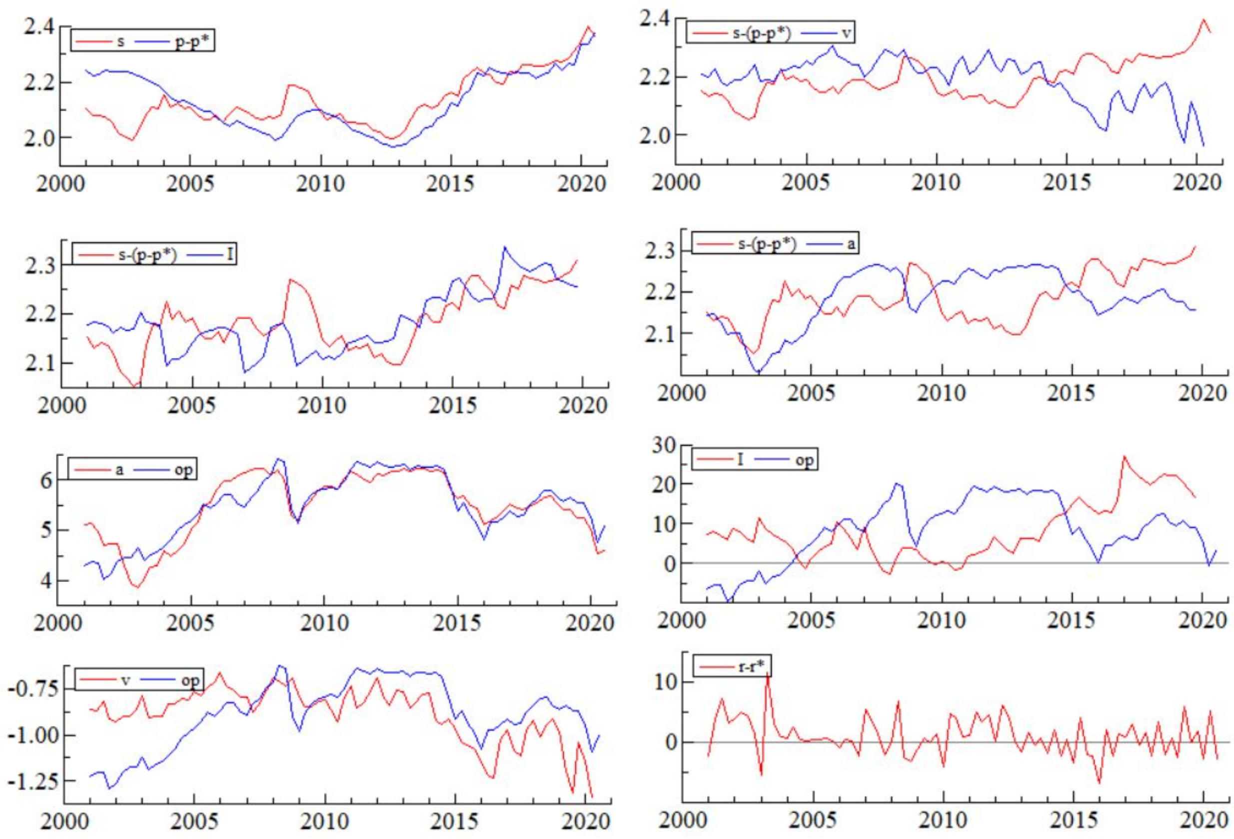
As in most oil-exporting countries, there is reason to believe that the oil price is important for the exchange rate. Higher oil prices and revenues can contribute to real appreciation pressure (and vice versa) which (in part) translates into the nominal exchange rate, see for example Benedictow et al. (2013). Akram and Mumtaz (2016) find an increasing correlation between oil prices and nominal exchange rates in the Norwegian economy, especially since around the turn of the millennium. This must be seen in connection with the introduction of the rule for the Petroleum Fund (Government Pension Fund Global) and rising oil prices beyond the 2000s, which led to the fund rapidly increasing in size.

Figure 1 shows that the krone euro exchange rate looks fairly stable at just over NOK 8 for large parts of the estimation period, at least until 2014 when it began to weaken considerably, partly as a result of sharply falling oil prices.

Figure 2 depicts simple bi-variate correlation patterns between some of the most important variables in our information set, where the variables have been scaled to match by means and ranges. First, panel a indicates a strong relationship between the logarithm of the nominal nok-euro exchange rate, s, and the nominal price differential between Norway and the euro area, $p - p^*$, a relationship that seems to be particularly pertinent from 2014 onwards when the krone started to weaken in earnest. However, looking at panel b, which depicts the real exchange rate, q, together with the value share of oil and gas in total exports, v, this relationship does not seem to be one-to-one in the sense of generating a stationary real exchange rate. Thus, this opens up for the possibility of other variables informing the real exchange rate in the long run, a key candidate in that respect - and as born out by the same panel- being the above mentioned value share of oil and gas exports. However, the two subsequent panels of the same figure, panel c and panel d, introduces two other candidates in this respect, respectively, an energy-specific share price index, a, and the development in the accumulated net capital flow as a share of GDP between EMU and Norway, I. Both variables demonstrate some capacity in capturing certain aspects of the non-stationary nature of the real exchange rate. Figure 2 also demonstrates the Norwegian economy's degree of oil dependence more in general as all the variables mentioned above seem to be highly connected to the US dollar price of oil, op, in one way or another. This applies not only to the value share of oil and gas in total exports, as born out by panel e, but also to the energy related share price index, (a), and the variable representing the expansion in the net capital position between Norway and the countries of the euro area. The last panel ,h, shows the real interest differential between Norway and the euro area, $r - r^*$, and clearly demonstrates its high degree of stationarity, a stylized fact that will later form the basis of the co-integration analysis.

Furthermore, our analysis is conditional on two uncertainty indices, the S&P volatility index (VIX) and a couple of world uncertainty indices from the FRED database.[3]

Figure 2: Data



Source: Norges Bank, Macrobond, Statistics Norway

[3]As non of these world uncertainty indices turned to be significantly estimated in the analysis we have in the following chosen not to comment on these, referring the interested reader to the FRED web page for more information: $https://fred.stlouisfed.org/$.

4 Econometric Analysis

We have chosen as a point of departure the error correction version of the vector autoregressive model written in reduced form. In the general case this can be given the following representation:

$$\Delta X_t = \Pi Y_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \Phi D_t + \epsilon_t, \quad (6)$$

where X_t represents a $p \times 1$ vector of endogenous variables, $Y_t = (X_t', Z_t')'$ a $(p+q) \times 1$, vector where Z_t is a $q \times 1$ vector of exogenous variables and k the order of the VAR. D_t is a vector composed of contemporaneous and lagged differences of the model exogenous variables, Z_t, deterministic variables like dummies, a trend and a constant. ϵ_t is a Gaussian white noise term with covariance matrix Ω. The rank of the Π matrix gives us information about the cointegration properties of the model, and in the case the rank, r, is less than full, i.e. less than p, the Π matrix may be written as the product of a $p \times r$ matrix, α, and a $(p+q) \times r$ matrix, β, with full column rank equal to $r < p$. The level term in equation (6) can then be written as $\Pi Y_{t-1} = \alpha\beta' Y_{t-1}$ where $\beta' Y_{t-1}$ represents the r cointegrating linear combinations of the variables while the α matrix has got the interpretation of a coefficient matrix with error correction coefficients or loadings. The cointegration analysis in connection with the preparation of the "structural" equilibrium correction model of the Norwegian euro krone exchange rate[4] is based on a five dimensional conditional VAR of order 3, for the simultaneous determination of, respectively, the real exchange rate, q,[5] the real interest rate differential vis-à-vis the euro area, $\tilde{r}$ = r-r^* , an equity index covering the Norwegian market for oil services and machinery, a, the ratio of the value of oil and gas exports to the total

[4]To distinguish the type of model developed in this paper from a reduced form model we will use the term structural thorough, being fully aware that a more proper term in this context would perhaps have been behavioural or relational, given the lack of a fully structural underpinning of its rationale.

[5]We have chosen to base the cointegration analysis on the presumption of a full pass-through of relative price changes to the nominal exchange rate in the long run. This restriction is given broad support based on preliminary analyses where such a restriction was not imposed a priori, and is later dissolved when we proceed with the dynamic design of our contingent model for the krone-euro exchange rate. This has been done to keep the system's dimension and complexity down to a manageable level.

value of Norwegian exports, v, and the net stock of accumulated foreign capital movements between the EMU and Norway, I. In addition to a constant and some dummies for structural breaks the model is contingent on the oil price in US dollar, op, and a volatility index[6] being exogenous processes.

4.1 Long-run Analysis

Starting out with the reduced form analysis and the identification of the model's long-run structure, the results, as reproduced in Table 1 and Table 2, give unambiguous support for the existence of no less than five cointegrating vectors. Without going into any great detail the overidentified structure in the upper part of Table 2 associates a long-run cointegration relationship with each of the individual variables treated as endogenous in our five dimensional VAR. In particular, the first two cointegrating relationships pertain to, respectively, the real krone euro exchange rate and the real interest rate differential, the last of these implying that the variable constitutes a stationary relationship in itself. The three other relationships can be said to intercept the degree of dependency on oil of the Norwegian economy, as measured by respectively two different kinds of investor behaviour and the relative contribution of oil and gas exports to the total value of exports in Norway. As for the long-term krone-euro exchange rate equation, it provides support for several hypotheses that could potentially help shed light on recent developments. To a varying degree all of these can be said to be related to the behavior of future-oriented investors both envisaging the possibility of a green shift and prospects for international tensions and unrest. First, according to the first long-run relationship, the real exchange rate will weaken as oil and gas make up a smaller share of the Norwegian economy, a one per cent fall in their export share estimated to lead to a long-term weakening of the krone-euro exchange rate of approximately 0.23 per cent.

Furthermore, a one per cent fall in the industry-specific share price index of the oil sector

[6] Including a volatility index based on the US S&P stock market index, VIX.

Table 1: Johansen's test for the number of cointegrating vectors

VAR order:3, unrestricted constant, ordinary and seasonal dummies and exogenous variables. Estimation period: 2001 Q1 to 2019 Q4.

Trace Eigenvalue test:		
H_0	H_1	Values of test statistics
r=0	r $\leq$ 3	130.22[0.000]**
r $\leq$ 1	r $\leq$ 5	106.16[0.000]**
r $\leq$ 2	r $\leq$ 5	62.224[0.001]**
r $\leq$ 3	r $\leq$ 5	38.855[0.003]**
r $\leq$ 4	r $\leq$ 5	19.609[0.010]*

1) The values in parentheses are the respective tests' significance probabilities.
2) * and ** signify that the test is significant at a level of 5 and 1%, respectively.

will also lead to a real exchange rate depreciation, though the effect is estimated to be rather weak.

However, combined with a potential outflow of capital as intercepted by the variable capturing the accumulating stock of net foreign direct capital movements between Norway and the countries in the euro area and a S&P volatility index denoted VIX, it is no denying that these effects taken together would contribute to mount a persistent negative long-term pressure on the krone-euro exchange rate in the absence of countervailing forces.[7]

Moreover, the F-test for the number of over-identifying restrictions in Table 2, shows that the identified system, consisting of five cointegrating relationships, constitutes a valid

[7]The VAR of order 3 amounts to a valid reduction of a data congruent VAR of a higher order. With the exception of a normality break in the foreign direct investment equation due to a structural break in the first quarter of 2017, which we deliberately have chosen not to allow for, none of the individual equation hypotheses for normality or absence of autocorrelation and heteroscedasticity are in this model rejected at conventional significance levels. The system diagnostics of the VAR(3) model, given below, where the figures in parentheses are the respective tests' significance probabilities, do neither give rise to any concern.

Vector AR 1-5 test:	$F(125, 98)$	=	1.0771[0.3519]
Vector Normality test:	$\chi^2(10)$	=	15.4444[0.1167]
Vector Heterosc. test:	$F(260, 95)$	=	0.96899[0.5840]

The F-test statistic for the elimination of all lags greater than 3 from the model is F(63,84)=1.2966[0.1325], where the figure in parenthesis is the test's significance probability. Nor where any of the partial reductions of the model reduction scheme - from a VAR of order 6 down to a VAR of order 3 (and even 2) - rejected.

restriction of a corresponding exactly identified long-run structure.

Table 2: The identified system of cointegrating linear combinations given r=5, the loading matrix and a test of overidentifying restrictions[8]

The identified long-run structure given 5 cointegrating relations:

$$\hat{\beta}'\begin{pmatrix} Y_t \\ X_t \end{pmatrix} = \begin{pmatrix} q_t + \underset{(0.013)}{0.023}\, a_t + \underset{(0.063)}{0.227}\, v_t - 0.004\,\{I+VIX\}_t \\ \{r-r^*\}_t \\ \{v-op\}_t \\ a_t + \underset{(0.014)}{0.043}\, VIX_t - op_t \\ I_t + \underset{(2.47)}{81.645}\, op_t \end{pmatrix}$$

Error correction coefficient matrix:

$$\begin{matrix} \Delta q \\ \Delta \tilde{r} \\ \Delta v : \\ \Delta a \\ \Delta I \end{matrix} \begin{pmatrix} \hat{\alpha}_{11} & \hat{\alpha}_{12} & \hat{\alpha}_{13} & \hat{\alpha}_{14} & \hat{\alpha}_{15} \\ \hat{\alpha}_{21} & \hat{\alpha}_{22} & \hat{\alpha}_{23} & \hat{\alpha}_{24} & \hat{\alpha}_{24} \\ \hat{\alpha}_{31} & \hat{\alpha}_{32} & \hat{\alpha}_{33} & \hat{\alpha}_{34} & \hat{\alpha}_{35} \\ \hat{\alpha}_{41} & \hat{\alpha}_{42} & \hat{\alpha}_{43} & \hat{\alpha}_{44} & \hat{\alpha}_{45} \\ \hat{\alpha}_{51} & \hat{\alpha}_{52} & \hat{\alpha}_{53} & \hat{\alpha}_{54} & \hat{\alpha}_{55} \end{pmatrix} = \begin{pmatrix} -0.15 & -0.002 & 0.05 & -0.18 & 0.0008 \\ (0.06) & (0.001) & (0.03) & (0.007) & (0.0004) \\ -22.492 & -0.96 & 3.92 & 1.17 & 0.05 \\ (7.52) & (0.16) & (3.38) & 0.85 & 0.04 \\ 0.51 & 0.000005 & 0.08 & -0.07 & 0.0006 \\ (0.30) & (0.006) & (0.136) & (0.034) & (0.0017) \\ -1.89 & -0.05 & -5.86 & -0.59 & -0.06 \\ (7.03) & (0.15) & (3.16) & (0.8) & (0.04) \\ -0.23 & 0.007 & -0.41 & 0.0015 & -0.005 \\ (0.20) & (0.004) & (0.09) & (0.023) & (0.001) \end{pmatrix}$$

LR-test of overidentifying restrictions: $\chi^2(11) = 17.898$ [0.0840]

* and ** signify that the test is significant to a level of respectively 5 and 1 %

8

[8] The value in parenthesis under each coefficient is the estimated coefficient's standard error while the value in parenthesis following the test of over-identifying restrictions refers to the test's significance probability. Note that the test of over-identifying restrictions refers to the restrictions one will have to

4.2 Dynamic design

Given the long-run structure in the upper part of Table 2 the next step is to specify a general unrestricted conditional "structural" dynamic model (GUM) of the krone-euro nominal exchange rate involving in principle all the cointegrating relationships and the variables in the VAR and to reduce it down to a parsimonious representation by resorting to a combination of automatic and manual hands-on model reduction schemes.[9]

The structural form or SEM representation of the reduced form is obtained by multiplying (6) by a contemporary response matrix B. This results in the simultaneous equation system:

$$B\Delta X_t = B\Pi Y_{t-1} + \sum_{i=1}^{k-1} B\Gamma_i \Delta X_{t-i} + B\Phi D_t + B\epsilon_t,$$

or after having set $B\Pi = B\alpha\beta' = \alpha^*\beta'$, $B\Gamma_i = \Gamma_i^*$, $B\Phi = \Phi^*$ and $B\epsilon_t = u_t$

$$B\Delta X_t = \alpha^*\beta' Y_{t-1} + \sum_{i=1}^{k-1} \Gamma_i^* \Delta X_{t-i} + \Phi^* D_t + u_t \tag{7}$$

Given the five previously estimated long-run relationships and the fact that the cointegration analysis was undertaken on a VAR(3), (7) will imply the following conditional structural GUM representation for the nominal krone-euro exchange rate, s_t:

$$\Delta s_t = \alpha_s^*\beta' Y_{t-1} + \sum_{i=1}^{3-1} \gamma_{s,i}^* \Delta s_{t-i} + \sum_{i=0}^{3-1} \Gamma_{s,i}^* \Delta \tilde{X}_{t-i} + \Phi_s^* D_t + u_t \tag{8}$$

impose on an exactly identified structure to arrive at the final structure given by the system's overidentified right hand side. The variables q_t, v_t, $\tilde{\mathrm{r}} = (r - r^*)_t$, a_t, I_t and op_t stand for, respectively, the real exchange rate, the ratio of the value of oil and gas to the value of total exports, the real interest rate differential, an equity index pertaining to the Norwegian oil industry, the accumulated net flow of direct capital as a share of GDP between EMU and Norway, the oil price in US dollars, lower case letters denoting logarithmic transformations of the original variables referred to in the text. ${r^i}_t$, where the index i is either a blank or a star, stands for the two real interest rates, neither of which has been transformed logarithmically. The vector to the left of the loading matrix and before the colon refers to the individual equations in the corresponding reduced form VECM representation. As usual the Δ symbol stands for the first difference operator.

[9] In reducing the GUM we have occasionally resorted to utilizing the Autometrics modul in Doornik (2015).

where a subscript s stands for the rows pertaining to the exchange rate in 7 and $\tilde{X}$ representing the vector of all the endogenous variables in 6 that remain after having removed the real exchange rate, substituted the real interest rate differential with the nominal one and relegated lagged and contemporaneous first differences of the relative price ratio to the container of exogenous variables and deterministic terms, the D_t variable vector.

Reducing the model down to a parsimonious representation taking into account the possibility of a structural change in the parameters governing the dynamic responses of the variables meant to intercept the effects of investor behaviour and market dynamics, respectively, the industry-specific oil and gas equity index and the variable capturing the net FDI movements between the EMU and Norway, we end up with the following representation:

$$
\begin{aligned}
\Delta s_t = & \underset{(0.005)}{0.008} + \underset{(0.1)}{0.18} \Delta s_{t-1} \underset{(0.08)}{+0.40} \Delta s_{t-2} - \underset{(0.014)}{0.095} \Delta op_t + \underset{(0.017)}{0.075} \Delta op_{t-1} \\
& - \underset{(0.008)}{0.06} \Delta(i-i^*)_t + \underset{(0.009)}{0.04} \Delta(i-i^*)_{t-1} + \underset{(0.001)}{0.0034} \Delta(I_{t-1} * SD161) \\
& - \underset{(0.035)}{0.09} \Delta(a_{t-1} * SD161) + \underset{(0.00035)}{0.0008} \Delta \mathrm{VIX}_t + \underset{(0.004)}{0.009} \Delta Seas_{t-3} \\
& - \underset{(0.036)}{0.06} ((s_{t-1} + p^*_{t-1} - p_{t-1}) + 0.023 a_{t-1} - 0.004 I_{t-1} + 0.23 v_{t-1} - 0.004 \mathrm{VIX}_{t-1}) \\
& - \underset{(0.00056)}{0.0009} ((i_{t-1} - \Delta p_{t-1}) - (i^*_{t-1} - \Delta p^*_{t-1})) \\
& + \underset{(0.014)}{0.031} ID061 + \underset{(0.014)}{0.045} ID133 + \epsilon^s_t
\end{aligned}
\tag{9}
$$

Vector AR 1-5 test:	$F(5, 56)$	=	0.98974[0.4323]
ARCH 1-4 test:	$F(4, 68)$	=	2.1078[0.0893]
Vector Normality test:	$\chi^2(10)$	=	3.5554[0.1690]
Vector Heterosc. test:	$F(23, 50)$	=	0.82385[0.6876]
RESET23 test:	$F(2, 59)$	=	0.27944[0.7572]

In 9 $IDYYQ$ and $SDYYQ$ stand for, respectively, an impulse dummy that is equal to one in quarter Q of year 20YY, and a step-dummy equal to one from the Q'th quarter of 20YY and throughout the whole sample period, YY in both cases denoting a combination of two individual numbers running from 0 to 9. The step-dummy SD161 thus implies that we operate with a structural break in the dynamic responses to, respectively, a change in the oil specific equity price index and a change in the accumulated stock of net direct capital movements between the EMU and Norway in the 1'st quarter of 2016, a one-percent increase in the oil industry-specific equity index in this context estimated to lead to a strengthening of the nominal krone-euro exchange rate of just short of 0,1 per cent in the quarter succeeding the change. Otherwise, we see that both the first and the second cointegrating vector in the long-run structure of Table 2 enters significantly in equation 9, implying that a one percentage point increase in the real interest rate differential is estimated to lead to a relatively small but significant real appreciation of approximately 0,1 per cent in the long run. Compared to an estimated contemporaneous effect of about -0,25 per cent, this implies overshooting in the wake of ceteris paribus changes to the nominal interest rate.[10]

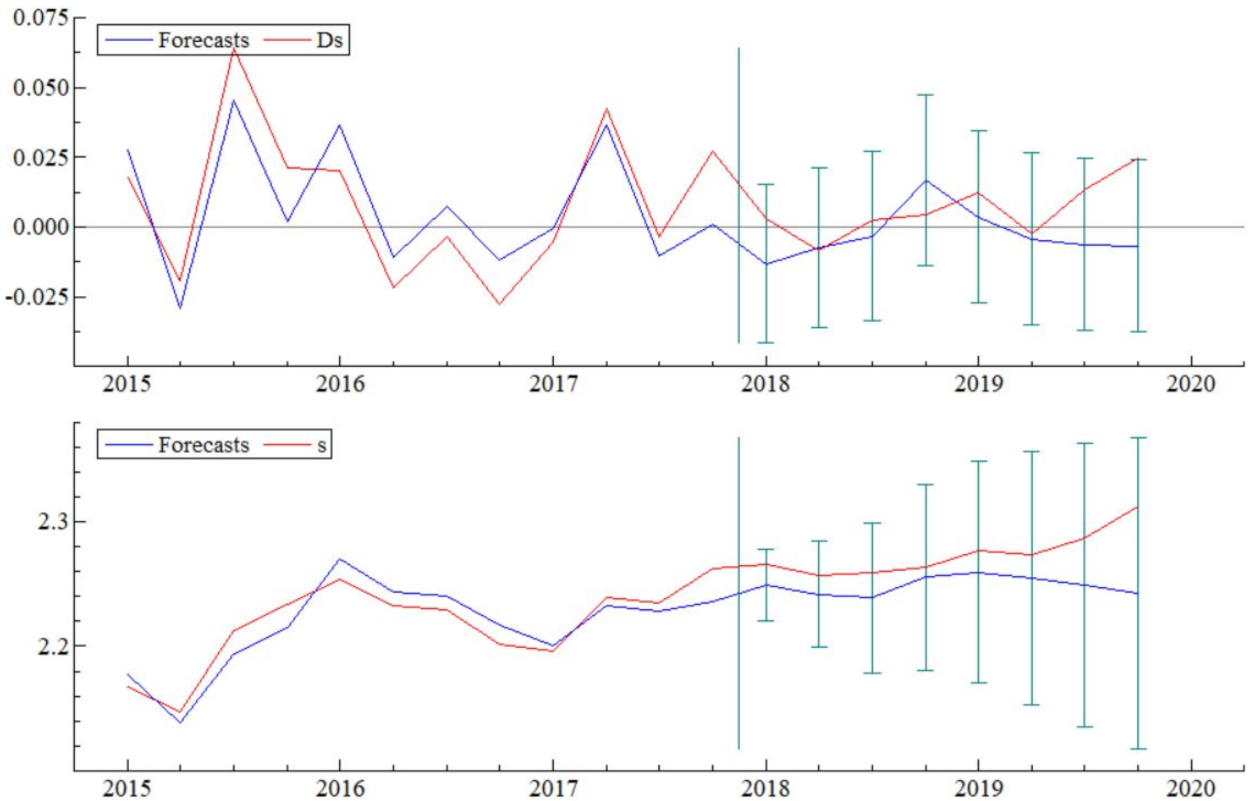
In addition to the effect that comes via the value-share of oil and gas exports in the long-term exchange rate relationship and which, if the relationship between these two quantities is based on the third cointegrating relationship in Table 2, would imply a long-term real appreciation of the krone euro exchange rate of approximately 0.23 per cent in the wake of a one percent increase in the US dollar price of oil, the oil price has according to 9 clear

[10]Note that the interest- and inflation rates in equation 9 are measured as annualized rates in percent. When discussing the effects of a quarterly change to these variables of a one percentage point, we therefore have to multiply the coefficient by 4 or to refer to interest rate changes of a quarter of a percentage point.

dynamic effects. A one-percent increase in the oil price is in this context estimated to lead to an instantaneous appreciation of about 0,1 percent, and while the effect is somewhat reversed the next quarter, the effect builds up gradually to its long-run effect captured by the effect that appears via the above mentioned increase in the export value share of oil and gas.

As far as the statistical properties of the contingent equation in 9 is concerned, the outcomes of the statistical tests quoted below the equation, all suggest that the model is a good candidate for the entitlement of being considered as a congruent representation of an underlying DGP. Recursive tests demonstrate, moreover, that the model and its parameters are stable.[11]

Figure 3: Dynamic Forecasts



Estimation period 2001q1 to 2017q4: 8 periods ahead forecasts

[11]See Figure 4 and Figure 5 in the Appendix.

Moreover, simulating the model dynamically from 2008 onwards by linking lagged values of the endogenous variable to the previously predicted ones, indicates that the in-sample prediction properties are fairly good, in the sense that there is no tendency for the simulated values to derail (see Figure 6 in the Appendix).

However, as born out by Figure 3 retaining 8 observations for the possibility of making ex ante forecasts and using the model to dynamically forecast eight periods ahead, does reveal a potential problem in the second half of 2019. Given the COVID-19 outbreak in the first part of 2020 and the fact that the krone as a result has continued to weaken, there is much to indicate that this problem will not necessarily diminish after the turn of the year 2019/2020.

5 Summary/conclusion

The aim of this article is to explain why the NOK has been so weak over the last 4-5 years. The theoretical starting point has been deviation from UIP, as expressed by the existence of a potential risk premium.

The analysis is based on the assumption that the risk premium is captured by a number of variables such as the oil price, the export value of oil and gas as a share of the total value of exports, the accumulated stock of foreign direct investments as a share of GDP between the EMU and Norway (net), an oil industry-specific equity index and a volatility index related to the US $S\&P$ stock market index.

We find convincing evidence that there is a risk premium in the process driving the krone-euro exchange rate. Accidentally this turn out to be a finding that renders possible the provision of support for several hypotheses that can potentially help to shed light on recent developments. To varying degrees, all of these can be said to be related to the behavior of future-oriented investors who envisage the possibility of everything from a potential green shift, a weak or weakening international economic business cycle and prospects related to the potential of a further build-up in international and geopolitical tensions, indeed even unrest.

Hence, the krone exchange rate does not depend on fundamentals only, like relative prices and the real interest rate differential vis-à-vis the euro area, but also on a number of variables that may be taken to represent a foreign exchange risk premium. In the model developed herein, the real exchange rate is estimated to weaken as oil and gas make up a smaller share of the Norwegian economy, a one per cent fall in their export share estimated to lead to a weakening of the krone-euro exchange rate of approximately 0.23 per cent in the long run. Furthermore, a one per cent fall in the industry-specific share price index of the oil sector is also estimated to lead to a real exchange rate depreciation in the long run, though the effect is rather weak. However, combined with a potential outflow of capital as intercepted by the variable capturing the accumulation of foreign net direct capital movements between Norway and the countries in the euro area and a rising S&P volatility index, there is little doubt that these effects taken together under certain conditions would contribute to mount a persistent negative long-term pressure on the krone-euro exchange rate in the absence of countervailing forces.

In the short term, the krone exchange rate is to a large degree driven by changes to the US dollar oil price and interest rates, although eigen dynamics and some additional variables related to the risk premium are found to be significant as well. However, with the exception of the $S\&P$ volatility index and in contrast to what applies to the long term, the effect of these additional variables primarily appears to be valid only from 2016 onwards.We do also identify a seasonal effect related to the last quarter of each year, as there is a general tendency for less krone trading at Christmas due to holidays.

All in all the model developed in this paper gives support to the existence of a foreign exchange risk premium in the process driving the krone-euro exchange rate. Consequently, a part of the depreciation of the NOK exchange rate over the last four to five years appears to stem from uncertainty related to oil and its future role for the Norwegian economy as well as uncertainty related to the international course of events in general. Moreover, the model surpasses a panoply of tests for non-spherical noise, is stable and does seem to fulfill most requirements for being reckoned as a congruent representation of an underlying data generating process. The dynamic forecasts do, however, reveal a potential problem in the second half of 2019. Given the COVID-19 outbreak in the first part of 2020 and the fact that the krone as a result has continued to weaken, there is little to suggest that this problem necessarily will disappear in the near future.

...

References

Akram, Q. F. (2006). Ppp in the medium run: The case of norway. *Journal of Macroeconomics*, 28(4):700–719.

Akram, Q. F. and Mumtaz, H. (2016). The role of oil prices and monetary policy in the norwegian economy since the 1980s. *Norges Bank Working Paper.*

Benedictow, A., Fjærtoft, D., and Løfsnæs, O. (2013). Oil dependency of the russian economy: An econometric analysis. *Economic Modelling*, 32:400–428.

Bjørnland, H. C. and Hungnes, H. (2006). The importance of interest rates for forecasting the exchange rate. *Journal of forecasting*, 25(3):209–221.

Bjørnstad, R. and Jansen, E. S. (2007). The nok/euro exhange rate after inflation targeting: The interest rate rules. Technical report, Discussion Papers.

Doornik, J. A. (2015). *An Object-Oriented Matrix Programming Language Ox 7,20.* Timberlake.

Fair, R. C. et al. (2009). *Estimating how the macroeconomy works.* Harvard University Press.

Juselius, K. et al. (1992). Testing structural hypotheses in a multivariate cointegration analysis of the ppp and the uip for uk. *Journal of econometrics*, 53(1-3):211–244.

Juselius, K. and MacDonald, R. (2006). *International parity relationships and a nonstationary real exchange rate. Germany versus the US in the post Bretton Woods period.* Nova Science Publishers.

Naug, B. (2003). Faktorer bak utviklingen i kronekursen–en empirisk analyse. *Hvilke faktorer kan forklare utviklingen i valutakursen.*

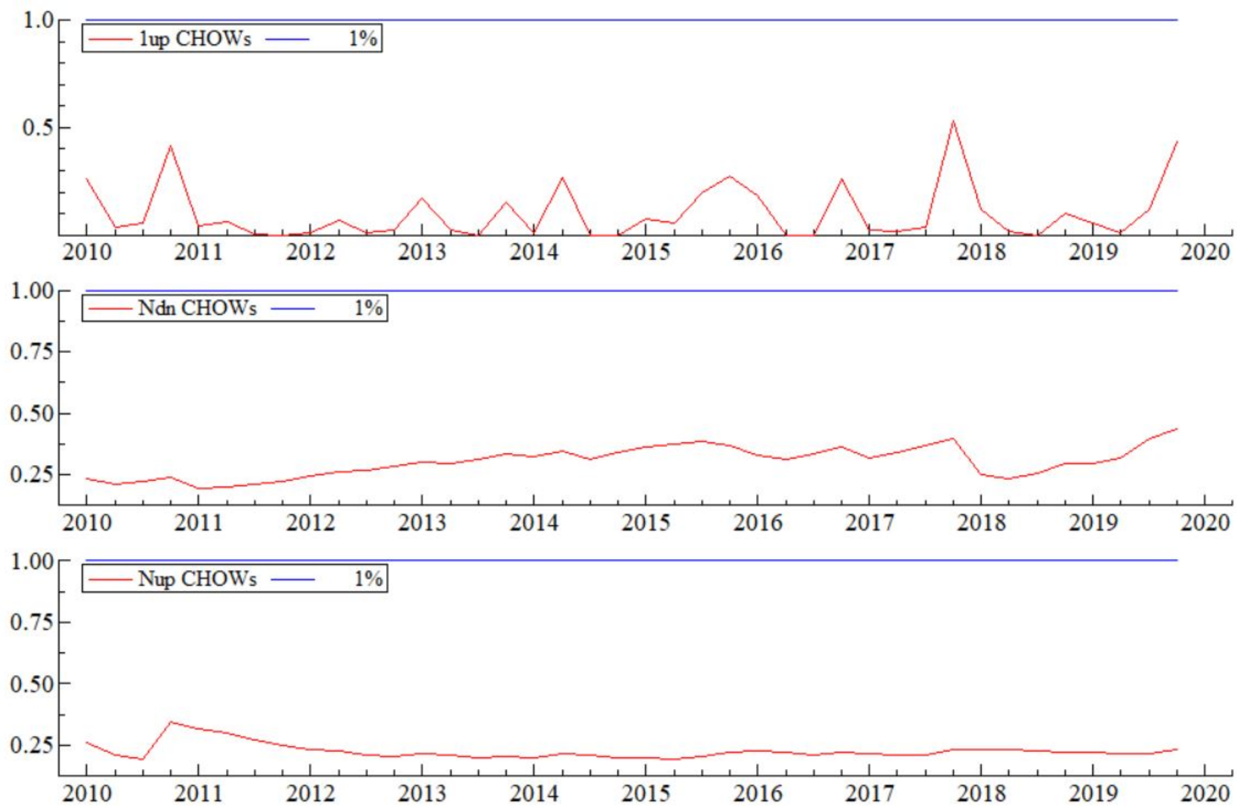
Rashid, A. et al. (2009). Testing the modified-combined ppp and uip hypothesis in south asian economies. *Applied Econometrics and International Development*, 9(1):199–218.

Sarno, L. (2005). Towards a solution to the puzzles in exchange rate economics: Where do we stand? *Canadian Journal of Economics/Revue canadienne d'économique*, 38(3):673–708.

Sarno, L. and Taylor, M. P. (2002). Purchasing power parity and the real exchange rate. *IMF staff papers*, 49(1):65–105.

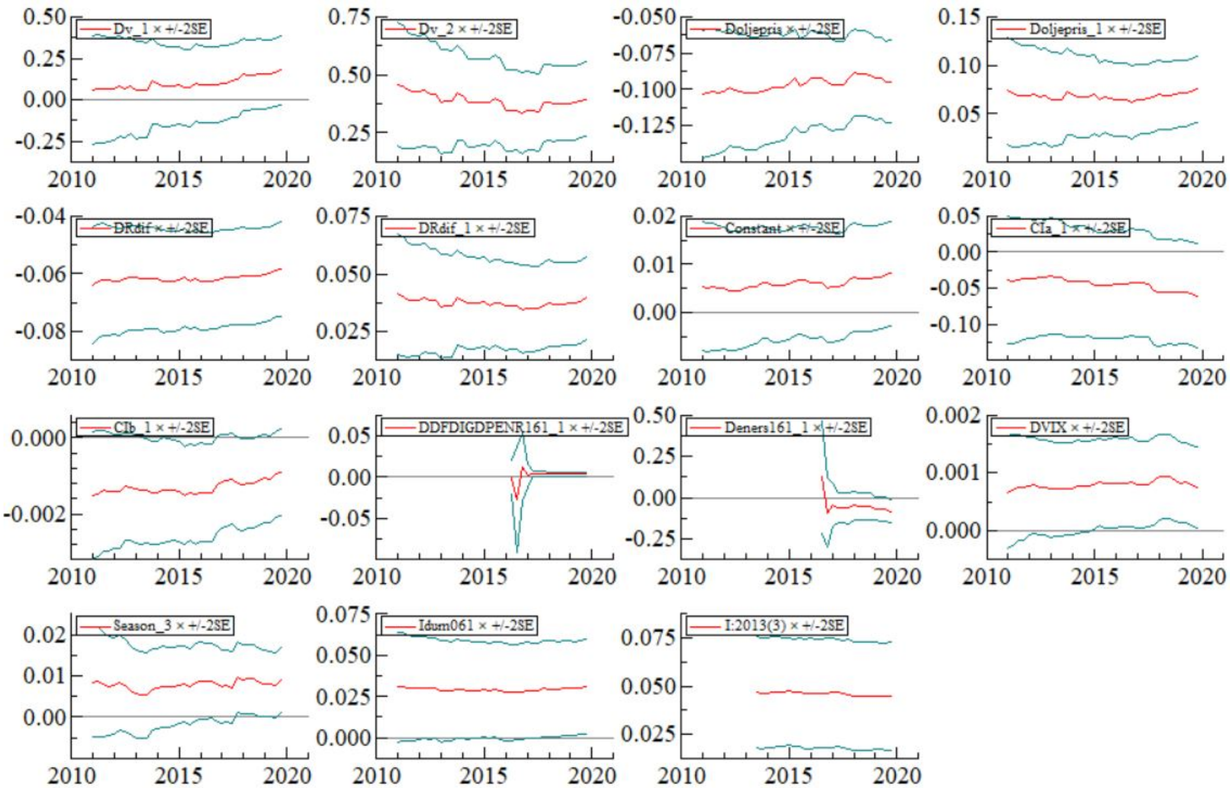
6 Appendix

Figure 4: Stability Tests



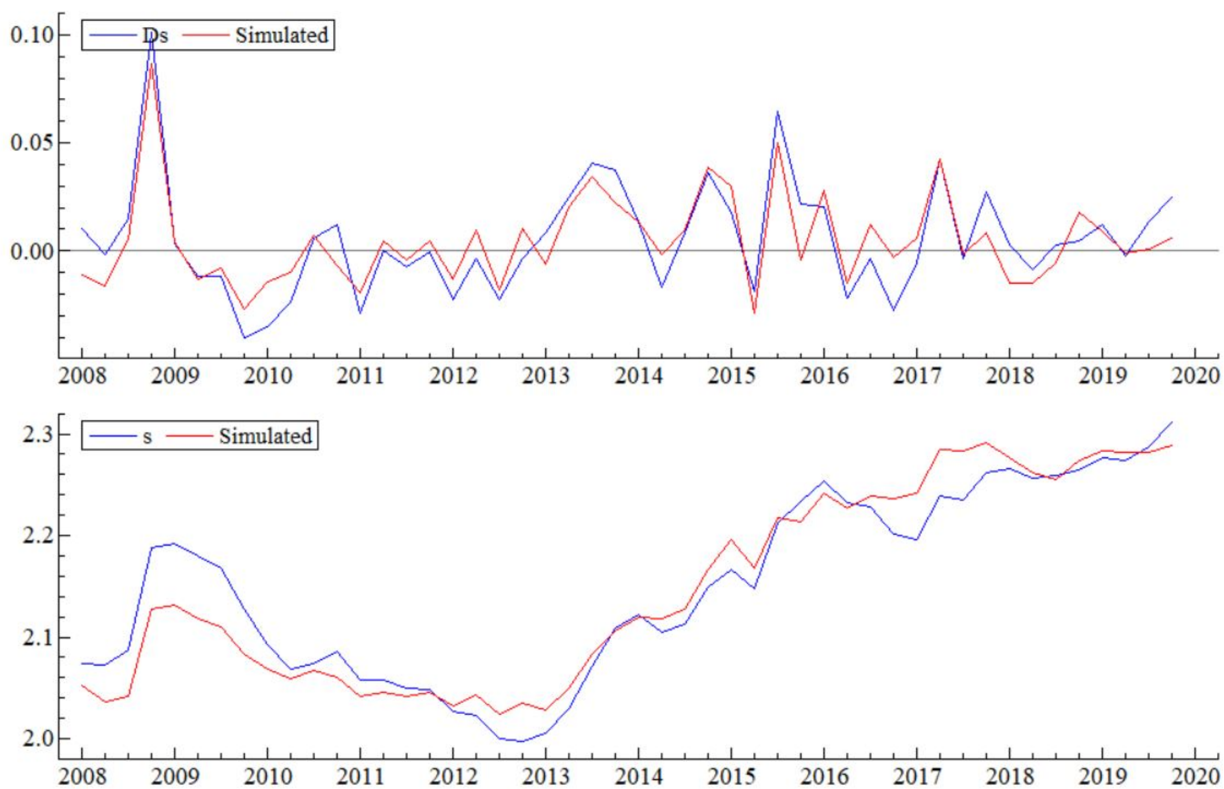
xxxxxxx

Figure 5: Recursively estimated parameters



xxxxxx

Figure 6: Dynamic Simulations



xxxxxx