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**Thesis Title:**

## "Is the Norwegian Krone exchange rate a commodity currency?"

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## Abstract

This study examines the validity of the view that Norway Krone is a commodity currency. Norway has a primary commodity (oil) that constitutes the majority of exports. We describe models where Norwegian krone (NOK) to US dollar (US$) exchange rate is measured against the Brent oil price.

We found that exchange rates, nominal and real are cointegrated with the Brent oil price. The long-run relationship seems to be robust. Moreover, the fact that the elasticity of Brent oil price is statistically significant confirms that Norwegian krone is a commodity currency or a petrocurrency according to literature studies. A Vector Error Correction Model analysis also identifies that oil price will affect the exchange rate. Through the latter, we can now see how VECM ties short-run dynamics to long-run relations via the error correction term.

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# 1. Introduction

Norway, with its population of 4.6 million on the northern flank of Europe, is today one of the most wealthy nations in the world, both measured as GDP per capita and in capital stock. On the United Nation Human Development Index, Norway has been among the three top countries for several years and in some years the very top nation.

The Norwegian economy is a prosperous bastion of welfare capitalism, featuring a combination of free market activity and government intervention. The government controls key areas, such as the vital petroleum sector, through large scale state-majority-owned enterprises. The country is richly endowed with natural resources - petroleum, hydropower, fish, forests, and minerals - and is highly dependent on the petroleum sector, which accounts for the largest portion of export revenue and about 20% of government revenue. Norway is the world's second-largest gas exporter; and sixth largest oil exporter, making one of its largest offshore oil finds in 2011 (CIA Factbook, 2012).

Huge stocks of natural resources combined with a skilled labor force and the adoption of new technology made Norway a prosperous country during the nineteenth and twentieth century.

## 1.1 Economic history of Norway

The Norwegian economy was traditionally based on local farming communities combined with other types of industry, basically fishing, hunting, wood and timber along with a domestic and international-trading merchant fleet. Foreign trade of fish and timber had already been important for the Norwegian economy for centuries.

After the war the challenge was to reconstruct the economy and re-establish political and economic order. The Labor Party, in office from 1935, grabbed the opportunity to establish a strict social democratic rule, with a growing public sector and widespread centralized economic planning. Norway first declined the U.S. proposition of financial aid after the world. However, due to lack of hard currencies they accepted the Marshall aid program.

As part of the reconstruction efforts Norway joined the Bretton Woods system, GATT, the IMF and the World Bank. Norway also chose to become member of NATO and the United Nations. In 1958 the country also joined the European Free Trade Area (EFTA). The same year Norway made the krone convertible to the U.S. dollar, as many other western countries did with their currencies. The years from 1950 to 1973 are often called the golden era of the Norwegian economy. GDP per capita showed an annual growth rate of 3.3 percent. Foreign trade stepped up even more, unemployment barely existed and the inflation rate was stable. This has often been explained by the large public sector and good economic planning.

After the Bretton Woods system fell apart (between August 1971 and March 1973) and the oil price shock in autumn 1973, most developed economies went into a period of prolonged recession and slow growth. In 1969 Philips Petroleum discovered petroleum resources at the Ekofisk field, which was defined as part of the Norwegian continental shelf. This enabled Norway to run a countercyclical financial policy during the stagflation period in the 1970s.

Norway lost significant competitive power, and large-scale deindustrialization took place, despite efforts to save manufacturing industry. Another reason for deindustrialization was the huge growth in the profitable petroleum sector. Persistently high oil prices from the autumn 1973 to the end of 1985 pushed labor costs upward, through spillover effects from high wages in the petroleum sector. High labor costs made the Norwegian foreign sector less competitive. Due to the petroleum sector, however, Norway experienced high growth rates in all the three last decades of the twentieth century, bringing Norway to the top of the world GDP per capita list at the dawn of the new millennium. Nevertheless, Norway had economic problems both in the eighties and in the nineties.

In 1981 a conservative government replaced Labor. Norway had already joined the international wave of credit liberalization, and the new government gave fuel to this policy. In consequence, a substantial credit boom was created in the early 1980s, and continued to the late spring of 1986. As a result, Norway had monetary expansion and an artificial boom, which created an overheated economy. When oil prices fell dramatically from December 1985 onwards, the trade surplus was suddenly turned to a huge deficit.

In the summer of 1990 the Norwegian krone was officially pegged to the ECU. When the international wave of currency speculation reached Norway during autumn 1992 the central bank finally had to suspend the fixed exchange rate and later devaluate. In consequence of these years of monetary expansion and thereafter contraction, most western countries experienced financial crises. It was relatively hard in Norway. Prices of dwellings slid, consumers couldn't pay their bills, and bankruptcies and unemployment reached new heights. The state took over most of the larger commercial banks to avoid a total financial collapse.

After the suspension of the ECU and the following devaluation, Norway had growth until 1998, due to optimism, an international boom and high prices of petroleum. At the same time petroleum prices fell rapidly, due to internal problems among the OPEC countries. Hence, the krone depreciated. The fixed exchange rate policy had to be abandoned and the government adopted inflation targeting. Along with changes in monetary policy, the center coalition government was also able to monitor a tighter fiscal policy. At the same time interest rates were high. As result, Norway escaped the overheating process of 1993-1997 without any devastating effects. Today the country has a strong and sound economy (Grytten, 2010).

## 1.2 Monetary Policy

According to economic theory, monetary policy that is implemented by the central bank has a strong interaction with exchange rates. Since the collapse of the Bretton Woods agreement, Norway has until 2001 pursued different exchange rate policies, where the task of maintaining stable exchange rates against a basket of currencies has been at the core. In 2001, however Norway formalised an inflation targeting regime. The characteristics of the different regimes can be summarised as the following:

-1972-1977: After the collapse of the Bretton Woods agreement Norway took part in the Western European “Snake”, which implied stabilizing the different currencies to each other.

- 1978-1990: Norway stabilized the kroner against a basket of currencies, where the weight reflected how much trade Norway had with the different countries. During this period, the Norwegian krone was devaluated a couple of times, most importantly in May 1986 when it was devaluated 12 per cent.

-1990-1992: Norwegian krone was stabilized against the European ECU.

-1993-2001: Due to several speculative attacks, by the end of 1992, the Norwegian government had to let the Norwegian krone float. The floating period was only intended to be temporary. When it turned out to be difficult to return to a normal fixed exchange rate system, Norway formalized the floating regime in May 1994. The Norwegian krone came under appreciation pressure by the end of 1996, and Norges Bank abandoned its attempt to stabilize the krone by intervening in the exchange market in January 1997. From the end of 1997 until August 1998, the Norwegian krone depreciated significantly, leading Norges Bank to increase its interest rates by 4.5 percentage points in that period.

- 2001 to present: Norges Bank adopted an inflation target instead of an exchange rate target. However, this change is not interpreted as a significant change in the monetary policy framework for Norway, since Norges Bank also before 2001 considered low inflation as an aim to stabilize the exchange rate (Bjørnland and Hungnes, 2005).

The long term role of monetary policy of Norway is to provide the economy with a nominal anchor. In the short and medium term monetary policy shall balance the need for low and stable inflation against the outlook for production and employment. The operational target for the implementation of monetary policy is defined as an annual increase in consumer prices of close to 2.5 per cent over time. (Royal Ministry of Finance, 2012)

In an open economy, the exchange rate channel is one of several channels through which monetary policy affects the economy. The extent to which the exchange rate appreciates as a result of an increase in key interest rates depends on several factors outside the control of the central bank. The potency of the exchange rate channel will therefore vary over time. The exchange rate will often function as an automatic stabiliser. In periods with high activity in the economy – or when there are expectations of high activity – the exchange rate may appreciate, even if the key interest rates remain unchanged. Similarly, the exchange rate may depreciate when activity is too low.

Moreover, competitiveness is important to activity in business and industry. When Norges Bank prepares the inflation outlook, it takes into account the exchange rate channel and the effects of the exchange rate on domestic activity and inflation. Thus the exchange rate is of significance to the setting of interest rates. When setting the key policy rate, Norges Bank takes also into account the impact of the interest rate on output and employment. In addition, it gives weight to the risk that a prolonged period of low interest rates can lead to elevated risk-taking and excessive debt accumulation in the household and business sectors. Inflation targeting has become more flexible. The key policy rate is currently 1.5 per cent (Olsen, 2012).

Monetary policy is, however, not based on a fixed view of what constitutes the correct level for the exchange rate over time and there is of course no accepted view of what is the correct business structure in the long term. This is in accordance with the operational target of low and stable inflation and in line with inflation targeting practice in other countries ( Eitrheim and Gulbrandsen, 2003).

### 1.3 Fiscal policy

The main objective of the Norway's government's economic policy is to contribute to high employment, sustainable development, fair distribution of income and well-functioning welfare schemes. This requires sound policies with emphasis on the handling of environmental challenges, long-term management of the national wealth and the development of a strong and sustainable public sector. The government adheres to the 2001 fiscal policy guidelines, which stipulate a gradual and sustainable use of petroleum revenues in step with the assumed real return of the Government Pension Fund Global, estimated at 4 per cent (the 4 per cent path).

The purpose of this fund is to facilitate government savings to finance the rising pension expenditures and to support long term considerations in the use of petroleum income. The fund comprises the Government Pension Fund Global (GPFG) and the Government Pension Fund Norway (GPFN). The operational management of the two parts of the fund is delegated to Norges Bank and National Insurance Scheme Fund (Norwegian: Folketrygdfondet), respectively, under mandates set by the Ministry of Finance.

The guidelines allow automatic stabilisers to work fully over the business cycle, and additional fiscal measures can be spent to counter economic fluctuation. The government has over the years made ample use of this flexibility. In 2009 the use of petroleum revenues increased rapidly to mitigate the effects of the global recession on production and unemployment. In 2011 and 2012 the spending of petroleum revenues was again brought below the 4 per cent path. The fund capital is invested abroad in international equities, bonds and real estate. The fund is managed with a view to achieving the highest possible return over time, subject to a moderate level of risk. The time horizon of the fund investments is very long. The market value of the Government Pension Fund is estimated at NOK 4425 billion at the end of 2013, of which NOK 4280 billion in the global fund (GPFG) The Government now proposes a structural non-oil deficit estimated at NOK 125.3 billion, which is NOK 26.4 billion below the 4 per cent path. Within the confines of the proposed spending and an unchanged overall level of taxation, the Fiscal Budget allows for some important policy measures to strengthen key welfare provisions and to reduce social inequalities.

The main features of fiscal policy in 2013 (Royal Ministry of Finance, 2012):

• Spending of petroleum revenues, as measures by the structural non-oil budget deficit is estimated at NOK 125.3 billion in 2013. This is NOK 26.4 billion below the expected real return in the Pension Fund Global and 3.3 per cent of the capital in the Pension Fund Global.

• The real underlying growth in the expenditures from 2012 to 2013 is estimated at 2.4 per cent, of which about close to half stems from growth in old age pensions.

• Net cash flow from petroleum activities is estimated at about NOK 373 billion

• The non-oil fiscal budget deficit is estimated at NOK 123.7 billion. The deficit is financed by a transfer from the Pension Fund Global.

• The consolidated surplus on the Fiscal Budget and the Government Pension Fund, including NOK 131 billion in interest and dividends, is estimated at NOK 380 billion (equivalent to 12.7 per cent of GDP).

• Unchanged level of taxation.

### 1.4 Commodity currency

The term ‘commodity currency’ has in recent years gained increased popularity among economists and currency traders. A country is generally deemed to have a commodity currency when there exists a persistent and long-term relationship between fluctuations in its real exchange rate and movements in the real price of its commodity, or resource-based, exports (Cashin, Céspedes & Sahay, 2003). It is logical to expect that economies, for which primary commodities comprise a significant portion of total exports, will tend to have currencies that are highly dependent upon the world price of commodities they export. This feature is generally associated with developing countries which are not sufficiently industrialised to diversify their export bases beyond raw materials and are consequently heavily reliant on primary exports. For example, during the 1990s commodity exports represented 97 percent of Burundi’s total exports, 90 percent of Madagascar’s, and 88 percent of Zambia’s. Furthermore, some developing countries are significantly dependent upon one single exportable commodity. The major export good exceeded 90 percent of commodity export receipts in Dominica (bananas), Ethiopia (coffee), Mauritius (sugar), Niger (uranium), and Zambia (coffee), (Cashin, Céspedes & Sahay, 2003).

In this context, a commodity currency might be regarded as an unfavorable attribute, a characteristic indicating backwardness and under-developed industry. As countries advance and become richer, the focus of the economy tends to shift away from raw materials and towards more technologically advanced processes. However, a handful of developed economies have industrialized and advanced in many areas while maintaining the traditional importance of natural resources to the economy. The prime examples are Australia, Canada, Iceland, New Zealand and Norway (Speller, 2006).

The most significant, recent works on defining the commodity currencies are those of Cashin, Céspedes & Sahay (2003) and Chen & Rogoff (2003), which identify these five nations as the industrialised commodity currencies. As the term commodity is not consistently interpreted in economic literature, it is useful to employ the framework of the Standard International Trade Classifications (SITC) formulated by the United Nations Statistics Division, in order to define what comprises a primary commodity. The SITC divides all internationally traded merchandise into nine broad categories, composed of various sub-categories. Classification is based primarily on the type of material, the level of processing undertaken and the technology used in production (United Nations Commodity Trade Statistics Database, 2006)

Norwegian export revenues from oil and gas have risen to 45% of total exports and constitute more than 20% of the GDP. Furthermore, Norway is the fifth largest oil exporter and third largest gas exporter in the world. It is obvious that country holds significant shares of the global exports in gas and oil products. Therefore, Norway could plausibly be described as 'commodity economy country', due to the large share of its production and exports accounted for by primary commodity products.

## 2. Literature review

Experience shows that it is difficult to construct robust models of short-term developments in the exchange rate (see Frankel and Rose, 1995). Random walk models, in which the exchange rate is expected to remain at the current level in the future, are often just as useful for forecasts as sophisticated models. It is hardly surprising that it is difficult to construct good models for forecasting developments in exchange rates in the short and medium term. Therefore, it is really important to investigate the forecasting ability of the Norwegian currency for international investors in our days. Norway is a small open Economy and can be a case that could give certain inferences concerning the exchange rate determination by macroeconomic factors. Moreover, forecasting exchange rate movements is always an attractive subject in the international finance literature.

The price of crude oil is commonly believed to have a significant influence on the Norwegian exchange rate. Empirical studies have, however, provided mixed support for the assumed covariance between the oil price and the Norwegian exchange rate, see e.g. Bjørvik, Mork and Uppstad (1998) and Akram and Holter (1996). These studies find a statistically insignificant and or numerically weak relation between the oil price and the value of the krone. Such empirical findings are puzzling in the light of the theoretical literature and the widely shared belief that the oil price has been an important factor behind the major fluctuations in the value of the krone during the 1990s and the devaluation in 1986.

Akram (2000) explains why the nominal exchange rate of an oil producing country may appreciate when the oil price rises and depreciate when it falls. Firstly, higher oil prices increase demand for the currency of an oil exporting country and thereby raise its price relative to other currencies. Secondly, if the long run real exchange rate depends on oil prices, higher oil prices may create a wedge between the long run (equilibrium) real exchange rate and the actual real exchange rate. Thirdly, if the real exchange rate is constant in the long run, as implied by the purchasing power parity (PPP) theory, higher oil prices may still bring about a short run appreciation of the real and nominal exchange rates through mechanisms that are well known from the Dutch disease literature.

He also concludes that there is a non-linear negative relationship between the value of the Norwegian krone and the crude oil price:  a rise in oil prices tends to raise the value of the krone while a fall tends to reduce the value of the krone. The study examines daily observation of the krone/ECU exchange rate (hereafter referred to as the ECU index) and the oil price over the period January 1986-August 1998, in search for empirically stable patterns. A regular pattern is likely to emerge more clearly in daily observations due to their large number than in observations collected at lower frequencies. The choice of the ECU index reflects the Norwegian policy of exchange rate stabilisation against the ECU during the 1990s. The examination turns out to reveal a non-linear, or state dependent, relation between the oil price and the ECU index. The findings from the bivariate analysis are tested and estimate the non-linear oil price effects using equilibrium correction models (EqCMs) for the exchange rate. To cross-check the findings, the ECU index is modeled  using monthly data over 1990:11 to 1998:11 and the nominal effective exchange rate (E) using quarterly data over the period 1972:2 to 1997:4. The quarterly data set covers almost all oil price shocks in the OPEC era and exchange rate fluctuations since the end of the Bretton Woods system.

The negative relation is however non-linear since the strength of this relation varies with the level and the trend in oil prices. A change in oil prices has a stronger impact on the exchange rate when the level of the oil price is below 14 dollars, than at higher levels. Moreover, the strength of this relationship increases when oil prices display a falling trend. Accordingly, changes in oil prices have negligible effects, if any, when oil prices are high, unless they exhibit a falling tendency. The reported non-linear oil price effects are only significant in the short run. In the long run, oil prices are found to have no effects on the exchange rate. In the long run, it reflects the ratio between domestic and foreign prices, in strict accordance with the Purchasing power parity (PPP) hypothesis. Implicitly, the Norwegian real exchange rate is constant and independent of oil prices in the long run.

On the other hand, Bernhardsen and Røisland (2000) study the movements in the exchange rate between the krone and the German Mark (from 1 January 1999 the euro) and developments in the trade-weighted exchange rate index. Short- and logterm exchange rate movements are modelled including also the price differential and the interest rate differential against other countries, as well as the oil price and an indicator of international financial turbulence. The main finding is that oil price is the only explanatory variable in the long-term solution for the exchange rate apart from the price differential against Germany. This implies that in the long term the exchange rate between the krone and the mark will be determined by the price differential between Norway and Germany and by the oil price. The long-term solution for the whole period of 1993-2000 implies that a sustained increase of 1 per cent in the oil price will lead to a real appreciation of 0.09 per cent. The figure for the sub-period 1997-2000 is somewhat lower, at 0.06 per cent. Although there is a relatively high degree of uncertainty associated with the exact relationship between the krone exchange rate and the oil price, the estimated coefficient has the right sign in view of what one would expect from economic theory. However, in a study of a more long-term nature, Akram (2000) does not find any systematic relationship between the krone exchange rate and the oil price in the long term.

In addition, Akram (2003) examines how the behavioral equilibrium real exchange rate (BEER) approach explains movements in the Norwegian real exchange rate in the long run using the real oil price as one of the examined variables. The other variables are the difference between relative product prices between Norway and its trading partners, the interest rate differential between Norway and its trading partners and the share of investment in GDP. The equilibrium real exchange rate in the long run has been estimated by making assumptions about the equilibrium levels of these variables. Implicitly, the real exchange rate may deviate from its equilibrium level partly because these variables may deviate from their equilibrium levels. As such deviations are assumed to be temporary, deviations from the equilibrium exchange rate will also be temporary.

He has demonstrated that the real exchange rate may be stronger than its equilibrium level for a long period as a result of planned growth in public expenditures in the period ahead. In the short run, he has also observed a tendency for the real exchange rate to continue moving in one direction or the other, even when the shock that caused the initial movement has dissipated.

Moreover, Bjørnland and Hungnes (2005) analysed the real exchange rate behavior in Norway, which has a primary commodity (oil) that constitutes the majority of its export. They show that despite controlling for the effect of the commodity export price on the real exchange rate, PPP (purchasing power parity) does not hold in the long run. However, when they also allowed the interest rate differential to enter the relationship, the real exchange rate is effectively made stationary. The long run relationship is consistent with a synthesis of PPP and UIP (uncovered interest parity). They argue also that once the interest rate differential is allowed to matter, the real oil price plays only a minor role in the long run real exchange rate relationship, although the sign of the effect is as expected. In particular, the Norwegian currency can be characterised as a petro-currency, which appreciates when the oil price increases and depreciates when the oil price falls. They conclude also that adjustment to shocks from the equilibrium relationship is fast, taking no more than one year on average.

Finally, Papadamou and Markopoulos (2012), by following vector error correction modeling, empirically investigate some of the popular monetary models in the NOK/USD rate by also taking into account the effect of oil prices. The coefficients in the cointegration equation of both money and output differentials are statistically significant and consistent with any of the forms of the monetary models. Different measures of unobserved expected inflation do not affect their main findings.

Moreover, empirical evidence for the proportionality between the exchange rate and relative money is provided. However, none of the various forms of monetary models is strictly identified empirically. Concerning the expected inflation differential, on the one hand it is responsible for a significant part of exchange rate variability. On the other hand, its estimated coefficient is not consistent with any of the various forms of the monetary models. This means that in the short run if the exchange rate is shocked it will rapidly return to its long run equilibrium. The weak or strong positive (instead of theoretical negative) long run relationship between real oil prices and the NOK/USD exchange rate implies that economic policy can be used effectively to counteract the effects of higher oil prices in Norway. The fact that funds (Global Pension Fund) are invested in high-grade securities for longer term, and usually the proceeds are supposed to benefit the future generation may hamper the theoretical long run link between real oil prices and Norwegian currency. However, over the short run, an oil price shock has a negative significant effect on the NOK/USD.

In summary, the results of Papadamou and Markopoulos paper suggest that there is some scope for the monetary approach to explain the development of the NOK/USD during the examined period. Although there is no clear evidence regarding the exact version of the monetary model, the estimated unrestricted error correction models fits the actual NOK/USD exchange rate. Their findings imply that macroeconomic policies do significantly affect the NOK/USD exchange rate. Fundamental factors play significant role in the long and short run dynamics of the exchange rate.

Most of the empirical studies have suggested an ambiguous relationship between crude oil prices and exchange rates.

# 3. Empirical Analysis

## 3.1 Data

The first step is to determine the variables in the model. We study the relationship between the Norwegian krone and the price of oil. It is examined whether the nominal exchange rate of Norwegian krone against United States dollar (NOK/US$) is affected by the Brent oil spot price. In addition, the analysis considers whether the real Norwegian exchange rate depends on the Brent oil price. In this case, the real exchange rate is defined as R ≡ E*(Pf /P), where E is the nominal exchange rate NOK/US$, and P f /P is the ratio of US consumer price index (CPI) to the consumer price index in Norway. It is obvious that in this occasion, Brent oil spot price, which is expressed in US$, should be divided by US CPI. We could characterise this variable as "real UK Brent price"

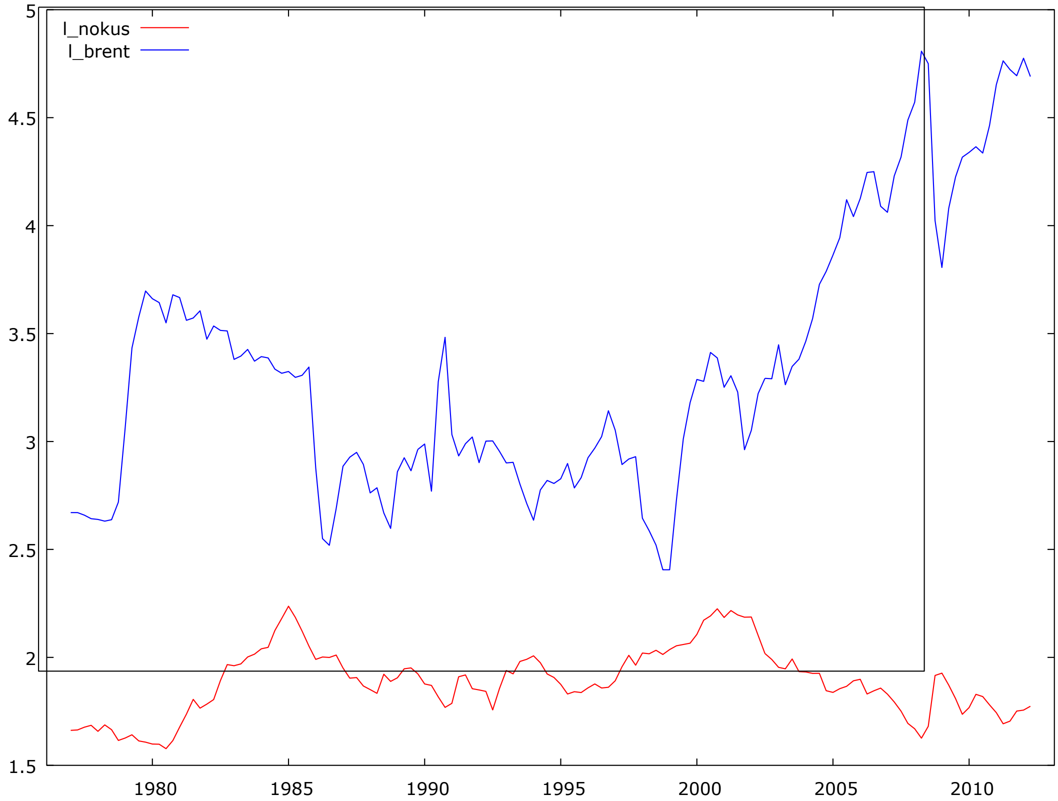
- The nominal exchange rate of Norwegian krone against US$ is available from Norges Bank, the central bank of Norway.
- CPI index for both countries is adopted from International Monetary Fund (IMF) time series data base. The base year for the index is 2005
- The Brent oil spot price is also obtained by IMF expressed in US$ per Barrel. It was originally traded on the open outcry International Petroleum Exchange in London, but since 2005 has been traded on the electronic Intercontinental Exchange, known as ICE.

All the time series that are used are quarterly average data. The sampling period begins at 1977 and ends on the half of 2012 for the nominal exchange rate tests. On the other hand, we investigate the real exchange rate from June of 1986 to first half of 2012, after the second devaluation of krone. The period 1977-first quarter of 1986 did not give results that confirm a robust relationship between the time series.

### 3.2 Methodology

We investigate the long-run equilibrium nominal exchange-rate equation by adopting a cointegrating relationship between the NOK exchange rate and the UK Brent spot price. By calculating the natural logarithms of nominal NOK exchange rate (l_nokus) and UK Brent spot price (l_brent), we produce a time series plot in figure 1.

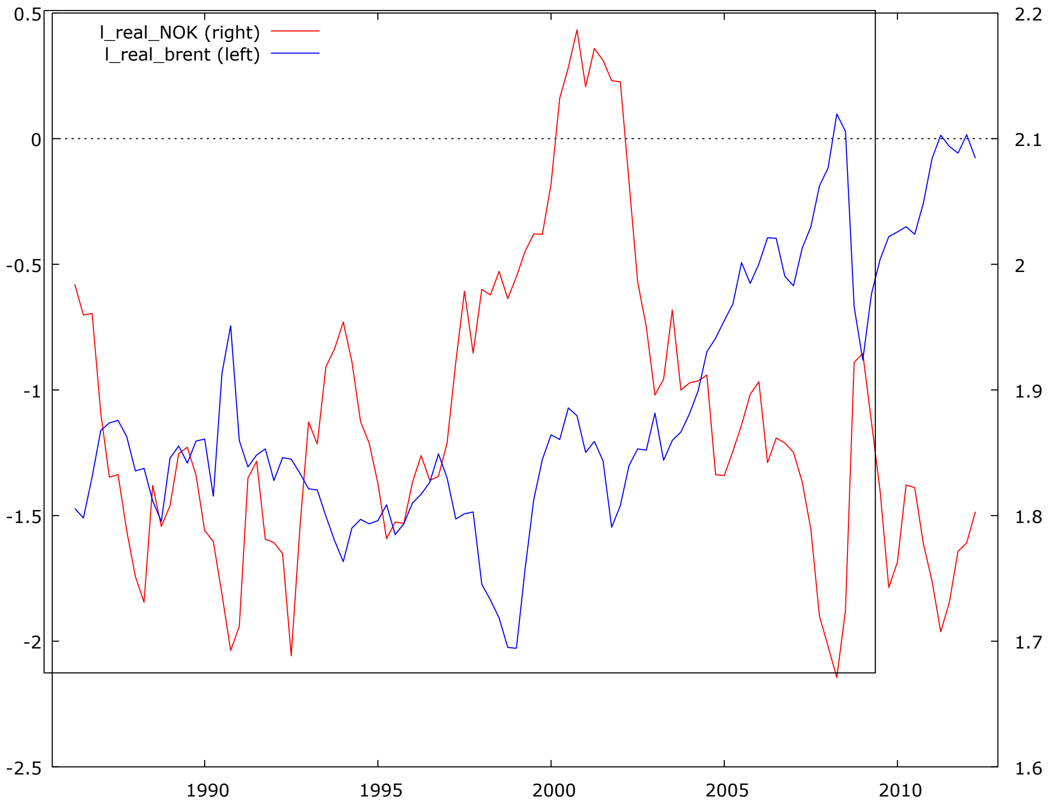
Figure 1. logarithms of nominal NOK/US$ and UK Brent spot price(US$ per barrel)




We could easy confirm, by observing periods from 1977-1986 and 2001-2012, that a rise of Brent oil price strengthens the Norwegian krone. We take note that nominal exchange rate is expressed as a number of krones per 1US$.

The same calculations for real exchange rate and real Brent price give the Figure 2.

Figure 2. logarithms of real NOK exchange rate and real UK Brent.




We could easy observe in some periods that a rise in oil price is followed by real NOK exchange rate's strength.

Most of the empirical studies have suggested an ambiguous relationship between crude oil prices and exchange rates. Although the price of crude oil is commonly believed to have a significant influence on the Norwegian exchange rate, there are many empirical studies that provided mixed support for the assumed covariance between the oil price and the Norwegian exchange rate. Many of them find a statistically insignificant and or numerically weak relation between the oil price and the value of the krone. On the contrary, other studies confirm that the oil price has been an important factor behind the major fluctuations in the value of the krone. The target of this paper is to explore if there is a stable and robust model for the link between exchange rate and oil price.

### 3.3 Unit root tests

After the determination of the variables, it is possible to conduct the econometric analysis, which consists of a few steps. The first is to test whether the data series are stationary. We perform Augmented Dickey-Fuller (ADF) test to examine the stationarity of the time series variables. An augmented Dickey-Fuller test is a version of the Dickey-Fuller test (Dickey, 1979) for a larger and more complicated set of time series models. The augmented Dickey–Fuller (ADF) statistic, used in the test, is a negative number. The more negative it is, the stronger the rejections of the hypothesis that there is a unit root at some level of confidence. This test is conducted by "augmenting" the preceding three equations by adding the lagged values of the dependent variable. Table 1 gives the result of the ADF test which performed for the natural logarithm of nominal NOK/US$ exchange rate.

Table 1. ADF test for l_nokus

```
Augmented Dickey-Fuller test for l_nokus
including one lag of (1-L)l_nokus (max was 13)
sample size 140
unit-root null hypothesis: a = 1

   test without constant
   model: (1-L)y = (a-1)*y(-1) + ... + e
   1st-order autocorrelation coeff. for e: 0.032
   estimated value of (a - 1): -8.59375e-005
   test statistic: tau_nc(1) = -0.042634
   asymptotic p-value 0.6687

Augmented Dickey-Fuller regression
OLS, using observations 1977:3-2012:2 (T = 140)
Dependent variable: d_l_nokus

                coefficient    std. error   t-ratio    p-value
  -------------------------------------------------------------
  l_nokus_1     -8.59375e-05   0.00201570   -0.04263   0.6687
  d_l_nokus_1    0.258579      0.0823041     3.142     0.0021  ***

  AIC: -467.549   BIC: -461.666   HQC: -465.158
```

It is clear that the asymptotic p-value in test (0.6687) is higher than 0.05 . Thus, the unit-root hypothesis cannot be rejected. Therefore, l_nokus is a non-stationary time series.

The same test also performed for the natural logarithm of the Brent UK oil spot price (l_brent). Table 2 gives similar results.

Table 2. ADF test for l_brent

```
Augmented Dickey-Fuller test for l_brent
including 4 lags of (1-L)l_brent (max was 13)
sample size 137
unit-root null hypothesis: a = 1

   test without constant
   model: (1-L)y = (a-1)*y(-1) + ... + e
   1st-order autocorrelation coeff. for e: -0.024
   lagged differences: F(4, 132) = 6.757 [0.0001]
   estimated value of (a - 1): 0.00374664
   test statistic: tau_nc(1) = 1.02246
   asymptotic p-value 0.92

Augmented Dickey-Fuller regression
OLS, using observations 1978:2-2012:2 (T = 137)
Dependent variable: d_l_brent

                coefficient   std. error   t-ratio   p-value
  -----------------------------------------------------------
  l_brent_1      0.00374664   0.00366434    1.022    0.9200
  d_l_brent_1    0.365524     0.0863102     4.235    4.26e-05 ***
  d_l_brent_2   -0.374728     0.0906144    -4.135    6.26e-05 ***
  d_l_brent_3    0.197409     0.0905587     2.180    0.0310   **
  d_l_brent_4   -0.177002     0.0864949    -2.046    0.0427   **

  AIC: -141.55   BIC: -126.951   HQC: -135.617
```

As we can see from the p-value, l_brent is an integrated variable of order one I(1). On the contrary, the results of stationarity tests for the real NOK exchange rate is on table 3.

Table3. ADF test for l_real_NOK

```
Augmented Dickey-Fuller test for l_real_NOK
including 4 lags of (1-L)l_real_NOK (max was 12)
sample size 100
unit-root null hypothesis: a = 1

   test without constant
   model: (1-L)y = (a-1)*y(-1) + ... + e
   1st-order autocorrelation coeff. for e: -0.011
   lagged differences: F(4, 95) = 2.413 [0.0543]
   estimated value of (a - 1): -0.000684025
   test statistic: tau_nc(1) = -0.284077
   asymptotic p-value 0.5839

Augmented Dickey-Fuller regression
OLS, using observations 1987:3-2012:2 (T = 100)
Dependent variable: d_l_real_NOK
                  coefficient    std. error   t-ratio   p-value
  ---------------------------------------------------------------
  l_real_NOK_1    -0.000684025   0.00240789   -0.2841   0.5839
  d_l_real_NO_1    0.210452      0.100495      2.094    0.0389  **
  d_l_real_NO_2   -0.161614      0.101436     -1.593    0.1144
  d_l_real_NO_3    0.0226207     0.101747      0.2223   0.8245
  d_l_real_NO_4   -0.194281      0.0991878    -1.959    0.0531  *

  AIC: -330.917   BIC: -317.892   HQC: -325.646
```

The asymptotic p-value in test (0.5839) is higher than 0.05 . Thus, the natural logarithm of real krone exchange rate is a non-stationary variable.

The same test which performed for the real Brent UK oil price gave the results of table 4.

Table 4. ADF test for l_real_brent

```
Augmented Dickey-Fuller test for l_real_brent
including 4 lags of (1-L)l_real_brent (max was 12)
sample size 100
unit-root null hypothesis: a = 1

   test without constant
   model: (1-L)y = (a-1)*y(-1) + ... + e
   1st-order autocorrelation coeff. for e: -0.032
   lagged differences: F(4, 95) = 5.015 [0.0010]
   estimated value of (a - 1): -0.0118221
   test statistic: tau_nc(1) = -0.988297
   asymptotic p-value 0.2899

Augmented Dickey-Fuller regression
OLS, using observations 1987:3-2012:2 (T = 100)
Dependent variable: d_l_real_bren

                  coefficient   std. error   t-ratio   p-value
  -------------------------------------------------------------
  l_real_bren_1   -0.0118221    0.0119621    -0.9883    0.2899
  d_l_real_br_1    0.299636     0.100494      2.982     0.0036  ***
  d_l_real_br_2   -0.407465     0.102547     -3.973     0.0001  ***
  d_l_real_br_3    0.217373     0.102090      2.129     0.0358  **
  d_l_real_br_4   -0.189063     0.0995157    -1.900     0.0605  *

  AIC: -103.367   BIC: -90.3413   HQC: -98.0953
```

As we can see from the p-values, l_real_brent is an integrated variable of order one I (1).

We conclude that the time series variables that examined are non-stationary.

### 3.4 Long-run cointegration

If we have two non-stationary time series X and Y that become stationary when differenced such that some linear combination of X and Y is stationary (aka, I(0)), then we say that X and Y are cointegrated. In other words, while neither X nor Y alone hovers around a constant value, some combination of them does, so we can think of cointegration as describing a particular kind of long-run equilibrium relationship.

We can investigate this relationship applying the Engle-Granger cointegration test. We assume that the linear combination between the variables is described from the following equation:

$$l\_nokus = \beta * l\_brent + u_t \tag{1}$$

the first step is to estimating β. This can be achieved by applying an ordinary least squares model (OLS). The next step is to perform an ADF test to the residuals of the OLS model in order to be examined for stationarity. If the residuals (uhat) are stationary, then the variables are cointegrated. The results of these tests are presented in table 5.

Table 5.Cointegration between l_nokus and l_brent

```
 Step 1: cointegrating regression

 Cointegrating regretion -
 OLS, using observations 1977:1-2012:2 (T = 142)
 Dependent variable: l_nokus
 HAC standard errors, bandwidth 3 (Bartlett kernel)
                  Coefficient  Std. Error   t-ratio      p-value
const             2.16878      0.0952966    22.7582      <0.00001     ***
l_brent           -0.0836741   0.0252018    -3.3202      0.00115      ***

Mean dependent var      1.888574       S.D. dependent var      0.155370
Sum squared resid       3.032278       S.E. of regression      0.147170
R-squared               0.109123       Adjusted R-squared      0.102759
F(1, 140)               11.02347       P-value(F)              0.001147
Log-likelihood          71.61314       Akaike criterion       -139.2263
Schwarz criterion      -133.3146       Hannan-Quinn           -136.8240
rho                     0.943531       Durbin-Watson           0.086485


 Step 2: testing for a unit root in uhat
 Augmented Dickey-Fuller test for uhat1
 including 6 lags of (1-L)uhat1 (max was 13)
 sample size 135
 unit-root null hypothesis: a = 1

    test without constant
    model: (1-L)y = (a-1)*y(-1) + ... + e
    1st-order autocorrelation coeff. for e: -0.024
    lagged differences: F(6, 128) = 2.655 [0.0184]
    estimated value of (a - 1): -0.0800418
    test statistic: tau_nc(1) = -2.90157
    asymptotic p-value 0.003615
```

The estimated from OLS model residuals are stationary. Thus, the time series are cointegrated and there is a long-term equilibrium relationship between them.

Since the calculated real values of NOK exchange rate and Brent UK oil price are integrated of order one I(1), the same method applied to study the cointegration of them . Table 6 depicts the test results.

Table 6. Cointegration test between l_real_NOK and l_real_brent

```
Step 1: cointegrating regression

Cointegrating regretion -
OLS, using observations 1986:2-2012:2 (T = 105)
Dependent variable: l_real_NOK
HAC standard errors, bandwidth 3 (Bartlett kernel)
                     Coefficient  Std. Error   t-ratio      p-value
   const             1.76515      0.0180094    98.0126      <0.00001     ***
   l_real_brent      -0.104391    0.0203616    -5.1269      <0.00001     ***

   Mean dependent var       1.876138       S.D. dependent var      0.118431
   Sum squared resid        1.155635       S.E. of regression      0.105923
   R-squared                0.207759       Adjusted R-squared      0.200067
   F(1, 103)                26.28468       P-value(F)              1.39e-06
   Log-likelihood           87.75027       Akaike criterion       -171.5005
   Schwarz criterion       -166.1926       Hannan-Quinn           -169.3497
   rho                      0.920952       Durbin-Watson           0.155046

Step 2: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including one lag of (1-L)uhat (max was 12)
sample size 103
unit-root null hypothesis: a = 1

   test without constant
   model: (1-L)y = (a-1)*y(-1) + ... + e
   1st-order autocorrelation coeff. for e: 0.002
   estimated value of (a - 1): -0.0903738
   test statistic: tau_nc(1) = -2.3417
   asymptotic p-value 0.01855

Augmented Dickey-Fuller regression
OLS, using observations 1986:4-2012:2 (T = 103)
Dependent variable: d_uhat

             coefficient   std. error   t-ratio   p-value
  -------------------------------------------------------
  uhat_1     -0.0903738    0.0385932    -2.342    0.0186  **
  d_uhat_1    0.166440     0.0978539     1.701    0.0920  *

  AIC: -365.643   BIC: -360.373   HQC: -363.509
```

We conclude that the calculated time series of real krone exchange rate and real UK Brent oil price are cointegrated. The equations that describe the log-run relationship between the Norwegian krone and Brent oil are the following:

- *nominal exchange rate* $l\_nokus_t = 2.16878 - 0.083674 * l\_brent_t + u1_t$ (2)

- *real exchange rate* $l\_real\_nok_t$=1.76515–0.104391*$l\_real\_brent_t$+$u2_t$ (3)

The former equations prove the widely shared belief that Norwegian krone is a commodity currency.

### 3.5 Vector Error Correction Model (VECM)

The existence of cointegration vector implies that a long-term relationship among the variables exists. According to the Granger theorem, if a cointegration relationship exists between I(1) variables, then an error correction model (ECM) can be applied.

If we rewrite the equations (2) and (3) as:

$$u1_t = l\_nokus_t - 2.16878 + 0.083674 * l\_brent_t \quad (4)$$

and

$$u2_t = l\_real\_nok_t - 1.76515 + 0.104391 * l\_real\_brent_t \quad (5)$$

we obtain the error terms $u1_t$ and $u2_t$ which can be treated as the terms which corrects the NOK exchange rate deviations from its equilibrium.

In the case we would take full account of the dynamic responses of all variables in the cointegrated system we use the Vector Error Correction Model (VECM). The latter estimates a system of equations and does not require the weak exogeneity condition of independent variables as does the single-equation ECM. The VECM estimation also provides a direct test of the exogeneity of one variable to one another.

A vector error correction model (VECM) adds error correction features to a multi-factor model such as a vector autoregression model (VAR). Thus, we have to estimate the optimum lag order.

The following tables gives the results of the test with constant and max. lag order is 8

Table 7. Lag selection for the l_nokus and l_brent VECM models

```
VAR system, maximum lag order 8
The asterisks below indicate the best (that is, minimized) values
of the respective information criteria, AIC = Akaike criterion,
BIC = Schwarz Bayesian criterion and HQC = Hannan-Quinn criterion.
lags        loglik    p(LR)       AIC          BIC          HQC

   1     295.64065             -4.322995    -4.193241    -4.270267
   2     306.20350  0.00030   -4.420948    -4.204691*   -4.333068
   3     312.80556  0.01032   -4.459784*   -4.157025    -4.336753*
   4     316.22041  0.14517   -4.451051    -4.061789    -4.292867
   5     318.65695  0.30057   -4.427716    -3.951951    -4.234380
   6     321.88023  0.16819   -4.416123    -3.853855    -4.187636
   7     324.49035  0.26544   -4.395378    -3.746608    -4.131739
   8     325.80616  0.62123   -4.355316    -3.620043    -4.056525
```

Table 8. Lag selection for the l_real_NOK and l_real_brent

```
VAR system, maximum lag order 8
The asterisks below indicate the best (that is, minimized) values
of the respective information criteria, AIC = Akaike criterion,
BIC = Schwarz Bayesian criterion and HQC = Hannan-Quinn criterion.
lags        loglik    p(LR)       AIC          BIC          HQC

   1     219.52130             -4.402501    -4.243241*   -4.338104
   2     223.58181  0.08724   -4.403749    -4.138315    -4.296420
   3     230.38316  0.00868   -4.461508    -4.089901    -4.311248
   4     238.38881  0.00300   -4.544099*   -4.066318    -4.350908*
   5     241.50850  0.18197   -4.525949    -3.941993    -4.289826
   6     244.11113  0.26688   -4.497137    -3.807008    -4.218082
   7     245.29385  0.66888   -4.439048    -3.642746    -4.117063
   8     250.39740  0.03708   -4.461802    -3.559326    -4.096885
```

The Akaike criterion (AIC) and Hannan-Quinn criterion (HQC) suggest that we should take into account 3 as optimum lag for the study of nominal exchange rate. On the other hand, studying the real exchange the optimum lag is 4. Schwarz Bayesian criterion (BIC) suggest optimum lag 2 for the first case and 1 for the latter.

Nominal values

We can now estimate a VECM of the l_nokus and l_brent by setting the lag order equal to 3. The results are depicted in Table 9.

Table 9. VECM estimation for l_nokus and l_brent

```
VECM system, lag order 3
Maximum likelihood estimates, observations 1977:4-2012:2 (T = 139)
Cointegration rank = 1
Case 2: Restricted constant
beta (cointegrating vectors, standard errors in parentheses)
l_nokus      1.0000
             (0.00000)
l_brent      0.095843
             (0.084385)
const        -2.2625
             (0.28494)
alpha (adjustment vectors)
l_nokus      -0.050533
l_brent      -0.11963
Log-likelihood = 325.35802
Determinant of covariance matrix = 3.1764395e-005
AIC = -4.5087
BIC = -4.2554
HQC = -4.4058
Equation 1: d_l_nokus
```

| | Coefficient | Std. Error | t-ratio | p-value | |
|---|---|---|---|---|---|
| d_l_nokus_1 | 0.257967 | 0.0879962 | 2.9316 | 0.00397 | *** |
| d_l_nokus_2 | -0.00958388 | 0.0880011 | -0.1089 | 0.91344 | |
| d_l_brent_1 | -0.0578473 | 0.0268008 | -2.1584 | 0.03269 | ** |
| d_l_brent_2 | 0.0745047 | 0.0270428 | 2.7551 | 0.00669 | *** |
| EC1 | -0.0505329 | 0.0249257 | -2.0273 | 0.04463 | ** |

| | | | |
|---|---|---|---|
| Mean dependent var | 0.000698 | S.D. dependent var | 0.046809 |
| Sum squared resid | 0.250153 | S.E. of regression | 0.043369 |
| R-squared | 0.172876 | Adjusted R-squared | 0.141782 |
| Rho | -0.017015 | Durbin-Watson | 2.031550 |

Equation 2: d_l_brent

| | Coefficient | Std. Error | t-ratio | p-value | |
|---|---|---|---|---|---|
| d_l_nokus_1 | -0.104853 | 0.292452 | -0.3585 | 0.72051 | |
| d_l_nokus_2 | 0.0921103 | 0.292468 | 0.3149 | 0.75330 | |
| d_l_brent_1 | 0.289925 | 0.0890714 | 3.2550 | 0.00144 | *** |
| d_l_brent_2 | -0.277548 | 0.0898755 | -3.0881 | 0.00245 | *** |
| EC1 | -0.119632 | 0.0828396 | -1.4441 | 0.15105 | |

| | | | |
|---|---|---|---|
| Mean dependent var | 0.014616 | S.D. dependent var | 0.152024 |
| Sum squared resid | 2.763034 | S.E. of regression | 0.144134 |
| R-squared | 0.141665 | Adjusted R-squared | 0.109397 |
| rho | 0.037707 | Durbin-Watson | 1.918330 |

```
Cross-equation covariance matrix:
                  l_nokus      l_brent
l_nokus          0.0017997     -0.0020023
l_brent          -0.0020023    0.019878

determinant = 3.17644e-005
```

By implying BIC criterion, we have results from table 10.

Table 10. VECM estimation for l_nokus and l_brent

```
VECM system, lag order 2
Maximum likelihood estimates, observations 1977:3-2012:2 (T = 140)
Cointegration rank = 1
Case 2: Restricted constant
beta (cointegrating vectors, standard errors in parentheses)

l_nokus        1.0000
              (0.00000)
l_brent        0.056519
              (0.080103)
const         -2.1223
              (0.27110)

alpha (adjustment vectors)

l_nokus       -0.065364
l_brent       -0.053951

Log-likelihood = 321.03483
Determinant of covariance matrix = 3.4936935e-005
AIC = -4.4719
BIC = -4.3038
HQC = -4.4036

Equation 1: d_l_nokus

                  Coefficient  Std. Error   t-ratio      p-value
d_l_nokus_1       0.227266     0.0869907    2.6125       0.01000      ***
d_l_brent_1       -0.0461301   0.0268036    -1.7210      0.08752      *
EC1               -0.0653637   0.0248332    -2.6321      0.00947      ***

Mean dependent var       0.000783       S.D. dependent var      0.046651
Sum squared resid        0.264944       S.E. of regression      0.044138
R-squared                0.124435       Adjusted R-squared      0.105121
rho                      0.056934       Durbin-Watson           1.885218

Equation 2: d_l_brent

                  Coefficient  Std. Error   t-ratio      p-value
d_l_nokus_1       0.0201447    0.293473     0.0686       0.94537
d_l_brent_1       0.240224     0.090425     2.6566       0.00884      ***
EC1               -0.053951    0.0837776    -0.6440      0.52067

Mean dependent var       0.014427       S.D. dependent var      0.151493
Sum squared resid        3.015393       S.E. of regression      0.148903
R-squared                0.063311       Adjusted R-squared      0.042648
rho                      0.065475       Durbin-Watson           1.865320
Cross-equation covariance matrix:
             l_nokus       l_brent
l_nokus             0.0018925    -0.0024133
l_brent             -0.0024133   0.021539

determinant = 3.49369e-005
```

In both cases, we would take into account only the first equation of each model. In table 9 Error Correction term is less significant than the EC in table 10. On the contrary, the price of Brent oil one or two periods back does not seems to affect the exchange rate in table 10. We will examine the two models.

The error term from table 9 could be written as:

$$e_t = l\_nokus_t + 0.095843 * l\_brent_t - 2.2625 \quad (6)$$

The difference from the term calculated in equation (4) is due to the different estimation method that is followed by VECM. Taking into account the statistical significant terms from VECM model we have the first different operator for the l_nokus (Δl_nokus) and the lagged error correction term (EC1)

$$\Delta l\_nokus_t = 0.257967 \Delta l\_nokus_{t-1} - 0.0578473 \Delta l\_brent_{t-1} + 0.0745047 \Delta l\_brent_{t-2} - 0.0505329 e_{t-1} \quad (7)$$

We conclude from equation (7) that the short-term relationship between l_nokus and l_brent has bilateral causality. Moreover, when the variables are in logarithms and one cointegrating vector is estimated, the coefficients can be interpreted as long run elasticities. The appreciations of the exchange rate are related to increasing oil price, thus, the estimated model was able to produce a consistent result.

The coefficient of about 0.26 in equation (7) means that a possible 1% rise in Δl_nokus could cause an 0.26% increase in Δl_nokus in the next quarter. Besides, the coefficient 0.074 suggests that an increase of 1% of Δl_brent will lead to 0.074% increase in Δl_nokus two quarters later. This is a short-run relation. The coefficient of -0.05 that refers to error correction term suggests that about 5% of the discrepancy between long-term and short-term l_nokus is corrected within a quarter. This suggests a slow rate of adjustment to equilibrium

The error term from table10 could be written as:

$$e_t = l\_nokus_t + 0.056519 * l\_brent_t - 2.1223 \quad (8)$$

The difference from the term calculated in equation (4) is due to the different estimation method that is followed by VECM.

Taking into account the statistical significant terms from VECM model we have the first different operator for the l_nokus (Δl_nokus) and the lagged error correction term (EC1)

$$\Delta l\_nokus_t = 0.227266\Delta l\_nokus_{t-1} - 0.0653637e_{t-1} \quad (9)$$

The coefficient 0.227 means that a 1% increase in Δl_nokus could cause about an 0.23% increase in Δl_nokus the next quarter. In addition, the error correction coefficient of 0.06 suggests that only 6& of the discrepancy between long-term and short-term l_nokus is corrected within a quarter. This suggests also a slow rate of adjustment to equilibrium

Real values

Applying optimum lag selection 1, as BIC criterion suggests, for building a VECM model for the real NOK and real Brent price, no significant results produced. Thus, we take consideration of AIC and HQC that suggest optimum lag order 4. The results are presented in table 11.

Table 11. VECM estimation for l_real_NOK and l_real_brent

```
VECM system, lag order 4
Maximum likelihood estimates, observations 1987:2-2012:2 (T = 101)
Cointegration rank = 1
Case 2: Restricted constant
beta (cointegrating vectors, standard errors in parentheses)
l_real_NOK    1.0000
              (0.00000)
l_real_brent  0.12874
              (0.077869)
const         -1.7268
              (0.092933)
alpha (adjustment vectors)
l_real_NOK    -0.10988
l_real_brent  0.067135
Log-likelihood = 247.21277
Determinant of covariance matrix = 2.5647703e-005
AIC = -4.5785
BIC = -4.1642
HQC = -4.4108
Equation 1: d_l_real_NOK
                       Coefficient   Std. Error    t-ratio       p-value
    d_l_real_NOK_1     0.207444      0.106697      1.9442        0.05489       *
    d_l_real_NOK_2     0.0651127     0.107044      0.6083        0.54448
    d_l_real_NOK_3     0.14909       0.104382      1.4283        0.15655
    d_l_real_bren_1    -0.0283672    0.032544      -0.8717       0.38564
    d_l_real_bren_2    0.0865453     0.0320119     2.7035        0.00816       ***
    d_l_real_bren_3    0.0775515     0.0339032     2.2874        0.02444       **
    EC1                -0.109877     0.0418369     -2.6263       0.01009       **

    Mean dependent var       -0.000779       S.D. dependent var       0.046467
    Sum squared resid         0.165825       S.E. of regression       0.042226
    R-squared                 0.232204       Adjusted R-squared       0.174413
    Rho                      -0.033170       Durbin-Watson            2.052194
Equation 2: d_l_real_brent
                       Coefficient   Std. Error    t-ratio       p-value
    d_l_real_NOK_1     -0.518605     0.363568      -1.4264       0.15709
    d_l_real_NOK_2     -0.0782021    0.364752      -0.2144       0.83071
    d_l_real_NOK_3     0.158637      0.355679      0.4460        0.65663
    d_l_real_bren_1    0.205019      0.110893      1.8488        0.06766       *
    d_l_real_bren_2    -0.378345     0.10908       -3.4685       0.00079       ***
    d_l_real_bren_3    0.204936      0.115525      1.7740        0.07934       *
    EC1                0.0671346     0.142559      0.4709        0.63880

    Mean dependent var        0.010728       S.D. dependent var       0.151480
    Sum squared resid         1.925389       S.E. of regression       0.143886
    R-squared                 0.165145       Adjusted R-squared       0.102307
    Rho                       0.023379       Durbin-Watson            1.946968
Cross-equation covariance matrix:
              l_real_NOK    l_real_brent
l_real_NOK    0.0016418    -0.0023772
l_real_brent  -0.0023772    0.019063
determinant = 2.56477e-005
```

The error term from table 11 could be written as

$e_t$ = l_real_NOK$_t$+0.12874l_real_brent$_t$-1.7268 (10)

The difference from the term calculated in equation (5) is due to the different estimation method that is followed by VECM.

We could estimate the first difference of l_real_NOK from the first equation of VECM model

$\Delta$l_real_NOK$_t$ = 0.0865453$\Delta$l_real_Brent$_{t-2}$+0.0775515$\Delta$l_real_Brent$_{t-3}$-0.109877$e_{t-1}$

(11)

The last equation shows that the short-term relationship between l_real_NOK and l_real_brent has bilateral causality. The coefficient of 0.08 suggests that when the $\Delta$l_real_Brent increases 1%, a 0.08% increase occurred in $\Delta$l_real_NOK after one year. Besides, the coefficient of error correction which is about -0.11 suggests that about 11% of the discrepancy between l_real_NOK and l_real_brent is corrected within a quarter. The rate of the adjustment is slow but faster than the one of models that deal with nominal values (eq.7, eq.9 )

### 3.6 Further VECM study and stability tests

In this step of study we will perform an OLS tests to explain the first difference of the depended variables, l_nokus and l_real_NOK, including lagged first differences of l_nokus, l_brent, l_real_NOK and error correction term.

Nominal values

From the estimated values of table 9, an OLS model is built taking into account the following variables.

$\Delta l\_nokus_t$ (depended)
$\Delta l\_nokus_{t-1}$(independed)
$\Delta l\_brent_{t-1}$(independed)
$\Delta l\_brent_{t-2}$(independed)
$e_{t-1}$(independed)

The lagged differences are calculated by the software. The term $e_{t-1}$ is calculated and inserted manually as the variable EC. For this occasion, EC is obtained from equation (6)

$$EC_t = l\_nokus_t + 0.095843 * l\_brent_t - 2.2625 \quad (12)$$

The results are presented in table 12

Table 12. OLS regression model (a) on Δl_nokus

Model 2: OLS, using observations 1977:4-2012:2 (T = 139)
Dependent variable: d_l_nokus
HAC standard errors, bandwidth 3 (Bartlett kernel)

| | *Coefficient* | *Std. Error* | *t-ratio* | *p-value* | |
|---|---|---|---|---|---|
| d_l_brent_1 | -0.0581044 | 0.0258877 | -2.2445 | 0.02643 | ** |
| d_l_brent_2 | 0.0755059 | 0.0247285 | 3.0534 | 0.00273 | *** |
| EC_1 | -0.0508669 | 0.0256229 | -1.9852 | 0.04915 | ** |
| d_l_nokus_1 | 0.255968 | 0.0774004 | 3.3071 | 0.00121 | *** |

| | | | |
|---|---|---|---|
| Mean dependent var | 0.000698 | S.D. dependent var | 0.046809 |
| Sum squared resid | 0.250176 | S.E. of regression | 0.043048 |
| R-squared | 0.172801 | Adjusted R-squared | 0.154418 |
| F(4, 135) | 6.668876 | P-value(F) | 0.000063 |
| Log-likelihood | 242.0121 | Akaike criterion | -476.0242 |
| Schwarz criterion | -464.2863 | Hannan-Quinn | -471.2542 |
| rho | -0.015375 | Durbin's h | -0.433911 |

The following equation expresses the $\Delta$l_nokus in time t:

$$\Delta l\_nokus_t = 0.255968\Delta l\_nokus_{t-1} - 0.0581044\Delta l\_brent_{t-1} + 0.0755059\Delta l\_brent_{t-2} - 0.0508669e_{t-1} + u_t \quad (13)$$

If we follow the same method dealing with results from table 10 (max. lag order = 2). Thus, an OLS model is built taking into account the following variables.

$\Delta l\_nokus_t$ (depended)

$\Delta l\_nokus_{t-1}$(independed)

$\Delta l\_brent_{t-1}$(independed)

$e_{t-1}$(independed)

The lagged differences are calculated by the software. The term $e_{t-1}$ is calculated and inserted manually as the variable EC. For this occasion, EC is obtained from eq.8

$$EC_t = l\_nokus_t + 0.056519\ l\_brent_t - 2.1223 \quad (14)$$

The results, after omitting the non significant parameters are presented in table 13

Table 13. OLS regression model (b) on $\Delta$l_nokus

Model 2: OLS, using observations 1977:3-2012:2 (T = 140)
Dependent variable: d_l_nokus
HAC standard errors, bandwidth 3 (Bartlett kernel)

| | *Coefficient* | *Std. Error* | *t-ratio* | *p-value* | |
|---|---|---|---|---|---|
| E_C_1 | -0.0604116 | 0.027862 | -2.1682 | 0.03185 | ** |
| d_l_nokus_1 | 0.282425 | 0.0671818 | 4.2039 | 0.00005 | *** |

| | | | |
|---|---|---|---|
| Mean dependent var | 0.000783 | S.D. dependent var | 0.046651 |
| Sum squared resid | 0.270714 | S.E. of regression | 0.044291 |
| R-squared | 0.105366 | Adjusted R-squared | 0.098883 |
| F(2, 138) | 9.994323 | P-value(F) | 0.000088 |
| Log-likelihood | 238.7319 | Akaike criterion | -473.4638 |
| Schwarz criterion | -467.5806 | Hannan-Quinn | -471.0730 |
| rho | 0.027291 | Durbin's h | 0.527086 |

The following equation expresses the $\Delta$l_nokus in time t:

$$\Delta l\_nokus_t = 0.282425\Delta l\_nokus_{t-1} - 0.0604116e_{t-1} + u_t \quad (15)$$

In eq. 13 and eq.15 $\Delta$, as usual, is the first-difference operator, $e_{t-1}$ is the lagged value of the error correction term and $u_t$ is a white noise error term.

The former equations explain how VECM combines the long-run equilibrium with short-run dynamics in order to reach this equilibrium.

Real values

In this step, we test with Ordinary Least Squares the behavior of real exchange rate and Brent oil price, considering the results of table's 11 VECM model. An OLS model is built taking into account the following variables.

$\Delta$l_real _$NOK_t$ (depended)
$\Delta$l_real _$NOK_{t-1}$ (independed)
$\Delta$l_real_$brent_{t-2}$(independed)
$\Delta$l_real_$brent_{t-3}$(independed)
$e_{t-1}$(independed)

The lagged differences are calculated by the software. The term $e_{t-1}$ is calculated and inserted manually as the variable EC. For this occasion, EC is obtained from eq.10

$$EC_t = l\_real\_NOK_t + 0.12874 l\_real\_brent_t - 1.7268 \quad (16)$$

Table 14. OLS regression model on $\Delta$l_real_NOK

Model 1: OLS, using observations 1987:2-2012:2 (T = 101)
Dependent variable: d_l_real_NOK
HAC standard errors, bandwidth 3 (Bartlett kernel)

| | Coefficient | Std. Error | t-ratio | p-value | |
|---|---|---|---|---|---|
| d_l_real_br_2 | 0.072736 | 0.0284638 | 2.5554 | 0.01216 | ** |
| d_l_real_br_3 | 0.0591179 | 0.0262021 | 2.2562 | 0.02630 | ** |
| EC_1 | -0.0960478 | 0.0388382 | -2.4730 | 0.01514 | ** |
| d_l_real_NO_1 | 0.247175 | 0.0851525 | 2.9027 | 0.00458 | *** |

| | | | |
|---|---|---|---|
| Mean dependent var | -0.000779 | S.D. dependent var | 0.046467 |
| Sum squared resid | 0.172255 | S.E. of regression | 0.042141 |
| R-squared | 0.202430 | Adjusted R-squared | 0.177763 |
| F(4, 97) | 7.304218 | P-value(F) | 0.000035 |
| Log-likelihood | 178.5691 | Akaike criterion | -349.1383 |
| Schwarz criterion | -338.6778 | Hannan-Quinn | -344.9036 |
| rho | -0.054693 | Durbin's h | -1.043144 |

The following equation expresses the $\Delta$l_real_NOK in time t:

$\Delta l\_real\_NOK_t = 0.247175 \Delta l\_real\_NOK_{t-1} + 0.072736 \Delta l\_real\_brent_{t-2} + 0.0591179 \Delta l\_real\_brent_{t-3} - 0.0960478 e_{t-1} + u_t$ (17)

In eq. 17 $\Delta$, as usual, is the first-difference operator, $e_{t-1}$ is the lagged value of the error correction term and $u_t$ is a white noise error term. The equation also explains how VECM combines the long-run equilibrium with short-run dynamics in order to reach this equilibrium.

**Stability tests**

The parameters of eq. 13, 15, and 17 should be tested for stability. We followed the recursive estimation method which begins with a subsample of the data, estimating the regression, then sequentially adding one observation at a time and re-running the regression until the end of the sample is reached. It is common to begin the initial estimation with the very minimum number of observations possible. Brooks (2008) argues that the parameter estimates produced near the start of the recursive procedure will appear rather unstable since these estimates are being produced using so few observations, but the key question is whether they then gradually settle down or whether the volatility continues through the whole sample. Seeing the latter would be an indication of parameter instability. Two important stability tests, known as the CUSUM and CUSUMSQ tests, are derived from the residuals of the recursive estimation. Ploberger and Kramer (1990) show the CUSUM test can be constructed with OLS residuals instead of recursive residuals.

The CUSUM statistic is based on a normalised version of the cumulative sums of the residuals. Under the null hypothesis of perfect parameter stability, the CUSUM statistic is zero however many residuals are included in the sum (because the expected value of a disturbance is always zero). A set of ±2 standard error bands is usually plotted around zero and any statistic lying outside the bands is taken as evidence of parameter instability. In addition, the CUSUMSQ test is based on a normalised version of the cumulative sums of squared residuals. The scaling is such that under the null hypothesis of parameter stability, the CUSUMSQ statistic will start at zero and end the sample with a value of 1. Again, a set of ±2 standard error bands is usually plotted around zero and any statistic lying outside these is taken as evidence of parameter instability.

Nominal values

The residuals from OLS regression models of Δl_nokus against time are plot in figures 3 and 4

Figure 3. Residuals from OLS regression (see Table 12)

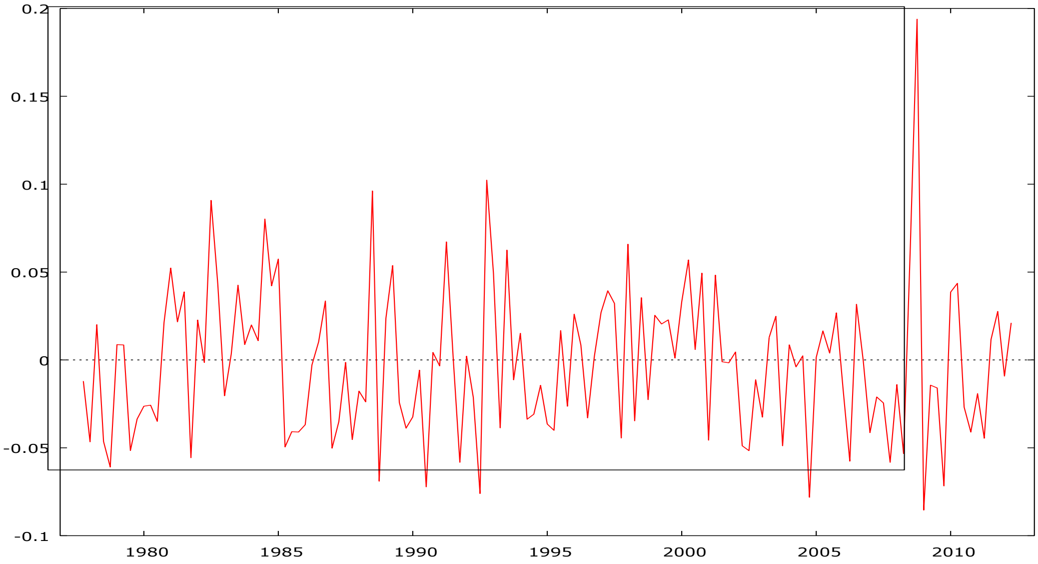
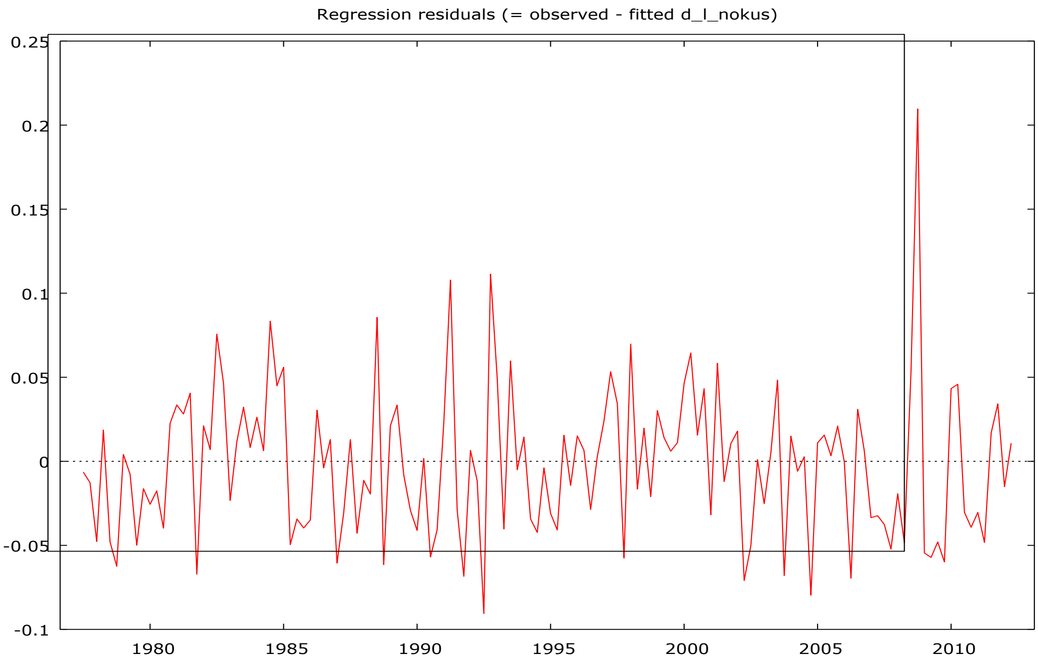


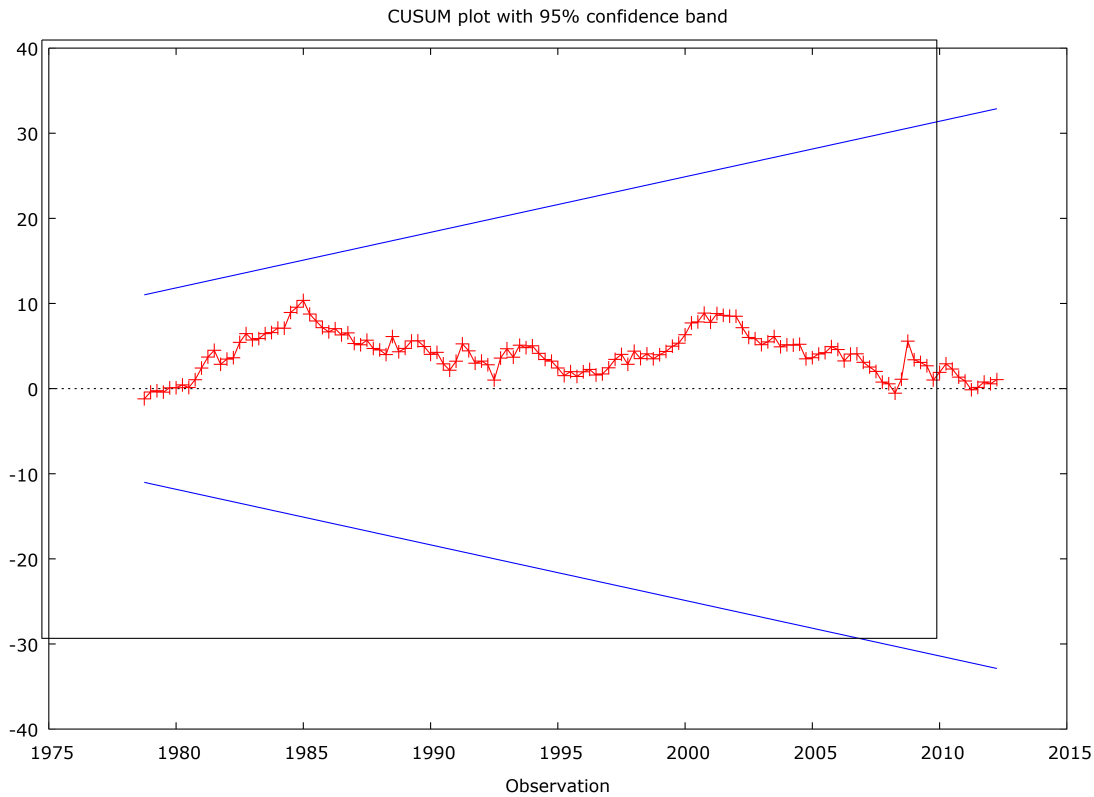

Figure 4. Residuals from OLS regression (see Table13)



QUSUM and QUSUMSQ

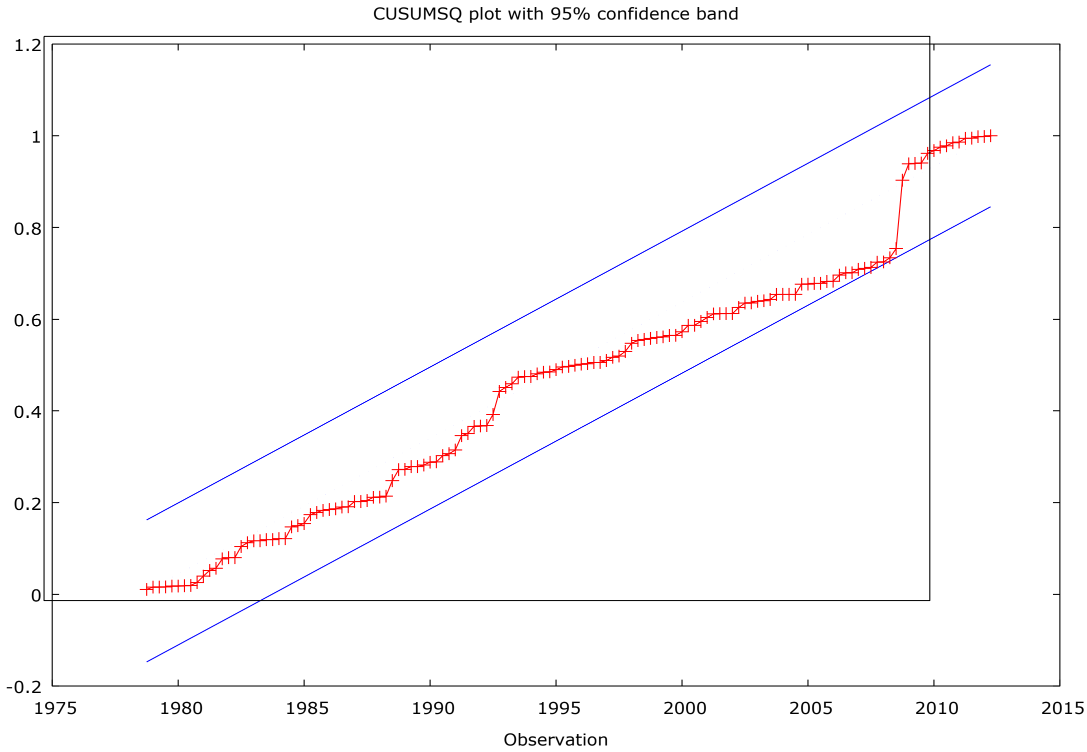
Figures 3 and 4 cannot confirm that the parameters of OLS models are stable. Thus, we perform CUSUM and CUSUMSQ test. The results are presented in figures 5, 6 and 7,8 for each OLS model.

Figure 5. CUSUM plot for the residuals of OLS regression model of Δl_nokus (see Table 12)



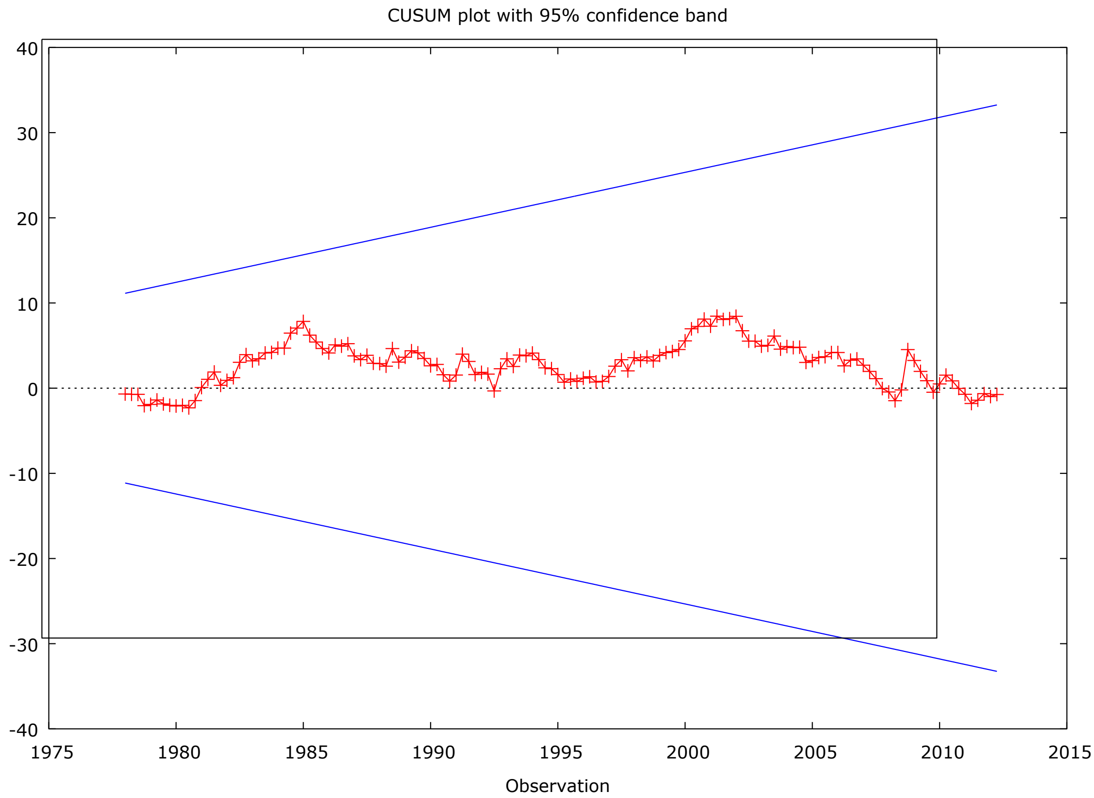

*Harvey-Collier t(134) = 0.0906623 with p-value 0.9279>0.05*

Figure 6. CUSUMSQ plot for the residuals of OLS regression model of Δl_nokus (see Table 12)



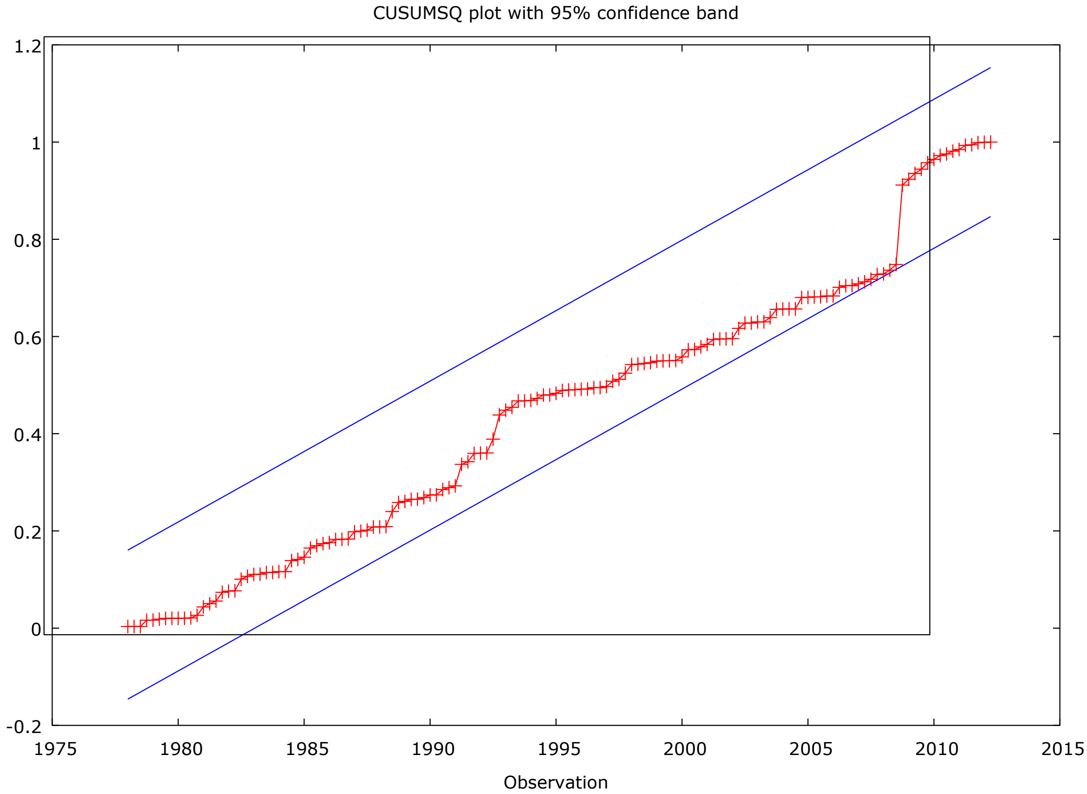

*Cumulated sum of squared residuals: none of the  values are outside of 95% confidence band*

Figure 7. CUSUM plot for the residuals of OLS regression model of Δl_nokus (see Table 13)




*Harvey-Collier t(137) = -0.0631667 with p-value 0.9497>0.05*

Figure 8. CUSUMSQ plot for the residuals of OLS regression model of Δl_nokus (see Table 13)



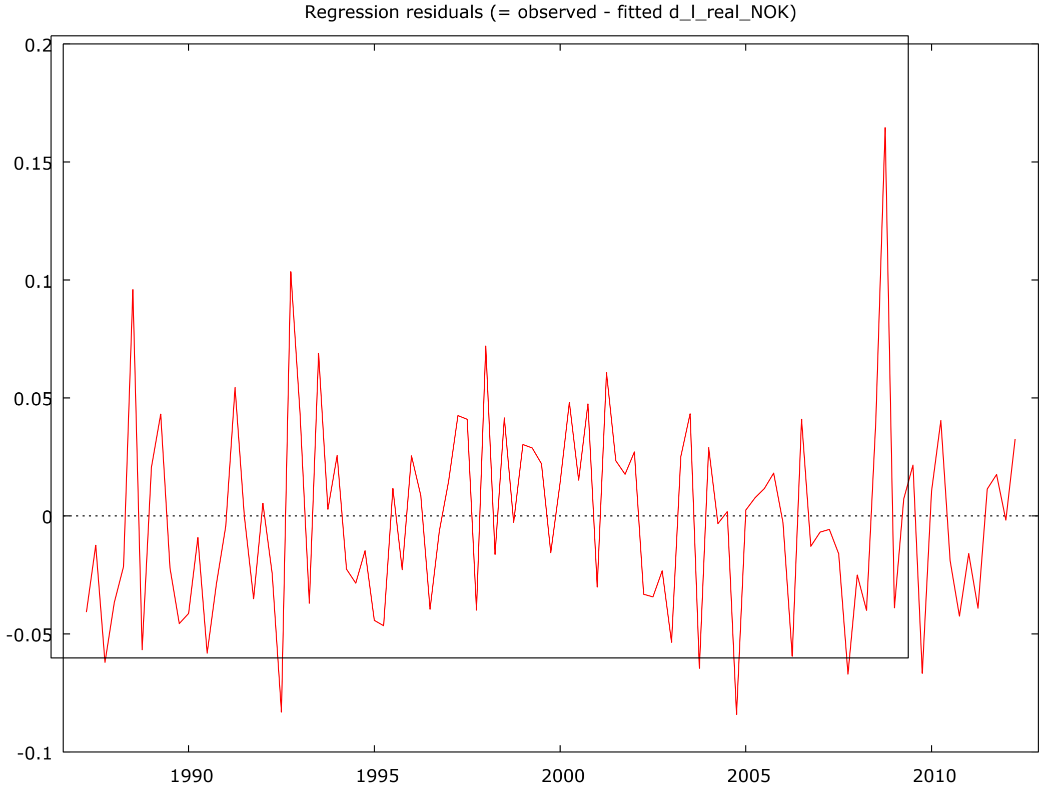

*Cumulated sum of squared residuals: none of the  values are outside of 95% confidence band*

The null hypothesis of the tests is that the stability of the parameters. At CUSUM tests, the p-value is higher than 0.05 . Moreover, we could easy observe that since the line is well within the confidence bands, the conclusion would be again that the null hypothesis of stability is not rejected.

<u>Real values</u>

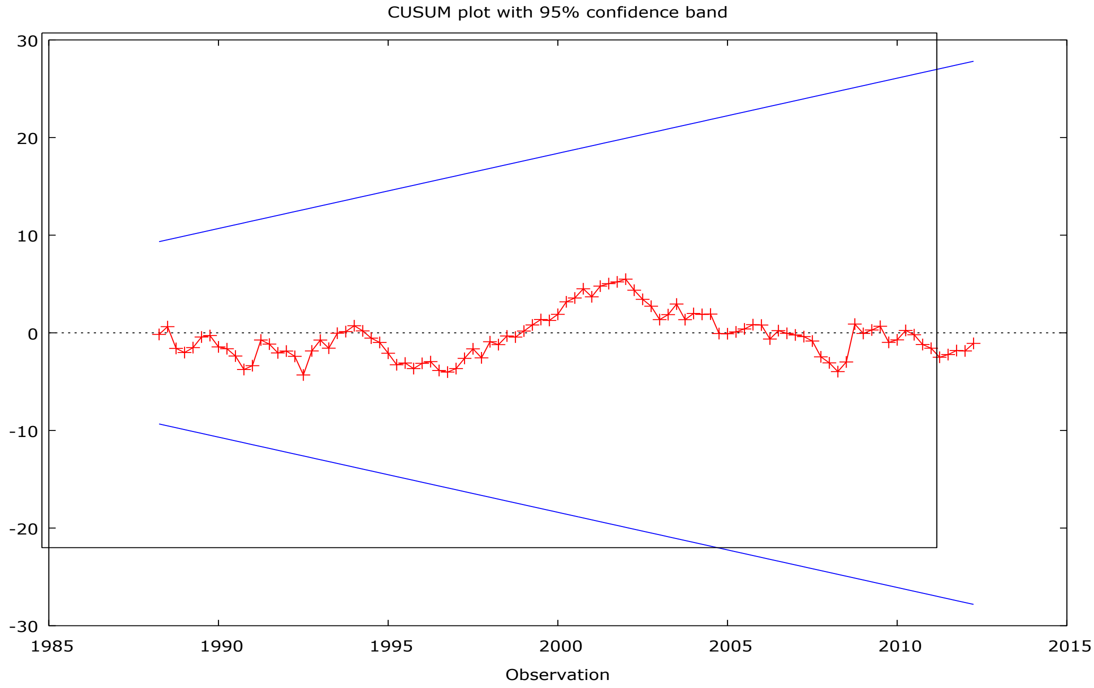
The same method followed to study the stability of OLS regression model on Δl_real_NOK. The residuals against time are plot in figures 9.

Figure 9. Residuals from OLS regression (see Table 14)



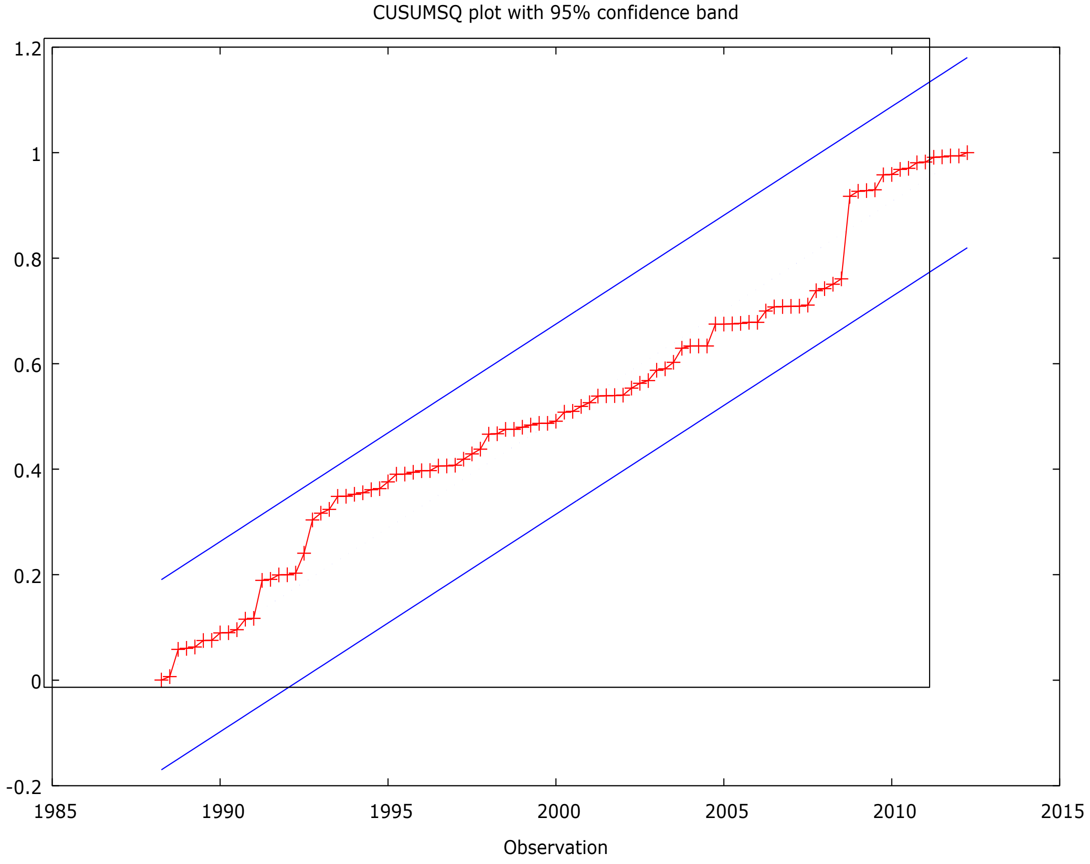

Figures 9 cannot confirm that the parameters of OLS models are stable. Thus, we perform CUSUM and CUSUMSQ test. The results are presented in figures 10 and 11.

Figure 10. CUSUM plot for the residuals of OLS regression model of Δl_real_NOK




*Harvey-Collier t(96) = -0.109967 with p-value 0.9127>0.05*

Figure 11. CUSUMSQ plot for the residuals of OLS regression model of Δl_real_NOK




*Cumulated sum of squared residuals: none of the  values are outside of 95% confidence band*

The null hypothesis of the tests is that the stability of the parameters. At CUSUM test, the p-value is higher than 0.05  . Besides, we could easy observe that  since the line is well within the confidence bands, the conclusion would be again that the null hypothesis of stability is not rejected.

## 4. Summary and conclusions

The price of crude oil is commonly believed to have a significant influence on the Norwegian exchange rate. Empirical studies have, however, provided mixed support for the assumed covariance between the oil price and the Norwegian exchange rate and most of them have suggested an ambiguous relationship between crude oil prices and exchange rates.

In this study we use quarterly data of nominal and real exchange rate of Norwegian krone against US$ to identify the relationship between the rates and the price of Brent oil. Norway is the sixth largest oil exporter and highly dependent on the petroleum sector, which accounts for the largest portion of export revenue and about 20% of government revenue. There appears to be a perception that the oil price influences the krone exchange rate. According to economic theory, a sustained rise in oil prices will result in more favorable terms of trade for an oil-exporting country such as Norway. This, in isolation, implies a strengthening of the exchange rate.

We found also that exchange rates and oil prices are cointegrated. They are moving together against time. The maximum elasticity of Brent oil price is 0.10 (real exchange rate). Thus, in the long run, a 1% increase in Brent oil price causes an appreciation of the NOK of 0.1% with standard error 0.02 . The negative coefficient means that a rise in oil price depreciates the ratio NOK/US$. Thus, the krone would be stronger against US$.

Furthermore, we have tested the rate of adjustment of the exchange rate. Error correction term (EC) is interpreted as a disequilibrium term. In VECM models, the EC terms are statistically significant. Moreover, we argued that adjustment to equilibrium has a slow rate because about 6.5% of the discrepancy between long-term and short-term l_nokus is corrected within a quarter. Besides, about 11% of the discrepancy between l_real_NOK and l_real_brent is corrected within a quarter. In addition, it is concluded that the short-term relationship between exchange rate and oil price has bilateral causality. On the other hand, tests performed to confirm the stability of parameters of the OLS regression models. The null hypothesis of stability is not rejected through CUSUM and CUSUMSQ tests.

In order to build a strong and robust model to predict krone exchange rate, it is rather important to include other variables that affect the krone exchange rate, like turbulence in international financial markets. In the international foreign exchange market, the Norwegian krone is regarded as a "peripheral" currency. In periods of high volatility in international financial markets, there is a tendency for international agents to seek to reduce the krone holdings in their portfolios. This leads to a depreciation of the krone.

The relationship between the krone exchange rate and the oil price probably depends on the degree of dependence of the domestic economy on the petroleum sector. If the level of domestic activity is largely independent of petroleum revenues, there is likely to be a weaker relationship between the krone exchange rate and the oil price. The Government Petroleum Fund may therefore contribute to making the krone exchange rate less dependent on the oil price.

## References

Akram, Q. F. and J. P. Holter (1996): Oil and the dollar - an empirical analysis. Economic credit 1996/3, Norges Bank, Oslo

Akram, Q. F. (2000), When does the oil price affect the Norwegian exchange rate?, Working Paper 2000/8, Norges Bank. URL:http://www.norges-bank.no/publikasjoner/arbeidsnotater/pdf/arb-2000-08.pdf.

Akram, Q. F. (2003), Real equilibrium exchange rates for Norway, Norges Banks Skriftserie / Occasional Papers No. 32

Akram, Q. F. (2004), Oil wealth and real exchange rates: The FEER for Norway, Working Paper 2004/16, Norges Bank.

Bernhardsen T., and Røisland Ø. (2000), Factors that influence the krone exchange rate, Economic Bulletin (Norges Bank), vol71 issue 4, p.143

Bjørnland, H. C. and H. Hungnes (2005),The commodity currency puzzle, Statistics Norway, Research Department/ Discussion Papers No. 423

Bjørvik, L. H., Mork, K. A. and B. H. Uppstad (1998), World price of oil affected the price of Norwegian krone? Norsk Økonomisk Tidsskrift, 1, 1-33.

Brooks, C. (2008), Introductory Econometrics for Finance, Cambridge University press, second edition, ISBN-13 978-0-521-69468-1

Burnham, K.P. and Anderson, D.R. (2002), Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach, 2nd ed. Springer-Verlag p. 287

Cashin P., L. F. Céspedes and R. Sahay (2003), Commodity currencies and the real exchange rate, Central Bank of Chile/Working Papers No. 236

Chen, Y., and K. S. Rogoff (2003), Commodity Currencies, Journal of International Economics 60, 133-169

CIA (2012), Norway Economy, World Factbook

Dickey, D.A. and W.A. Fuller (1979), Distribution of the Estimators for Autoregressive Time Series with a Unit Root, Journal of the American Statistical Association, 74, p. 427–431

Eitrheim, Ø. and K. Gulbrandsen (eds.) (2003), Explaining movements in the Norwegian exchange rate, Norges Banks Skriftserie / Occasional Papers No. 32

Frankel, Jeffrey A. and Andrew K. Rose (1995): "Empirical Research on Nominal Exchange Rates". In Grossman, Gene M. and Kenneth Rogoff (ed.) Handbook of International Economics Vol. 3, North- Holland.

Grytten, Ola H.(2010), The economic history of Norway, URL: http://eh.net/encyclopedia/article/grytten.norway

OLSEN, Ø. (2012), Monetary policy from the perspective of a commodity-exporting country, dinner speech from Norges Bank governor at the European Central Bank in Frankfurt, URL: www.norges-bank.no/en/about/published/speeches/2012/ecb/

Papadamou, S. and Markopoulos T. (2012), The Monetary Approach to the Exchange Rate Determination for a “Petrocurrency”: The Case of Norwegian Krone, International Atlantic Economic Society

Ploberger, Werner & Krämer, Walter, 1990, The Local Power of the CUSUM and CUSUM of Squares Tests, Econometric Theory, Cambridge University Press, vol. 6(03), pages 335-347, September.

Royal Ministry of Finance (2012), Press Release No.32/2012, URL: http://www.regjeringen.no/en/dep/fin/press-center/press-releases/2012

Speller, W. R. (2006), Real Exchange Rate Determinants in the Industrialised Commodity Currency Economies: An error- correction framework Master's Thesis in Economics Stockholm School of Economics, URL: http://arc.hhs.se/download.aspx?MediumId=204

United Nations, United Nations Commodity Trade Statistics Database, various issues