Norwegian School of Economics
Bergen, spring 2013

NORWEGIAN PETROLEUM TAXATION AND ITS EFFECT ON CONDITIONAL VARIANCE IN THE NORWEGIAN KRONE

EVIDENCE FROM THE NORWEGIAN KRONE – U.S. DOLLAR MARKET

Jon Håkon Findreng

Supervisor: Professor Liam Brunt

Master thesis within the main profile Financial Economics

NORWEGIAN SCHOOL OF ECONOMICS

ABSTRACT

The principles of Norwegian petroleum taxation create a loop of excessive currency exchange operations. Petroleum firms operating on the Norwegian shelf is obligated to pay tax in Norwegian krone. The government petroleum tax revenue is partly used to cover the non-oil national budget and partly invested in the Norwegian Government Pension Fund Global. Through monthly announcements, Norges Bank discloses how much foreign currency they plan to buy. This paper aims to analyse to what extent, if any, the volatility increases on those particular days. Several models are specified to explain the daily percentage change and the conditional variance in the Norwegian krone – U.S. dollar market over the period 29th of March, 2001 to 6th of May, 2013. Our findings indicate that the conditional variance was affected positively on announcement days prior to 1st of August, 2008. The econometric approach involves ordinary least squares, weighted least squares and several models from the general autoregressive conditional heteroskedasticity family.

FOREWORD

I would like to express my gratitude to Professor Liam Brunt, Per Marius Pettersen and Uliana Gorbolskaya. My thesis advisor Professor Brunt has provided me with helpful guidance and constructive discussion regarding all areas of my thesis, and has been available at all hours. Per Marius Pettersen is as fellow student at the Norwegian School of Economics who has been of great support through brainstorming, editing and his knowledge of economics. Uliana Gorbolskaya, a Harvard University student, provided a great help in editing and adding structure to the text.

CONTENTS

1 INTRODUCTION AND MOTIVATION

Today, the principles of Norwegian petroleum taxation create a loop of excessive currency exchange operations. Most income from the Norwegian petroleum sector is generated in foreign currency, which needs to be converted to the Norwegian krone to pay tax bills. Part of the taxation is used to cover the non-oil budget deficit. According to a fiscal rule, this part cannot exceed four percent of the Norwegian Government Pension Fund Global in yearly expenditures. The remaining part of the tax income is transferred to the Norwegian Government Pension Fund Global, which is invested exclusively in foreign currencies. [1] Thus, the money has to be converted once again. Consequently, the Norwegian Central Bank, Norges Bank, must sell significant amounts of local currency in the Norwegian money market. The currency exchanges are done daily, based on the monthly schedule announced by Norges Bank (Aamodt, 2012).

In a letter sent to the Norwegian Ministry of Finance, November the 15th 2001, the Norwegian Oil and Gas Association requested an option to pay the Norwegian petroleum tax in foreign currency. On 20th of December 2002, the Ministry of Finance denied the request through a public letter (Sollund & Lystad, 2002). In additional to the extra administration cost related to operating with foreign currencies, the Ministry of Finance notes the relatively low liquidity of the Norwegian money market. They argue that an elimination of the operations caused by the petroleum taxation could create wide fluctuations in the short term market.

The purpose of this paper is to quantify what effect, if any, this extra transaction through the Norwegian krone has on fluctuations in the Norwegian currency market. The research is based on the assumption of efficient markets. Thus, the paper aims to study how the information provided to the market, on days when Norges Bank announces its monthly foreign exchange purchase plan, affects the daily fluctuations. If significantly higher volatility is found on those specific days, this could be an argument for encouraging or mandating firms, who are obliged to pay petroleum taxes, do so in foreign currency. The data applied covers the period from March 29th, 2001, when Norway officially changed their monetary policy from a fixed exchange regime to a floating exchange regime, to May 2013.

Chapter 2 provides an outline of the Norwegian petroleum taxation system with a focus on the - perhaps unnecessary - transaction through the Norwegian money market. Chapter 3

[1] The Norwegian Government Pension Fund Global is managed by Norges Bank Investment Management (NBIM) on behalf of the Ministry of Finance.

discusses factors believed to affect the daily changes in the exchange rate between the Norwegian krone and the U.S. dollar (expressed as the Norwegian krone per U.S. dollar).

Chapter 4 covers the econometric approach and the variables used to quantify the impact on fluctuation in the Norwegian money market, possibly created by Norges Bank's monthly announcements. The first approach is done by a simple OLS regression of the absolute change in the exchange rate on the particular dates when Norges Bank announces the daily purchase in foreign currency for the next month. In the second approach we first attempt to create a model explaining the short term changes in the krone-dollar exchange rate. This is followed by a regression trying to explain the residuals obtained from the former model. The idea is to test whether the absolute residuals are significantly higher on announcement dates. This approach also includes a possible structural change, as the petroleum taxation system was updated in 2008. The final approach attempts to explain the fluctuations in the Norwegian currency market through the general autoregressive conditional heteroskedasticity model family (GARCH). Chapter 5 summarizes the results and chapter 6 provides a conclusion.

Optimally, the research could also have included other bilateral exchange rates, or indices of foreign currencies. Doing that would enrich the discussion. However, in this research paper, only the exchange rate between the Norwegian krone and U.S. dollar is analyzed.

2 BACKGROUND

2.1 THE PETROLEUM TAXATION SYSTEM

The Norwegian Government Pension Fund Global (GPFG) today is worth more than 4 300 billion NOK[2], or about 750 billion USD[3]. The total amount is invested solely in foreign currency. It was established in 1990, but the first transfer was not carried out until 1996.

The GPFG is financed by the Norwegian government's petroleum revenue, which is derived from three sources: the State's Direct Financial Interest (SDFI), managed by Petro AS, petroleum taxes from firms operating on the Norwegian shelf[4]; and dividends from Statoil ASA, in which the government owns about two thirds of the shares. Government petroleum revenues are divided into two parts. One part is to cover the non-oil national budget deficit. The non-oil national budget deficit is the difference between governmental income, without the petroleum revenues, and governmental expenditures. The amount to be covered by petroleum revenues is determined by the overall economic situation on the short term and a fiscal rule on the long term. When the economic situation is bad, the government might have abnormally high expenditures and abnormally low revenues. A situation like this can be offset by using a larger share of the petroleum revenue. When the overall economic situation is bright, the government can choose to use less petroleum revenue in the national budget. In the long run, the fiscal policy is bound by a fiscal rule. The fiscal rule states that the non-oil national budget deficit should equal the expected real return from GPFG's investments. This is estimated to be four percent. The second part of the government petroleum revenues are transferred to GPFG. The relationship can be expressed as follows (Aamodt, Petroleumsfondsmekanismen og Norges Banks valutakjøp til SPU, 2012):

$$Cash\ flow\ from\ petrolium\ activities = Petroleum\ taxation + Revenues\ from\ SDFI + Dividends\ from\ Statoil = Non-oil\ national\ budget\ deficit + Transfers\ to\ GPFG$$

Taxation and dividends are paid in Norwegian krone. The petroleum tax is payable six times a year, on the first day of every even-numbered month. Before the first of August 2008, the tax was paid only two times a year. The first was paid on 1st of October in the fiscal year; the second was paid on 1st of April the following year. Most revenues from the petroleum sector are earned in foreign currency, so the petroleum firms need to change huge amounts of

[2] NBIM 5.9.2013
[3] NOK/USD = 5.75, 5.9.2013
[4] The marginal tax rate for firms operating on the Norwegian Shelf is 78 percent (Oljeskattekontoret, 2013).

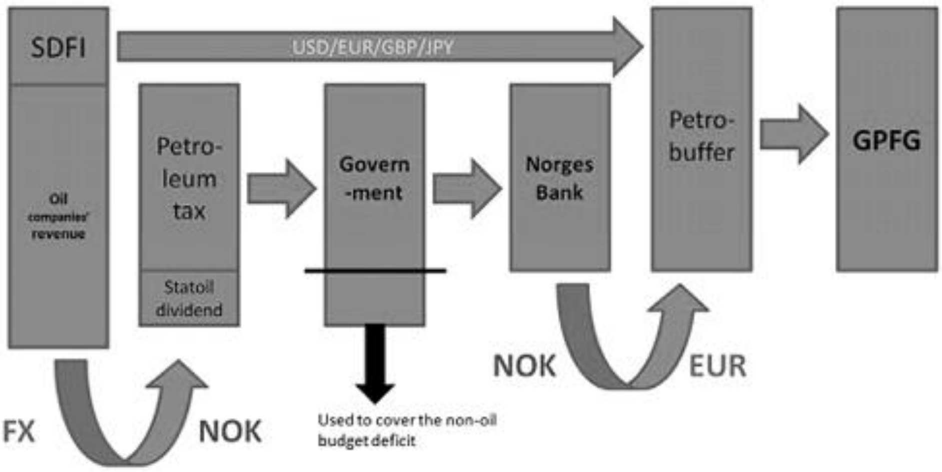
currency to meet their obligation. Dividends from Statoil ASA are paid once a year. Since GPFG is solely invested in foreign currency, Norges Bank' (on the behalf of the Ministry of Finance') needs to buy foreign currency for the part that is transferred to GPFG. Norges Bank decides each month how much currency to buy. The amount is announced on the last business day of the preceding month. The purchasing is then spread evenly between every day of the month. Until 2012, it was not considered normal to purchase foreign currency in December. This was prompted by the lower liquidity in international finance markets at the end of the year, making it less attractive for GPFG to invest. The monthly purchase is given by the following model (Aamodt, 2012):

$$Foreign\ \ currency\,purchase = \ Allocations\ to\ GPFG - SDFI\ foreign\,currency\ income \\ + (Balance\ petrobuffer\ start\ of\ month - Balance\ petrobuffer\ end\ of\ month)$$

The allocations to GPFG are affected by several factors, such as oil- and gas prices, the health of the economy and petroleum production. All revenues from SDFI in foreign currency are transferred directly to a so-called petrobuffer, as it is governmental and therefor exempt from taxation. Petroleum taxes, dividends from Statoil ASA and the non-oil national budget deficit may fluctuate. In order to reduce fluctuations in the currency purchases, the petro-buffer was established. As foreign currency is bought, it is transferred to this temporary account.

The transfer from the petrobuffer to GPFG is done on the first day of every month. As the petrobuffer is allowed to change in size over time, the purchases and the transfers are able to be smoothed and do not need to deviate from what is planned. This transaction scheme is illustrated in figure 1 (Aamodt, 2012).

Figure 1: Governmental Petroleum Revenues and the Transmission to GPFG



Notes: FX denotes foreign currency. The foreign currencies in the model are for illustrational purposes. They must therefore not be taken literally as Norges Bank and the petroleum firms are operating with several different currencies. Source: The Norwegian Central Bank 2013.

2.2 The Operations of Norges Bank

A simplified balance sheet for Norges Bank is given in table 1**.** An increase in Norges Bank's assets will, in isolation, increase the liquidity in the banking system through the private bank's deposits in Norges Bank. An isolated increase in L1-L4 and L6-L8, without an increase in assets, will decrease the liquidity in the bank system (the bank's deposits, given by L5, will decrease) (Flatner & Tornes, 2002).

In a hypothetical situation where the non-oil national budget deficit is zero, the long term effect on the krone exchange rate due to the payment by the Norwegian krone would be zero. The firms operating on the Norwegian shelf would have to buy Norwegian krone in the currency market to meet their tax obligation. This puts pressure on the krone. The purchased krone is then placed as deposits in Norges Bank through a private bank. When the taxation is paid, there will be a withdrawal from the bank's deposit in Norges Bank. The money is transferred to the account for government deposits. This will reduce the liquidity in the banking system. In isolation, this will put pressure on the interest rate in the money market and lead to an increase in the krone. Both the increase in supply for the krone and the reduction in the liquidity are offset when Norges Bank purchases foreign currency. Norges Bank purchases foreign currency from private banks. Money is therefore transferred back to the private bank's deposit account, as the assets side of Norges Bank's balance sheet increases

Table 1: Norges Bank's Balance Sheet

Assets	Liabilities
A1 Currency receivables	L1 Bills and coins
A2 Governmental securities	L2 Governmental deposits
A3 Loans to banks	L3 Deposit for governmental securities
A4 Other assets	L4 Other public deposits
	L5 Bank's deposits
	L6 Other deposits from banks
	L7 Remaining deposits
	L8 Other liabilities

Notes: A simplified version of Norges Bank's balance sheet. L5 equals the total liquidity in the banking system. In reality this can be seen as the overall liquidity as bills and coins constitute a relatively small part.

by foreign currency. This increases the liquidity and increases the supply for krone. Both the original increase in the demand and the original decrease in the liquidity are therefore offset.

However, the money market rates in Norway are controlled indirectly through a floor system.[5] The change in liquidity is therefore not likely to affect either the interest rate or the value of the krone. If the liquidity change were large enough to change the money market rates, then the central bank would likely offset it by supplying liquidity through another channel.

2.3 An Unnecessary Cycle of Purchases?

The currency trading loop explained in the last subsection might seem unnecessary. The trading does improve the liquidity in Norwegian money markets, but the trading might create undesirable fluctuations in the value of the Norwegian krone, both as petroleum firms purchase krone and when the central bank purchases foreign currency. In the example above, there were no petroleum revenues used to cover the non-oil national budget deficit. The whole process was therefore unnecessary as petroleum revenue could have been transferred directly to the petrobuffer. As long as the amount used to cover the non-oil national budget deficit is less than fifty percent of the petroleum tax revenues, the volume of transactions would be reduced if the tax were collected in foreign currency and transferred directly to the petrobuffer, in line with the request by the Norwegian Oil and Gas Association.

It should be mentioned that the krone is assumed to appreciate as the Norwegian government uses revenues made in foreign currency in the national budget. However, this paper aims to research the possible extra fluctuations created by the current system for petroleum taxation. Measuring the extra fluctuations in the krone created by the petroleum taxation system is a

[5] See the appendix for an illustration regarding the floor system.

hard task. The focus of this paper is limited to the Norges Bank's purchase of foreign currency and does not analyze petroleum firms purchasing krone, even though focusing on both parts of the process would give more insight.

The money markets are assumed to be efficient.[6] In other words, the exchange rate is supposed to reflect all information available to the market. The money market reacts only to newly available information. For example, if the market knows that one week from now a foreign investor will buy a huge amount of krone for speculation, the krone is expected to appreciate immediately, as a result of the increased demand one week from now. In response to the expected appreciation, other investors will buy krone until there is no more profit to be made. The krone will therefore appreciate close to immediately after the new information becomes available. With this assumption, this paper will investigate the fluctuations on the specific days when Norges Bank announces how much foreign currency they will purchase the following month. A finding of significantly higher fluctuations on those particular days will therefore serve as an argument against the current petroleum taxation system.

3 Factors Driving the Norwegian Exchange Rate

Currency exchange for financial purposes is far larger than currency exchanges needed for trading goods[7]. The exchange rate can therefore be seen as the discounted value of such fundamental factors as monetary policy, economic development, risk premiums, assets prices, the trade balance and oil prices. Formally this can be written as

$$S_t = \left(\frac{1}{1+\alpha}\right) \sum_{i=0}^{\infty} \left(\frac{\alpha}{1+\alpha}\right)^i E_t f_{t+i},$$

where $E_t f_{t+i}$ is the expected value of the logarithm of the future fundamental factors, α is the discount factor and *t* denotes time. In this perspective, the demand for the currency is a result of actual and expected returns (Aamodt, 2009). In this section of the paper, factors that affect the exchange rate are discussed. The variables to include in a short term model for the exchange rate between the U.S. dollar and the NOK are then chosen in the following chapter.

[6] See the appendix for a formal discussion about market efficiency.
[7] Aamodt (2009) argues that purchase of foreign currency for financial purposes is about four times larger than foreign currency purchases for trading in goods.

3.2 NORWEGIAN MONETARY POLICY

Norwegian monetary policy has historically been based on fixed exchange rate regimes. In 1994 Norway implemented a regulation that said that the operational goal of monetary policy was to ensure a stable exchange rate. Even though the regulation did not formulate a specific interval, the general opinion was that the krone was supposed to be between 8.2 and 8.4 against the euro[8]. Throughout 1998, there was high growth in Norwegian wages, turmoil in the currency market and the Norwegian krone was under speculative attacks. The key interest rate was increased from 3.5 percent to 8 percent, a level too high for the economic situation in Norway at the time. In January 1999, the central bank changed focus from exchange rates to inflation targeting. Even though it was still a fixed exchange regime, the change of focus did not violate the regulations, as the currency actually became more stable. On the 29th of March, 2001 an official target for inflation with a floating exchange rate regime was introduced. The inflation target was set at 2.5 percent. At the same time, the fiscal rule was introduced, stating that only 4 percent of the Norwegian Government Pension Fund Global can be used to cover the national budget deficit (Thøgersen, 2011).

The inflation target requires transparency, as the market participants need to understand the interest rate decision. Consequently, Norges Bank needs to create trust and transparency surrounding its decisions in order to convince market participants to act in line with the intentioned policy. In 2005 the central bank started publishing predictions about future interest rates. This created international attention as the central bank of New Zealand was the only central bank that had ever done something similar. The interest rate forecast is an important part of Norges Bank's communication strategy (Thøgersen, 2011).

As the key interest rate[9] set by the central bank is a very short-term interest rate, it is expectations about future policy that affect the longer market interest rates and economic decisions. Since 2005, the volatility on days when the key interest rate is decided has decreased (Holmsen, Qvigstad, Røisland, & Solberg-Johansen, 2008).

3.2.1 NORGES BANK'S LOSS FUNCTION

Norwegian monetary policy follows a flexible inflation target. In practice this means that Norges Bank can deviate from the inflation target in favor of other factors that Norges Bank

[8] Before the Euro was introduced in 1999 the European Currency Unit (ECU), which is a basket of European currencies, was used.

[9] The key interest rate is the interest rate banks earn on their deposits in Norges Bank overnight.

considers important. In general, Norges Bank follows three criteria in deciding the key interest rate. First, the interest rate should be set so that inflation is stable, or that a deviation from the inflation target is brought back to the desired level. Second, the path chosen for the interest rate should be balanced between inflation considerations and the path for overall capacity utilization in the economy. In other words, deviations from normal output need to be taken into account. Third, the interest rate should be set to ensure interest smoothing avoid deviations from what is considered a normal interest rate. Norges Bank's loss function as of 2012 is given by

$$L_t = (\pi_t - \pi^*)^2 + \lambda(y_t - y_t^*)^2 + \gamma(i_t - i_{t-1})^2 + \tau(i_t - i_t^*)^2,$$

where π denotes inflation, *y* denotes output, *i* denotes the interest rate, *t* denotes time and * denotes the normal[10] level or the target. λ, γ and τ indicate how much detention is given to deviations in output, interest rate smoothing and deviations in the interest rate, respectively.[11] A successful interest rate is set to minimize L_t. The weightings inside the function and the function itself have been changing, and will probably also change in the future. For instance, the last term (regarding deviations of the interest rate from normal levels), was new in 2012, in order to help mitigate the risk of a build-up of financial imbalances (Evjen & Kloster, 2012).

3.3 The Current Account Deficit and the Exchange Rate

Bernanke (2005) describes the current account deficit from two perspectives. The first view focuses on trade flows and related payments. This is, for many countries, mostly the difference between exports and imports[12]. If exports are larger than imports then the nation will have a trade surplus and this will create higher demand for the domestic currency (leading to an appreciation). The second view, which Bernanke (2005) explains to be equivalent, focuses on investments and national savings. If the nation's savings are higher than the nation's investments, then the excess value can be transferred out of the country to a nation where there is need for capital. This will create a supply of currency and lead to a depreciation.

[10] A normal output implies a zero output gap, while a normal interest rate is the interest rate where the economy is neither pressured upwards or downwards.
[11] Norges Bank varies the coefficient adjusted for the economic situation. For example announced Norges Bank in March 2012 the following coefficients: λ = 0,75, γ = 0,25 og τ = 0,05 (Norges-Bank, 2012).
[12] The account deficit consists of export versus import, but also from payments such as dividends, interest and remittances.

Focusing on the first view, it is straightforward that prices of exported products partly determine the value of the Norwegian krone. A higher price of exported goods will create a higher demand for the domestic currency. A typical example for the Norwegian economy is the exports due to the petroleum sector. In the last decade the petroleum sector has been fluctuating around 20 percent of total gross national product (Oljeskattekontoret, 2013). A higher oil price is therefore assumed to have an appreciating effect on the Norwegian krone. Bernhardsen and Røisland (2000) find that over the period 1993 to 2000 a one percentage increase in the oil price appreciated the Norwegian krone by 0.02 percentages against a trade-weighted synthetic currency, in the short run. They also find a long term solution where the corresponding change was 0.06 percentages.

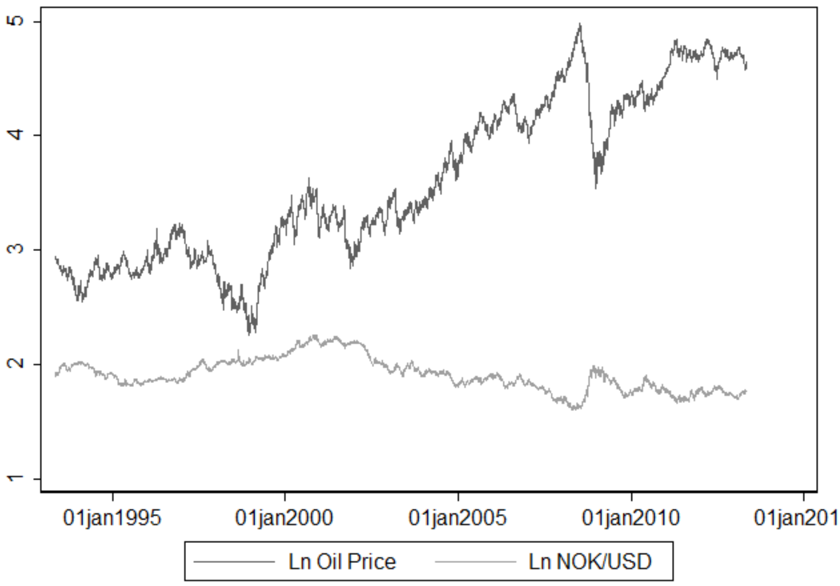
Focusing on the second view presented by Bernanke (2005), one could look at the oil price as an indicator of the attractiveness of investing in the Norwegian petroleum sector. If investment is increasing, then the Norwegian krone will appreciate. However, within this perspective it is rather important to focus on the future rather than the present. First of all, it is not given that today's oil price is permanent. Second, and perhaps most importantly, the discounted future cash flow from the petroleum sector must be evaluated. The value of the unused petroleum on the Norwegian continental self is a determining factor, even though we can only rely on general estimates.

Figure 2 displays the development of the oil price and the exchange rate expressed as the price of one U.S. dollar in krone, both series in logarithmic form, from the 6th of May 1993 to the 6th of May 2013. Ignoring other factors affecting the two series, it seems as the two series are negatively correlated, in line with what we could expect.

Still focusing on investments, savings and international capital flows, the stock market may be a determining factor for the krone. An increase in the Norwegian stock market puts pressure on the demand for the Norwegian krone, directly dependent on the degree of international buyers. Following the same argument as for the oil, the stock market reflects discounted future cash flow, and is therefore an indicator of the investments done in Norway.[13]

[13] This argument is in line with the efficient markets hypothesis.

Figure 2: Oil Price Versus $\frac{NOK}{USD}$, 1993-2013



3.4 Purchasing Power Parity

Purchasing power parity (PPP) claims that goods market arbitrage forces goods to have the same price in different countries, after converting to the same currency (Rogoff, 1996). The law of one price is given by $P_i = SP_i^*$, where P_i is the domestic price of product i, P_i^* is the foreign price of product i, and S is the exchange rate expressed as the price of one unit foreign currency in domestic currency. It is intuitively clear that the law of one price does not hold for most products. For instance, Rogoff (1996) illustrates how the price of a BigMac purchased at McDonald's differs across national borders. He also argues that even though there are highly international traded commodities, such as oil and gold, for which the law of one price holds, these products are rather the exceptions than the rule.

Absolute purchasing power is given by $\sum P_i = S \sum P_i^*$, where the sums are taken over a consumer price index. There are especially two problems in measuring absolute purchasing power parity. First, and perhaps the more obvious problem, concerns which consumer price index to use. Consumer price indices differ across countries. Governments do not construct indices with an international standard.[14] The consumption weights are shifting and new products are introduced (Rogoff, 1996). The second problem is due to the base year. There will not exist any information regarding whether PPP holds in the year chosen as the base

[14] There have been attempts on making an international basket of goods for comparison. However, the basket has proved to have number of limitations (Rogoff, 1996).

year for the consumer price index. If there are deviations from PPP in the base year, but the parity holds afterwards, this is not entirely proof of absolute power purchasing parity. Another scenario could be that the deviation is reversed in the period after the base year, thus PPP holds in the years after, but because of the base year, it will seem that the absolute purchasing power does not hold.

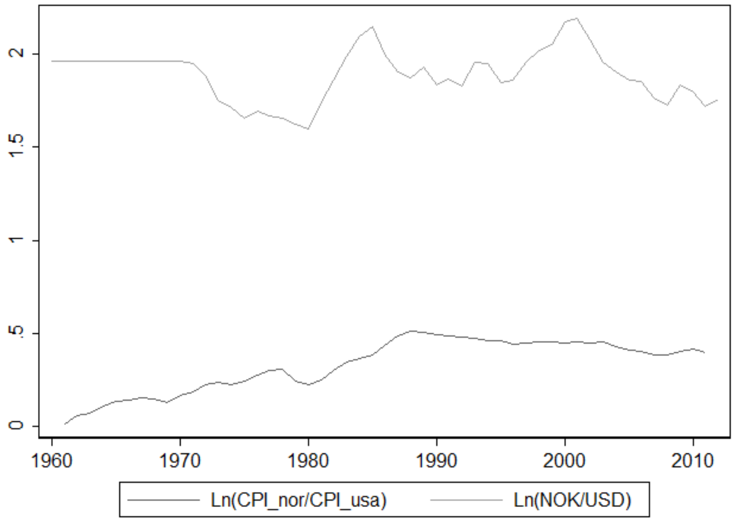
Relative purchasing power is given by

$$\frac{\sum P_{it}}{\sum P_{it-1}} = \frac{S_t}{S_{t-1}} * \frac{\sum P_{it}^*}{\sum P_{it-1}^*},$$

where *t* denotes time. Relative PPP states that a change in the exchange rate is offset by the change in domestic and foreign prices (Rogoff, 1996). If for instance the domestic currency appreciates, this needs to be offset by a fall in foreign prices relative to domestic prices.

Throughout his article, Rogoff (1996) refers to several empirical studies that have found inconsistent results regarding the validity of PPP. It seems that, in the very long run, exchange rates and price levels tend towards PPP. However, there are deviations from PPP in the short run. The exchange rates are more volatile than the price levels. The price levels shift too slowly to keep up with exchange rate changes in the short run. In other words, inflation is sticky. Figure 3 shows the development in the exchange rate and the development in price levels between Norway and USA over the period 1961 to 2011. From the graph, it is clear that the exchange rate is far more volatile than the relative price level. Until 1973, there were no changes in the exchange rate between Norway and USA; in this period Norway was in the Bretton Woods regime with a fixed exchange rate to USD. During Bretton Woods, the Norwegian prices increased relatively to the U.S. prices, and this shows pretty clearly the lack of relationship suggested by PPP. As studies have trouble proving a long term relationship between the two series, it is pretty clear that in an attempt to estimate the daily changes in the exchange rate between the Norwegian krone and the U.S. dollar is not likely to be a successful one. In addition, inflation indices are not reported on a daily basis.

Figure 3: Exchange Rate and Relative Price Level in Norway versus USA, 1961-2011



3.4.2 Imported Inflation

An increase in the key interest rate will generally lead to a stronger domestic currency. As inflation is sticky and does not react fast, the immediate change in inflation is due to imported inflation. A higher currency leads to cheaper imports of foreign goods, leading directly to a fall in the consumer price index. Cheaper inputs to domestically produced goods lead to an indirect fall in the consumer price index. The inflation rate will therefore fall as a result of the imported deflation (Røisland & Sveen, 2006).

3.5 Interest Parity

Covered interest parity explains the relationship between today's exchange rate, the expected exchange rate in $t + 1$, and the money market interest rate. In the following subsections, interest parity is explained through covered interest rate and uncovered interest rate. In covered interest rate, the investor is hedged against all risk. In uncovered interest rate, the formula builds on the investor's expectations about the future exchange rate.

3.5.1 Covered Interest Parity

Covered interest parity implies that it is impossible to obtain arbitrage in currency exchanges. This can be illustrated with an example where a Norwegian investor holds one unit of foreign currency. There are two ways to invest that unit of currency, risk free over the period; in the Norwegian money market, or in the money market where the foreign currency is denominated. In the first alternative, the investor transfers the foreign unit to NOK in today's spot market, and invests it in the Norwegian money market. At the end of the period, she will receive

$1 * s_t * (1 + i^{NOK})$, where s_t is today's spot exchange rate and i^{NOK} is in the interest rate earned in the Norwegian money market.

In the second alternative, the investor places the unit of foreign currency in the foreign money market. At the same time, she sells the same unit inclusive interest rates on the forward market. The investor will then receive $1 * (1 + i^*) * F_t$ at the end of the period. i^* is the interest rate in the foreign money market and F_t is the exchange rate determined by the forward market.

If there are no arbitrage opportunities, then these two options will create the same return. In other words:

$$1 * s_t * (1 + i^{NOK}) = 1 * (1 + i^*) * F_t.$$

This can be rewritten as

$$i^{NOK} - i^* = \frac{F_t - S_t}{S_t} * (1 + i^*).$$

The difference in the money market interest rate is equal to the forward premium adjusted for foreign interest rate. This example ignores transaction costs (Klovland, 2012).

3.5.2 Uncovered Interest Parity

With uncovered interest parity, the investor does not hedge her risk. Thus, the investment is not risk free. The relationship between interest rates and the exchange rates builds on actual and expected values. More formally, instead of using a forward agreement, the expected exchange, $E_t[S_{t+1}]$, is used. The relationship can then be showed as

$$i^{NOK} - i^* = \frac{E_t[S_{t+1}] - S_t}{S_t} * (1 + i^*).$$

There is no unambiguous belief about the value of $E_t[S_{t+1}]$; therefore it depends on each investor's belief about the future, and the average of these beliefs (Klovland, 2012).

3.5.3 Implications of Interest Parity

According to uncovered interest parity, a relative increase in the Norwegian money market interest rate is offset by a lower expectation for Norwegian currency (a higher exchange rate, as the exchange rate is expressed as the price of one foreign unit in Norwegian krone). In other words, higher interest rates, are associated with lower expected exchange rates (Juel, Haarberg, & Brice, 2002).

3.5.4 The Link Between Interest Parity and Purchasing Power Parity

If inflation differences are assumed to be the basis of the market's expectations regarding the future exchange rate, then the interest difference will equal the inflation difference (Juel, Haarberg, & Brice, 2002). With this perspective, the link between uncovered interest parity and relative power purchasing parity is quite clear. An increase in inflation or interest rates will make the krone depreciate. Both these theories are straightforward, but they both lack empirical evidence (Juel, Haarberg, & Brice, 2002).

3.5.5 Overshooting

An increase in the money market interest rate will make the Norwegian money market more attractive as an investment opportunity. As opposed to power purchasing parity and uncovered interest parity, which predict a fall in the currency, in the short term one can expect the krone to appreciate and then depreciate gradually. This phenomenon is called overshooting (Bjørnstad & Jansen, 2006). Consequently this implies that - one a daily basis - one could expect that an increase in the domestic interest rate, relative to foreign interest rate, would give an appreciation in the domestic currency.

3.6 The Norwegian Krone as a Safe Haven

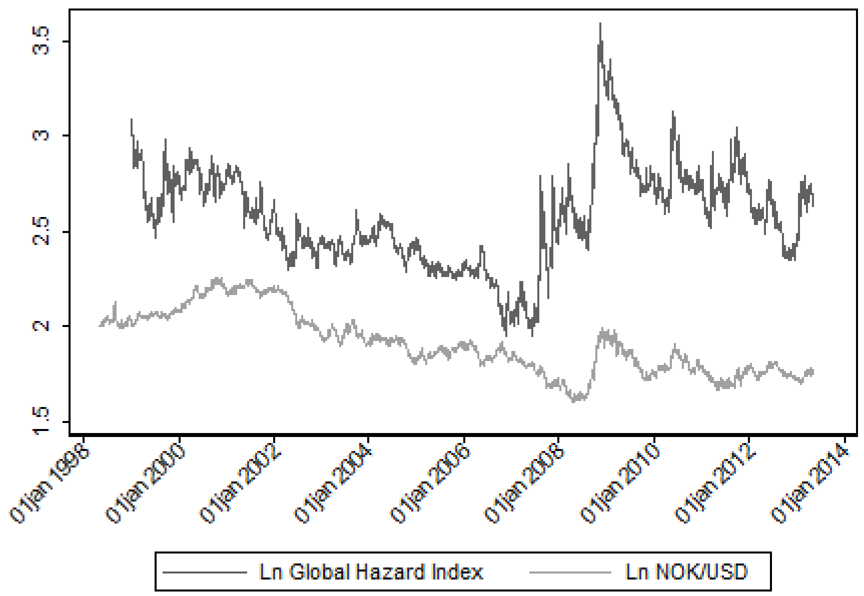
The Norwegian economy is strong, and has been over the last decade. The media has at times described the Norwegian krone as a safe haven for international investors, especially during the financial crisis from 2007 to 2009, and during the ongoing crisis in Europe. As early as 2002, the Financial Times designated the Norwegian krone a "safe haven par excellence"; and in October of the same year, a Reuter's survey concluded that the Norwegian krone is the best investment protection against currency turbulence from a possible war in Iraq. Geopolitical turmoil would increase the oil price and Norway has an economy that can handle a strong currency (Juel, Haarberg, & Brice, 2002).

If Norwegian krone is a safe haven, one would expect the krone to appreciate as turbulence in the international money market increases. Flatner (2009) analyzes the Norwegian krone and its correlation with several indicators of financial turmoil during the financial crisis, 2007-2009. The Norwegian krone was both argued to be a safe haven and to be the opposite. On the one hand, Norway has a solid financial position and is expected to manage financial crises relatively better than other countries. On the other hand, the krone is peripheral and liquidity is low (Flatner, 2009). Flatner (2009) finds no clear evidence to support either argument. However, he argues that liquidity of the Norwegian krone dried up too much during the fall of

2008, so that the Norwegian krone could not be assessed as a safe haven during the financial crisis.

As suggested by Brousseau and Scacciavillani (1999), we are using the global hazard index (HGI) which is based on implied volatility in the U.S. dollar, the Japanese yen and the euro. [15] Figure 4 displays the development of the GHI and NOK/USD exchange rate over the period 4th of January 1999 to 6th of May 2013. Both variables are in their logarithmic form. Even though there is not a clear relationship between the two series over the period, it might seem that they have a negative correlation in the early 2000s, but a positive correlation during the financial crisis (2007-2009). In other words, the relationship between the two variables seems ambiguous, consistent with Flatner's (2009) findings.

Figure 4: GHI and NOK/USD 04.01.1999-06.05.2013



[15] See the appendix for a discussion and the deriving of the formula behind the global hazard index.

4 Econometric Approach and Variables

This section discusses the econometric approach and its accompanying variables to explain the daily percentage change in the exchange rate between the Norwegian krone and the U.S. dollar; and the impact on fluctuations possibly created by the Norges Bank monthly announcements.

4.1 Econometric Approach

In this paper three approaches are adopted to measure whether the daily change in the exchange rate is higher on Norges Bank's announcement dates. The first approach is simply a regression of the absolute daily percentage change in the exchange rate on a binary variable for the announcement dates.

In the second approach a model explaining the daily percentage change in the exchange rate is created. The residuals from this regression are then obtained. Then the absolute values of the residuals are regressed on announcement dates and other possible independent variables, as outlined in section 3. This enables us to analyze whether the residual is conditional on a set of independent variables. In this approach it is important to consider whether a particular variable affects the exchange rate in one or the other direction, or if it is just affecting the absolute magnitude of a change in the exchange rate. For example, it is not clear whether increased global volatility drives the exchange rate to increase or decrease; however, increased volatility is likely to increase the absolute change in the exchange rate. If the variable is assumed to increase the absolute change, independent of the direction, it is used as an explanatory variable in the model explaining the absolute value of the residuals. If we find significantly larger residuals on the announcement dates, then this implies that announcements from Norges Bank increase the volatility in the NOK/USD market. The models in this approach are estimated by ordinary least squares (OLS) and weighted least squares (WLS), since there is evidence of heteroskedasticity and WLS is more efficient in that case.

In the third approach, models from the autoregressive conditional heteroskedasticity (ARCH) family are used. Here we allow the variance to be conditional on former variance, in addition to a set of independent variables.

4.2 VARIABLES

The exchange rate is expressed as the price of one U.S dollar in Norwegian krone. All variables except binary variables are tested for unit roots. It follows from the test statistics that all variables follow a random walk and are intergraded of order 1. Thus, all variables in their first differenced form reject the hypothesis of having a unit root.[16] All variables are in their logarithmic form and in first difference. This enables us to see how a daily percentage change in the explanatory variables affects the daily percentage change in the exchange rate; we are therefore measuring the elasticity of the exchange rate with respect to the explanatory variables. All variables are daily observations from 28th of March 2001 to 6th of May 2013. Even though Norway officially changed to a floating regime on the 29th of March 2001, the 28th of March 2001 is chosen as all variables are in first difference form. For the variable *lnstl*, which is the daily stock price for Statoil ASA, the observations go back to the 18th of June 2001. Regressions including this variable are therefore somewhat limited. All variables are obtained from Thomson Datastream sources: Bank of England, Norges Bank and New York Stock Exchange. In the following, all variables used to explain the daily percentage changes in the NOK/USD exchange rate, are presented.

***lnnok_usd* - $\boldsymbol{ln\frac{NOK}{USD}}$**

The exchange rate is measured as the price of one U.S dollar in Norwegian krone. The relationship is written as $\frac{NOK}{USD}$. The exchange rate is observed at 14.30 each day, and is the mid-rate between the bid and ask prices[17].

***lneuro_usd* - $\boldsymbol{ln\frac{EUR}{USD}}$ and *lnjpy_usd* - $\boldsymbol{ln\frac{JPY}{USD}}$**

While estimating a bilateral exchange rate between the Norwegian krone and the U.S. dollar, we want to capture changes in the exchange rate that has no direct relationship with the Norwegian krone (Bernhardsen & Røisland, 2000). While including the exchange rate between the euro and the U.S. dollar, we attempt to capture the changes in the exchange rate that is solely due to factors affecting the U.S. dollar. Including the exchange rate between the Norwegian krone and the euro would cause perfect collinearity.[18] This is therefore avoided. By the same token, the exchange rate between the U.S. dollar and the yen is included in the model.

---

[16] See the appendix for a discussion about unit root problems and test statistic for the variables.
[17] The exchange rate is observed 14.30 with the exception of some holidays when the exchange rate is observed 9.45 (Norges-bank).
[18] No arbitrage opportunities are assumed.

***lnidiff* - Interest Difference** $(\boldsymbol{i^{NOK} - i^{USD}})$

The interest rate differential is the logarithmic value of the three-month Norwegian money market rate and the logarithmic value of the three-month U.S. money market rate. Thus, the variable denotes the relative difference between the money market rates. According to interest rate parity, an isolated rise in the Norwegian money market rate will push up the Norwegian krone. In other words, we could expect it to have a negative coefficient on the exchange rate, as a decrease in the exchange rate is equivalent to appreciation for the Norwegian krone. The three-month rate is chosen because it is the most liquid money market rate in Norway. Choosing a shorter rate would potentially create a problem as the liquidity premium would drive the interest rate, and it might not be a good explanatory variable for changes in exchange rates.

The maturity of the money market rate is longer than the frequency of the observations. This deals with the potential problem of relatively large changes in the daily money market rate, as the three-month rate also reflects the market's expectations for the future development of the interest rate.

The three-month money market rate is likely to follow the key interest rate quite closely. The key interest rate is set to minimize Norges Bank's loss function (see the discussion above). One of the factors Norges Bank evaluates is the output gap. The exchange rate is likely to affect this factor, especially in a small open economy like Norway. It is therefore likely that the exchange rate affects the interest rate decision to some extent. In other words, the interest rate difference might suffer from endogenity problems as the causality is not perfectly clear. However, the potential problem is not likely to create large problems for the model, as the channel where the interest rate affects the exchange rate is much clearer than the channel where the exchange rate affects the interest rate. By the same token, if Norges Bank's expects an appreciation of the krone, and at the same time is worried about a positive output gap as a consequence, they might lower the interest rate. The krone might still appreciate, but less severely. Situations like this will create a reverse relationship to what one might expect (Bernhardsen & Røisland, 2000). The relative value of the krone will also affect the magnitude of imported inflation. As inflation targeting is the operational goal for monetary policy, this might create similar problems.

***lnoil* - Oil price**.

A change in the oil price is likely to change the demand for Norwegian krone. We can therefore expect a negative relationship between the oil price and the exchange rate (a fall in the exchange rate is equivalent with an appreciation of the Norwegian krone). Over the research period the petroleum sector has accounted for more or less 20 percent of the total gross national product in Norway (Oljeskattekontoret, 2013).

Akram (2004) suggested that the relationship between the Norwegian krone and the oil price need not be linear. He studied the Norwegian krone and the oil price over the period 1972 to 1996. Even though the operational goal for Norwegian monetary policy changed several times, there was a fixed exchange rate regime over the whole period. Akram (2004) argues that a central bank which aims to stabilize the exchange rate may resist exchange rate fluctuations by adjusting interest rates only as long as economic shocks are within a given range. If the shocks are larger, then the interest rate might be too high or low and the central bank might find it better to let the exchange rate float. Because the oil price is very important for the Norwegian economy, a relationship between the Norwegian krone and the oil price can exist when oil prices are abnormal high or low. For example, the central bank can lower the interest rate when the oil price is low. Most likely, the krone will depreciate and there will be a relationship between the two. Akram (2004) finds that when the oil price is below 14 USD per barrel, the Norwegian krone is sensitive to oil price changes. When the oil price is between 14 and 20 USD, which was considered normal during Akram's research period, there is no effect. When the oil price is above 20 USD the effect is weak and insignificant. What was considered a normal oil price when Akram did his research is likely not what is considered normal today. The normal level is likely to be far higher today (Aamodt, 2009).

As the oil price is still important for the Norwegian economy, there might be a non-linear relationship between the oil price and the exchange rate also in the current floating exchange regime. The interest rate decisions made on the background of Norges Bank's loss function reflects the oil price through the output term. We might therefore find a stronger relationship between the oil price and the exchange rate when the oil price is abnormal. However, the Norwegian three-month money market rate is included in the model, and the relationship caused by interest rate decisions should be picked up by this variable. This paper therefore assumes a linear relationship between the oil price and the exchange rate as other variables are expected to pick up the non-linearity.

The oil price will also to some extent capture the willingness to invest on the Norwegian continental shelf. However, the stock price for Statoil ASA is included to capture investments in the Norwegian capital stock. Also the variable for Oslo Stock Exchange should capture some of this effect.

***lnosebx* - Oslo Børs Stock Exchange**

Changes in the Oslo Stock Exchange are captured by the OSEBX index and is intended to be a representative selection for the firms listed on the Oslo Stock Exchange (Oslo-Børs, 2013). An increase in the stock market put pressure on the Norwegian krone, both by the international purchases and to the extent that these were changes the investment-saving ratio in Norway (and thus the need for foreign capital).

***lns&p_500* – S&P500**

The S&P500 is an index representing the 500 largest companies on U.S. stock exchanges. Following the same argument as with Oslo Stock Exchange, an increase in S&P500 puts pressure on the U.S. dollar and is also an indicator of the investment-saving ratio in the U.S.

The indices are likely to be correlated. If only one of them increases, only one of the currencies will be pushed upwards, while an increase in both might reflect a better economic situation worldwide. The latter will not be captured including only one of them.

***lnstl* - Statoil ASA**

Statoil ASA is by far the largest operator on the Norwegian shelf. Statoil ASA represents 80 percent of all oil and gas production (Gjerstad & Skard, 2013). The variable for Statoil ASA is chosen as a proxy for the future value of investments at the Norwegian shelf. However, Statoil ASA does not solely operate on the Norwegian shelf, and must therefore be treated with caution.

***lnghi* - Volatility**

As explained above, the global hazard index (GHI) is used as a measure of international turbulence in the money market. The GHI is calculated using the formula above, and is based on the three-month implied volatility in the money market for the respective currency pairs.

If the Norwegian krone is used as a safe haven, then the krone should appreciate if the GHI increases. However, the liquidity of the Norwegian krone is far less than of the U.S. dollar. As a result, there may be reasons to believe that the Norwegian krone depreciates during higher financial turmoil.

Even though the volatility might have a positive or negative relationship with the exchange rate, it is assumed that volatility first of all will affect the magnitude of the daily changes in the exchange rate. If the market does not prefer the Norwegian krone over the U.S. dollar, or the other way around, then the variable should have no explanatory power in explaining the daily changes in the exchange rate. The variable is therefore used to explain the absolute values of the residuals. In other words, some of the unexplained change in the daily exchange rate might be due to higher volatility in the market not captured by the model, as it has no clear relationship in one or the other direction on the exchange rate.

If the real volatility was used in the model, the variable could suffer from endogenity problems. A higher change in the exchange rate would lead to higher volatility. There are two reasons for this problem not to be severe. Firstly, real volatility is not observable. The implied volatility is used as a proxy, and the daily change is not likely to affect the markets expectations for the volatility over the next three months. Secondly, the GHI index is calculated on the basis of the euro, the U.S. dollar and the Japanese yen. More volatility between the U.S. dollar and the yen or the euro, or between the euro and the yen, is likely to increase the volatility between the Norwegian krone and the U.S. dollar as well. However, the problem would have been higher if the GHI also consisted of the exchange rate between the Norwegian krone and the U.S. dollar, or if the implied volatility between the Norwegian krone and the U.S. dollar was used alone.

***ann* – Norges Bank's Announcement Date for Foreign Currency Purchases**

On the last business day of every month the Norwegian Central Bank announces the daily purchases of foreign currency for the next month. The currency market is assumed to be efficient. Thus, the market should react to the announcement immediately, even though the actual purchases are smoothed over the next month. On the 20th of May 2003, and on the 22th of October 2008, Norges Bank released a press release communicating that they were going to change the daily purchases for the rest of the respective month. The two dates are included in the original announcement date dummy.[19] Before 2012, currency purchases were not normal for December. However, Norges Bank did purchase foreign currency in December in 2000, 2001 and 2002 (Norges-bank). The announcement dates in November for those years are therefore also included. The rest of the November dates are not included as they are assumed to have no information value to the market. The announcement day is expected to increase the volatility in the Norwegian krone. Thus, the announcement day is assumed to affect the absolute change in the exchange rate.

4.3 Multicollinearity in the Variables

There are two groups of the variables described above in which the link between the variables inside each group is strong. In one group there are the two variables for exchange rates, $ln\frac{EUR}{USD}$

[19] The actual announcement date in May 2003 is not clear, to the author's knowledge. The 20th of May is chosen based on the Norwegian Central bank's behavior in similar situations.

and $ln \frac{JPY}{USD}$. In the other group we have Oslo Stock Exchange, S&P500, Statoil ASA and oil price. Within both of these groups, the variables are likely to be highly correlated. These might create problems with multicollinearity, and make it difficult to find significant coefficients.[20]

5 Methodology and Results

In this section we describe the methodology used to quantify the possible extra fluctuations in NOK/USD on the specific days when Norges Bank announces next month's purchase of foreign currency. The results are presented consecutively.

Figure 5 graphs the absolute percentage change in the exchange rate expressed as the Norwegian Krone per U.S. dollar over the period 29th of March 2001 to 6th of May 2013. The fluctuations in the Norwegian Krone were especially high during the financial crisis, and seem somewhat higher in the post-financial crisis than pre-financial crisis. The average daily change over the period was 0.58 percent.

Table 2 displays the average absolute percentage change in the NOK-USD exchange rate, given that it was an announcement date or not. The average change on announcement days is about 4.96 percent higher (or about 0.029 percentage points more) than other days, with values of 0.6094 and 0.5806 percent, respectively. The standard error for announcement dates is more than four time larger than for the case of no announcement, which may be due to the announcement date having far fewer observations than non-announcement days. The 95 percent confidence interval of the announcement day changes covers the entire 95 percent confidence interval of the non-announcement day changes. Consequently, the percentage change in the exchange rate on announcement dates cannot be said to be statistically different than for the other days.

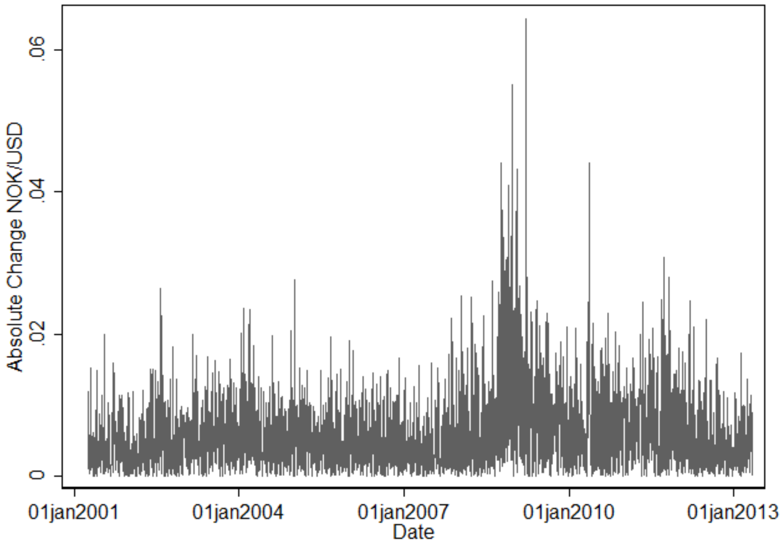
Table 2: Average Absolute Percentage Change in NOK/USD Sorted for Announcement days and non-announcement days

Announcement date	Observations	Percentage Change	Standard Error	95% Confidence Interval	
0	2890	0.58061	0.01038	0.56026	0.60097
1	138	0.60938	0.04939	0.51169	0.70707

Notes: All variables scaled by 100.

[20] See the appendix for a description of multicollinearity.

Figure 5: Absolute Percentage Change in $\frac{NOK}{USD}$, 29th of March 2001 – 6th of May 2013



5.2 A SIMPLE REGRESSION

The econometric approach begins with a simple model where it is assumed that all factors that affect movements in the exchange rate, except the announcement date, cancel each other out. In other words, over time all factors are a part of the error term, and the error term has an expected value of zero.

Table 3 displays the result from a simple regression given by:

$$|ln\Delta\frac{NOK}{USD}|_t = constant + \beta_1 ann_t + u_t$$

$|\Delta ln\frac{NOK}{USD}|_t$ is the absolute value of the change from time *t*-1 to time *t* in logarithmic form of the exchange rate given by NOK per USD. ann_t is a binary variable equal 1 if Norges Bank announces a purchase of foreign currency on day *t* and equals 0 otherwise. The null hypothesis is that the daily change in the exchange rate is not affected by whether it is an announcement date or not. The alternative hypothesis is that the changes in the exchange rate are higher on announcement dates. The hypotheses are given by $H_0: \beta_1 \leq 0$ and $H_1: \beta_1 > 0$.

The result indicates that the change in the exchange ratio is 0.02877[21] percent higher on announcement dates. The regression cannot reject the null hypothesis on any satisfying significance levels. The one sided p-value for β_1 is 0.2837. The simple regression can therefore not prove that the percentage change in the exchange ratio is higher on

[21] This is log-level model measuring the semi-elasticity. The correct equation to solve the coefficient is, $\exp(\beta) - 1$, (the coefficient is already scaled by 100 in table 3). Thus, the result described is approximate.

Table 3: Absolute Percentage Change $\frac{NOK}{USD}$ on Announcement Date

	$\lvert ln\Delta\frac{NOK}{USD}\rvert_t$
ann_t	0.0288
	(0.0503)
$constant$	0.5806***
	(0.0104)
N	3024
R^2	0.0001

Standard errors in parentheses. All values are multiplied by 100.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

announcement days. It is also clear, and not surprising that the regression earns a r-squared of 0.0001. The announcement date cannot explain the changes in the exchange rate at any practical level. This is the same result as we obtain from table 2 above, however, the regression is run using the robust function in STATA, and the standard errors differ slightly.

5.3 Creating a Short Term Model for the Exchange Rate

The simple regression above had no power in explaining changes in the exchange rate or revealing larger daily changes on announcement days. Now we want to find out whether the announcement dates causes the conditional variance to be larger on announcement dates. Recall from the appendix that stationary variables have constant variance. Thus, the unconditional variance or more intuitively, the long run variance, is constant. However, the stationarity requirement is not violated with varying conditional variance. As varying conditional variance is the same as heteroskedasticity, it violates the homoscedastic assumption, $var(u|X) = \sigma^2$, where u is the residual, X is a k-dimensional vector of the independent variables and σ^2 is the variance. In the presence of heteroskedasticity, the variance can be shown to be, $var(u|X) = \sigma^2 h(X)$, where $h(X)$ is some function of the independent variables (Enders, 2010).

In this sub-section we are using a two-step procedure to test whether the announcement date causes the conditional variance to be larger. The first step is to produce a model explaining the daily changes in NOK/USD. The second step is inspired by the Breusch-Pagan test for heteroskedasticity. The residuals from the model in step one are obtained and regressed on the announcement date dummy and other variables that possibly causes the conditional variance to vary.

The models suggested are represented in table 4. All models are obtained by regressing the percentage change in NOK/USD on oil price (lnoil), interest difference (lnidiff), euro – U.S. dollar exchange rate ($ln\frac{EUR}{USD}$), Statoil ASA (lnstl), the GHI index (lnghi), S&P500(lns_p500 and Osebx (lnosebx). JPY/USD was also tested, but found to be insignificant in all models. All significant variables are removed one by one in each model.

Unfortunately, data for Statoil ASA was only available from the 6th of June 2001. The number of observations for models including Statoil ASA is therefore reduced from 3023 to 2972.

In all models we have included one lag for the variable s&p500 to account for the large time difference between the USA and Europe.[22] All models are tested for autocorrelation through Durbin's alternative statistic. The test with one lag is given by:

$$\hat{u} = x_{t1} + x_{t2} + \cdots + x_{tk} + \hat{u}_{t-1}, for\ all\ t = 2, \ldots, n$$

where $\hat{u}$ is the residual obtained from the model we wish to test, x_{tk} is the independent variable *k* and *t* denotes time. This test for autocorrelation allows for the independent variables to be endogenous, as the variables can correlate with the lagged value of the obtained residual.[23] But the test is invalid in the presence of heteroskedasticity. Thus the test is used with heteroskedastic robust t statistics on $\hat{u}_{t-1}$. All models are tested with five lags. None of them exhibits autocorrelation when the heteroskedastic option in STATA is used. The null hypothesis is no autocorrelation. The p-values are presented in table 4 (Wooldridge, 2009).

The first column of table 4 displays the results from a simple OLS regression. The model seems to explain the daily percentage changes in NOK/USD quite well, with a R-squared of 0.7087. This implies that the independent variables are explaining 70.87 percent of the changes in NOK/USD. The coefficient on the change in $ln\frac{EUR}{USD}$ is very significant and large in magnitude. A one percent change (equivalent to a depreciation of the USD to the euro) is estimated to appreciate the NOK with 0.95 percent with respect to the USD, and has a t-statistic of 74.43. It is perhaps not surprising that a depreciation of USD to euro, holding all

[22] Variables obtained from Norwegian markets suffer from a time difference from one to two hours compared to variables obtained from the Bank of England. This relatively small difference is ignored in the estimations.
[23] A simpler model without the independent variables would be invalid in the presence of endogenous variables (Wooldridge, 2009).

other variables fixed, is highly significant and has a coefficient close to unity.[24] The regression was also done without including $ln\frac{EUR}{USD}$. The coefficients on all remaining variables did increase in magnitude to some extent. However, they still had the same signs and were all significant. The variable *lnidiff*, representing the relative difference between the money markets rate in Norway and USA, is significant with a coefficient of -0.0262 and a t-statistic of -5.46. This indicates that overshooting is present. An increase of one percent in the global hazard index is estimated to depreciate the NOK by 0.0144 percent. This indicates that investors escape the NOK as international turmoil increases. Thus this is evidence against the NOK being a safe haven over the period. Both the oil price and the Oslo Stock Exchange index are significant and with the expected signs. A one percent change in oil price and Oslo Stock Exchange are estimated to appreciate NOK by 0.03 and 0.04 percent, respectively. The coefficient on S&P500 is perhaps more surprising. An increase in both the S&P500 and its corresponding lagged value appreciates the NOK. Intuitively, one could assume that a rise in S&P500 would appreciate the USD. However, we might have a problem with omitted variables. A possible explanation could be that the S&P500 correlates with some financial markets in Norway, or that an increase in the S&P500 can be associated with brighter economic prospects, and more investors are likely to invest in NOK (as it is already established that NOK behaves as the opposite of a safe haven).

In the presence of heteroskedasticity, the OLS coefficients are not biased but an estimator with smaller variance exists. Also, the standard errors from the regression are incorrect and the test-statistics might be misleading. Heteroskedasticity is tested through the Breuch-Pragan test.

$$\hat{u}_t^2 = \delta_t + \delta_{t1}x_{t1} + \delta_{t2}x_{t2} + \cdots + \delta_{tk}x_{tk} + e_t$$

The squared residual $\hat{u}_t^2$ is obtained from the model and regressed on all independent variables including a constant term. Then a F-test for joint significance of the variables is calculated (Hill, Griffiths, & Lim, 2012). From table 4 we can see that the null hypothesis of homoscedasticity is overwhelmingly rejected in favor of the alternative hypothesis of heteroskedasticity. In the second column the regression is done using the heteroskedastic robust standard errors. This procedure only changes the standard errors in the estimation. However, as the coefficient on the S&P500 is not significant, even at the ten percent level, it

[24] If NOK/EUR is constant (and there is no arbitrage opportunities), the coefficient on EUR/USD should equal one. However, including NOK/EUR in the regression would cause perfect collinearity.

Tabel 4: Daily Percentage Changes in NOK/USD

	OLS	OLS Robust	WLS	WLS Robust
D.lnoil	-0.0316***	-0.0313***	-0.0298***	-0.0314***
	(0.0040)	(0.0048)	(0.0043)	(0.0054)
D.lnidiff	-0.0262***	-0.0262***	-0.0280***	-0.0275**
	(0.0048)	(0.0076)	(0.0049)	(0.0096)
$D.\ ln\frac{EUR}{USD}$	0.9452***	0.9460***	0.9497***	0.9454***
	(0.0127)	(0.0169)	(0.0134)	(0.0170)
D.lnghi	0.0144***	0.0152***	0.0159***	0.0163**
	(0.0031)	(0.0043)	(0.0031)	(0.0056)
D.lns_p500	-0.0170*		-0.0131	
	(0.0070)		(0.0071)	
LD.lns_p500	-0.0311***	-0.0271**	-0.0392***	-0.0340*
	(0.0065)	(0.0096)	(0.0068)	(0.0134)
D.lnosebx	-0.0420***	-0.0490***	-0.0347***	-0.0527***
	(0.0063)	(0.0087)	(0.0089)	(0.0118)
D.lnstl			-0.0133*	
			(0.0066)	
Constant	0.0000	0.0000	0.0000	0.0000
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
N	3023	3023	2972	3023
R^2	0.7087	0.7081	0.7022	0.7015
adj. R^2	0.7080		0.7014	
Durbin's Alternative Statistic	0.6355	0.6334	0.6510	0.6281
Breusch-Pagan	0.0000		0.0000	

Standard errors in parentheses: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Durbin's alternative statistic for autocorrelation is adjusted for heteroskedasticity using STATA's robust command with five lags. The values for the Breusch-Pagan test for heteroskedasticity and the Durbin's alternative statistic are their corresponding p-values. D. indicates first difference and L. indicates lagged variable.

is excluded from the model and the model is re-estimated. The new model is quite similar to the original. However, the standard errors are larger for all variables.

In column 3 the model is estimated with weighted least squares (WLS). The method is based on correcting the model for some form of known heteroskedasticity. In this model there is no obvious form or function for heteroskasticity, and a more general approach is used. We will a study a flexible model where the conditional variance is given by:

$$Var(u|X) = \sigma^2 \exp(\delta_0 + \delta_1 x_1 + \delta_2 x_2 + \cdots + \delta_k x_k)$$

The approach involves obtaining the residual from the model, then regressing $\log(\hat{u}^2)$ on all independent variables and obtaining the fitted values, $\hat{g}$, and calculating the weighting function $\hat{h} = \exp(\hat{g})$. All terms in the original model are then divided by $\sqrt{\hat{h}}$ (Wooldridge, 2009). The interoperation of the WLS estimates is the same as for OLS, as the results are re-multiplied with the weighting function.

Overall the WLS results do not differ largely from the OLS results. This is an indication that the weighting function is not far off. Statoil ASA now has a significant coefficient of -0.0133 with a t-statistic of -2.02. Also the coefficient on the S&P500 reappears in the model, significant at the ten percent significance level. Also in this model, the null hypothesis of homoscedasticity is rejected.

Column 4 displays the result of the WLS model but with heteroskedastic robust standard errors. Just as before, the model is re-estimated as the S&P500 and Statoil ASA are no longer significant. The standard errors are higher for all variables - especially for the interest differential and the lagged variable for the S&P500, where the standard errors are approximately double compared to the non-robust WLS model. All models seem to fit the daily exchange rate fairly well as the R-squared is above 0.70 and does not vary much between the models. The variance inflation factor (VIF) is calculated for all models. It seems that none of the models suffer from multicollinearity with values for each variable laying in the interval zero to four, despite the similarities in the variables.

5.4 Explaining the Residual

In this sub-section a model is created to explain the conditional variance of the models created in the last sub-section. The residuals from each model are obtained, and the absolute values of the residuals are regressed on the absolute value of the same independent variables as above. The assumption is that, if the volatility is conditional on some of the independent variables, the volatility should increase whether the independent variable is increasing or decreasing. In addition the value for the global hazard index also appears in its regular form. It is assumed that a drop in the international implied volatility will lower the volatility in the exchange rate. Thus a drop in the index will lower the absolute value of the residual. The absolute value of *lnghi* will have a different interpretation, as it will (as above) indicate whether the NOK is a safe haven or not, and therefore if the volatility is conditional on investor’s preferences. The models also include binary variables for each day of the week and the binary variable for announcement days.

Table 5: Model for Volatility in NOK/USD

	$\lvert\hat{u}\rvert$ (OLS)	$\lvert\hat{u}\rvert$ (OLS-R)	$\lvert\hat{u}\rvert$ (WLS)	$\lvert\hat{u}\rvert$ (WLS_R)
ann	0.000200	0.000219	0.000234	0.000192
	(0.000255)	(0.000256)	(0.000259)	(0.000124)
Tuesday	0.000113	0.000097	0.000102	-0.000103
	(0.000165)	(0.000165)	(0.000167)	(0.000080)
Wednesday	0.000383*	0.000371*	0.000390*	-0.000034
	(0.000165)	(0.000165)	(0.000167)	(0.000080)
Thursday	0.000074	0.000061	0.000076	-0.000070
	(0.000166)	(0.000166)	(0.000168)	(0.000081)
Friday	0.000091	0.000088	0.000081	-0.000200*
	(0.000168)	(0.000168)	(0.000170)	(0.000082)
$\lvert D.lnoil\rvert$	0.015233***	0.015089***	0.013450***	0.017970***
	(0.003690)	(0.003696)	(0.003725)	(0.001788)
$\lvert D.lnidiff\rvert$	0.028758***	0.028264***	0.028290***	0.006349***
	(0.003777)	(0.003783)	(0.003819)	(0.001821)
$\lvert D.ln\frac{EUR}{USD}\rvert$	0.066355***	0.066818***	0.064785***	0.948591***
	(0.012521)	(0.012541)	(0.012675)	(0.006089)
$D.lnghi$	0.005942**	0.006117**	0.005806**	-0.000188
	(0.001936)	(0.001939)	(0.001957)	(0.000976)
$\lvert D.lnS\&P500\rvert$	0.015954**	0.016088**	0.018181**	
	(0.005938)	(0.005947)	(0.006021)	
$\lvert LD.lnS\&P500\rvert$	0.024508***	0.024640***	0.026612***	
	(0.005465)	(0.005473)	(0.005532)	
$\lvert D.lnosebx\rvert$	0.020740***	0.020930***	0.018932***	0.045865***
	(0.005123)	(0.005131)	(0.005174)	(0.002345)
$\lvert D.lnghi\rvert$				0.011375***
				(0.001316)
Constant	0.001610***	0.001619***	0.001654***	-0.000540***
	(0.000145)	(0.000145)	(0.000146)	(0.000071)
N	3023	3023	2972	3023
R^2	0.1003	0.1000	0.0983	0.9114
adj. R^2	0.0977	0.0964	0.0956	0.9111
Durbin's Alternative Statistic	0.0000	0.0000	0.0000	0.0052

Standard errors in parentheses: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Durbin's alternative statistic for autocorrelation is adjusted for heteroskedasticity using STATA's robust command; the corresponding values are p-values for 5 lags. D. indicates first difference and L. indicates lagged variable.

From a first look at table 5 it is clear that the model explaining the residuals from the WLS-r model is ridiculous. It has an R-squared of 0.9114, suggesting that the model can explain 91.14 percent of the volatility, which is highly unlikely. The coefficient on $|D.ln\frac{EUR}{USD}|$ suggest that a one percentage change in EUR/USD in on or the other direction increases the volatility by 0.95 percent. The model is clearly wrong and dropped from further analysis.

The magnitudes of the changes of nearly all variables from the original models are significant, except for Statoil ASA and the absolute percentage change in the global hazard index. The residual from the WLS model originally includes Statoil ASA and has therefore fewer observations. All models can explain about ten percent of the volatility. The effect of the announcement date is insignificant in all specifications. In the model based on WLS, the announcement date raises the volatility by 0.0234 percent, with a one sided p-value of 0.217. This result is very similar to the result obtained in the very first test of the absolute percentage change in NOK/USD on the announcement date. It seems that the assumption of all variables affecting the exchange rate canceling each other out over the period is fairly correct. The relatively more advanced method created so far in this paper cannot explain the announcement any better than the simple approach. Following Baillie and Bollerslev (1989), dummies for each day of the week are included. Interestingly, the volatility on Wednesday is higher for all models, significant at the five percent level, relative to Mondays (the base day in the regression). This could be explained by higher information flows to the USD market, the NOK market or both markets on Wednesdays. Baillie and Bollerslev (1989) argue that the volatility should be higher on Wednesdays as the currency transactions in USD happen on specific days. However, this system was prior to October 1, 1981.

5.4.2 Structural Change

The petroleum taxation system was changed in 2008 from a system where by petroleum taxes were payable twice a year to a system where petroleum taxes were payable six times a year. The new system is smoother as it enables petroleum firms to pay taxes more regularly throughout the year. This will reduce the uncertainty in the amount the firms must pay to meet their obligation and, more importantly, the firms will have incentives to spread their purchase of krone more evenly through the year. The hypothesis is that the volatility in the NOK/USD market is lowered as a result of this new system.

The first payment of this tax was 1st of August, 2008. A binary policy variable for the tax-system change, *ptax*, equaling one for 1st of August, 2008 and subsequent dates, is included in the models. In addition, interaction terms of the policy variable and all independent variables (except weekdays) are created. The interaction terms will measure whether the volatility is more elastic to absolute changes in the independent variables or to the ghi index subsequent to the policy change.

Table 6 displays the results similarly to table 5 above, but with a binary variable and interaction terms for the policy change. Just as above, all insignificant non-binary variables are removed from the model. The coefficient on *ptax* has the expected sign in all models. The models null hypothesis, $Ho\colon \beta \geq 0$, is not rejected with one sided p-values of 0.1194, 0.1029 and 0.1061, respectively. This implies, while holding all other factors affecting volatility fixed, the volatility is reduced after the implementation of the system with about 0.018 percent. A practically small result, but significant. Interestingly, the absolute change in oil price is only significant after the system change. In the first column, the coefficient implies that a one percent change in the oil price increases the volatility by 0.028. The result from table 5 above, for the entire period, is 0.015. This implies that the volatility was only affected by changes in oil prices after August 1th, 2008. It is therefore not surprising that the coefficient is larger in the later model. At this point it is tempting to conclude that, as the oil price is an important factor in determining the amount of petroleum taxation, the petroleum firms' activity in the currency market is more elastic to oil price after the system change. Even though this conclusion might be sensible, it is important to notice how the petroleum sector has grown through the period. Around 2005-2006 petroleum investment as a share of Norwegian GDP increased rapidly, from being somewhat steady below 20 percent in the beginnings of the 2000's to being steady above 30 percent after 2008 (Oljeskattekontoret, 2013). In other words, the oil price has grown even more important for the Norwegian economy in later years, and its effect on the NOK has therefore most likely grown correspondingly.

The coefficients on the announcement days now turn out to be significant. In all models, the announcement days prior to the new policy, holding all other factors fixed, pushes up the volatility by approximately 0.07 percent, with one sided p-values of 0.0129, 0.0129 and 0.0086, respectively. However, the interaction term, *ptax_ann*, tells us that the extra volatility is reversed after the policy change. In fact, not only did the effect on announcement days get reversed, but the total effect is negative. The effect of announcement days after the policy change is according to model one, $100 * e^{0.0007-0.0015} - 1 = -0.08$ percent. While it seems sensible that the volatility was larger on announcement days prior to the policy change, it does not make any intuitive sense that the announcement day has a negative effect after the policy

Table 6: Model for Volatility in NOK/USD with Structural Change

	$\lvert\hat{u}\rvert$ (OLS)	$\lvert\hat{u}\rvert$ (OLS-R)	$\lvert\hat{u}\rvert$ (WLS)
ptax_ann	-0.001463**	-0.001395**	-0.001478**
	(0.000521)	(0.000522)	(0.000526)
ann	0.000712*	0.000706*	0.000770*
	(0.000316)	(0.000317)	(0.000323)
ptax	-0.000170	-0.000183	-0.000183
	(0.000144)	(0.000145)	(0.000146)
Tuesday	0.000114	0.000099	0.000103
	(0.000163)	(0.000164)	(0.000165)
Wednesday	0.000392*	0.000381*	0.000392*
	(0.000164)	(0.000164)	(0.000165)
Thursday	0.000101	0.000088	0.000090
	(0.000165)	(0.000165)	(0.000166)
Friday	0.000110	0.000108	0.000093
	(0.000166)	(0.000166)	(0.000168)
$D.lnghi$	0.006002**	0.006167**	0.006003**
	(0.001919)	(0.001922)	(0.001939)
$\lvert D.lnidiff\rvert$	0.025375***	0.024800***	0.025180***
	(0.003771)	(0.003775)	(0.003811)
$\lvert D.ln\frac{EUR}{USD}\rvert$	0.056847***	0.056909***	0.054538***
	(0.012487)	(0.012502)	(0.012660)
$\lvert LD.lnS\&P500\rvert$	0.022151***	0.022124***	0.023743***
	(0.005385)	(0.005391)	(0.005475)
$ptax\_\lvert D.lnoil\rvert$	0.028142***	0.028414***	0.027644***
	(0.006063)	(0.006070)	(0.006264)
$ptax\_\lvert D.lnS\&P500\rvert$	0.023967**	0.024952**	0.028504***
	(0.007951)	(0.007961)	(0.007508)
$ptax\_\lvert D.lnosebx\rvert$	0.017980**	0.018046**	
	(0.006968)	(0.006977)	
$ptax\_\lvert D.lnstl\rvert$			0.013142*
			(0.006606)
Constant	0.002010***	0.002023***	0.002042***
	(0.000138)	(0.000138)	(0.000140)
N	3023	3023	2972
R^2	0.1178	0.1181	0.1156
adj. R^2	0.1137	0.1140	0.1114
Durbin's Alternative Statistic	0.0000	0.0000	0.0000

Standard errors in parentheses: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. *ptax* is a binary variable for structural change. Durbin's alternative statistic for autocorrelation is adjusted for heteroskedasticity using STATA's robust command; the corresponding values are p-values for 5 lags.

change. However, it is likely that the new tax system has allowed Norges Bank to be more transparent. While petroleum taxes are payable six times a year, it makes Norges Bank analyses for the amount to transfer to GPFG more accurate. In addition, Norges Bank has in general become more transparent through the period, and it is more likely that the market was surprised by their action in the first part of the data set.

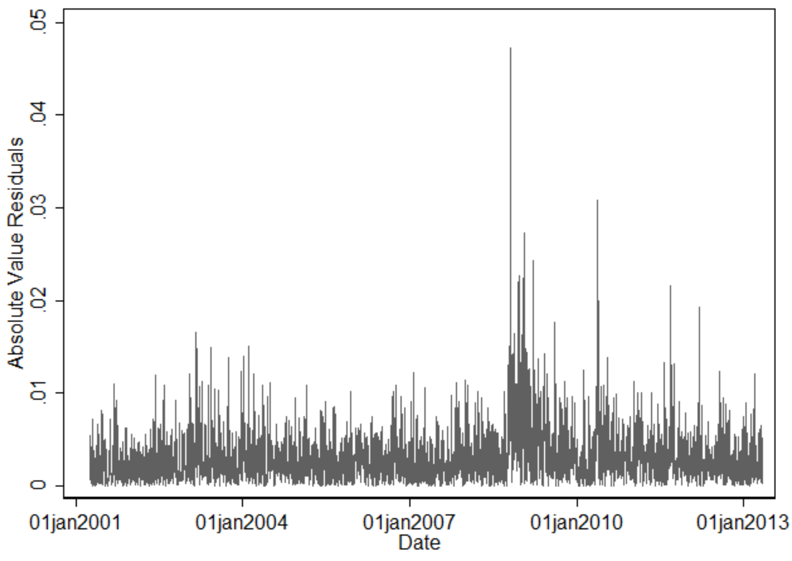
5.5 Allowing the Variance to be Conditional on Previous Variance

The models above explaining the absolute residual, or the volatility, all exhibit autocorrelation. In table 5 and 6, we can see that none of the models passes Durbin's alternative statistic for autocorrelation. In this section we will control for the possibility of the volatility being conditional on previous values of volatility. In other words, the variance might follow an autoregressive moving average (ARMA) process. The simplest form is given where the variance follows an MA(1) model where the variance depends on the squared term of the previous period.

$$\sigma_t^2 = E\{\varepsilon_t^2 | L_{t-1}\} = \alpha_0 + \alpha\varepsilon_{t-1}^2$$

Where *L* denotes the information set available at *t-1*. This model is a called an autoregressive conditional heteroskedasticity (ARCH(1)) model of order one, which was proposed by Engle (1982). The idea is based on the belief that a large (small) variance in one period is followed by a large (small) variance in the next period. In other words, the variance is conditional on previous variance (Verbeek, 2012). Figure 6 shows the absolute value of the residuals obtained from column 1 in table 4. It seems from the figure that the residuals are clustered.

Figure 6: Absolute Residuals



In the previous approach, the global hazard index was used to explain the residuals. The idea was simple, a large upward change in global volatility would explain the larger volatility in the NOK. However, there is one important drawback with the model. As the *ghi* is a non-stationary variable in its level form, it had to be first-differenced. A large change did indeed significantly increase the absolute residual. However, if the there was a large upwards change in *ghi* one particular day followed by no change in the succeeding day, then the variable would have no explanatory power in explaining the large residual on the second day as a consequence of the sustained large volatility. This pushes us towards the approach utilized in the sub-section, where the variance is allowed to be conditional on previous variance in the model.

5.5.2 PROPERTIES OF THE ARCH MODEL

An important property of the ARCH model is that it computes the conditional variance simultaneously as it computes the original model. It will therefore enable us to compute the model for the percentage change in NOK/USD at the same time as it computes the model for conditional variance for NOK/USD. In order to solve these two simultaneous equations, the ARCH model uses a maximum-likelihood estimation. Consider that the values of ε_t has zero mean and constant variance. If we draw it from a standard normal distribution, then its likelihood, *L*, for any outcome of ε_t will be:

$$L = \left(\frac{1}{\sqrt{2\pi\sigma^2}}\right) exp\left(\frac{-\varepsilon_t^2}{2\sigma^2}\right).$$

Similarly, it can be showen that the likelihood for the joint realization of $\varepsilon_1, \varepsilon_2, \dots, \varepsilon_T$, where T is the total observations, is:

$$L = \prod_{t=1}^{T}\left(\frac{1}{\sqrt{2\pi\sigma^2}}\right) exp\left(\frac{-\varepsilon_t^2}{2\sigma^2}\right)$$

Taking the natural log of each side yields:

$$lnL = -\frac{T}{2}\ln(2\pi) - \frac{T}{2}\ln\sigma^2 - \frac{1}{2\sigma^2}\sum_{t=1}^{T}(\varepsilon_t)^2$$

Now suppose that the residual comes from a simple model with one explanatory variable, $\varepsilon_t = y_t - \beta x_t$ and the conditional variance is a simple MA(1) process, $\sigma_t^2 = \alpha_0 + \alpha\varepsilon_{t-1}^2$. The model can then be expressed as:

$$lnL = -\frac{T-1}{2}\ln(2\pi) - 0.5\sum_{t=2}^{T}\ln(\alpha_0 + \alpha\varepsilon_{t-1}^2) - \frac{1}{2}\sum_{t=2}^{T}\frac{(y_t - \beta x_t)^2}{\alpha_0 + \alpha_1\varepsilon_{t-1}^2}$$

The model above is an ARCH(1) model. The equation is solved by maximizing L with respect to α_0, α_1 and β. The first observation for ε_t is lost because we cannot measure ε_0 (Enders, 2010).

5.5.3 Fitting a GARCH Model

In this approach to analysing the announcement effect, we will use the original OLS model obtained in table 4**.** Figure 7 displays the autocorrelation function and the partial autocorrelation function of the squared residuals. It is clear from the figure that the squared residuals exhibit a rather large persistence. As Enders (2010, p.138) notes, it would be tempting to use the Box-Jenkins method to fit an autoregressive moving average (ARMA) model for the squared residual. The problem is that the original OLS model was estimated under the assumption that the conditional variance was constant. It is therefore not a good approach to use these estimates to compute the time varying conditional variance. Thus figure **7** cannot reveal the precise model specification, but it is a good indicator that there exist errors that needs be accounted for by using the ARCH model.

The first column of table **7** displays the results from an ARCH(1) model. The model is based on the OLS model for the absolute change in NOK/USD and corresponding structural change model explaining the absolute value of the residuals. The two models that will be estimated simultaneously through the maximum likelihood estimation are,

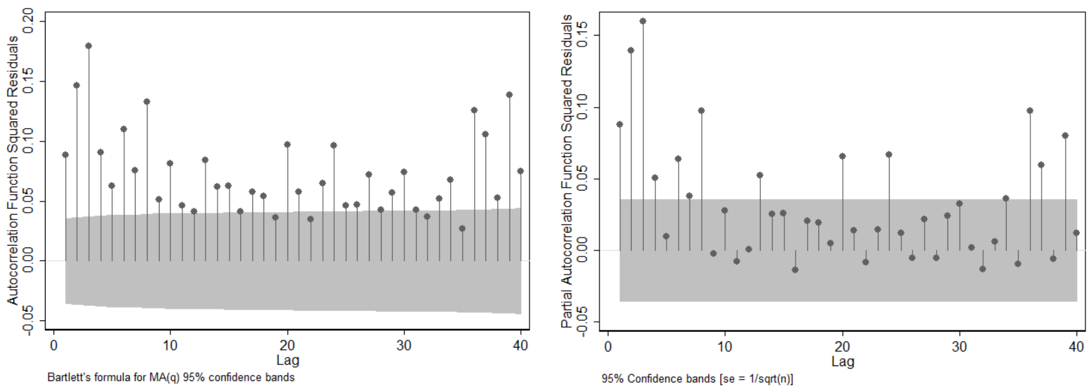
$$y_t = \beta_0 + \beta x_{t1} + \beta x_{t2} + \cdots + \beta x_{tk},$$

where y_t is the absolute percentage change in NOK/USD and x_{tj} the explanatory variables, and

$$\sigma_t^2 = \delta x_{t1} + \delta x_{t2} + \cdots + \delta x_{tk} + \alpha_0 + \alpha\varepsilon_{t-1}^2,$$

where, x_{tj} refers to the independent variables explaining the conditional variance. The ARCH(1) term, $\alpha\varepsilon_{t-1}^2$, is significant with a p-value of 0.000 implying that a one percent increase in the previous squared residual increases the squared residual by 0.073 percent.

Figure 7: Persistence in the Squared Residual



Before interpreting the results, it is important to note that including one lag of squared variance not necessarily satisfactory in explaining the conditional variance. ARCH(q) models were tested for up to 20 lags. Lag 1-7,13,14 and 20 were all significant. This implies that lags are quite persistent over long periods. Especially troublesome is lag 13, 14 and 20. It does not make sense that, while the variance is conditional on the variance in the seven previous days, it is also conditional on the variance 13, 14 and 20 days ago, but not on the lags in between. As an alternative to specifying an ARCH(q) model of high order, we can specify a generalized ARCH model, GARCH(1,1). In this model the variance follows an ARMA process given by:

$$\sigma_t^2 = \alpha_0 + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2$$

This model is equivalent to an ARCH(q) model with infinite-order of lags with geometrically declining lags (Verbeek, 2012). The GARCH(1,1) model is displayed in column two. We can see that the coefficient on σ_{t-1}^2 is 0.570 with a p-value of 0.000. This implies that a one percent increase in the variance two days ago will increase the current variance by $0.570^2 = 0.325$. For five lags the corresponding effect is 0.060. The MA-term ε_{t-1}^2 is still significant with approximately the same coefficient and a p-value of 0.000.

A drawback of the GARCH model is the symmetry of the variables affecting the conditional variable. The change in the variables are implicitly assumed to have the same effect on the conditional variance whether it is a positive change or a negative change, although the variable *ghi* is included and controls for both increases and decreases in the global volatility. A model that allows for asymmetric effect in the variables was proposed by Nelson in 1991. The exponential GARCH (EGARCH) model is an extension of the GARCH(1,1) model. The conditional variance is given by

$$ln\sigma_t^2 = \alpha_0 + \beta ln\sigma_{t-1}^2 + \gamma \frac{\varepsilon_{t-1}}{\sigma_{t-1}} + \alpha_1 \frac{|\varepsilon_{t-1}|}{\sigma_{t-1}},$$

If γ is negative, it implies that negative shocks have larger impact on next period's variance than positive shocks. As long as $\gamma \neq 0$, the model will be asymmetric (Verbeek, 2012). As it can be argued that, in some financial markets, a negative shock is followed by relatively larger variance the following day than is for a positive shock. Engle and Nh (1993) did indeed find evidence for this (Verbeek, 2012, p. 328). However, in the NOK/USD market there is no clear distinction between negative shocks versus positive shocks. A positive shock for investors holding NOK is a negative shock for investors holding USD and vice versa. In the NOK/USD market, a negative shock is defined by the model as a depreciation of USD. Column three displays the result of the EARCH model. The coefficient on $\frac{\varepsilon_{t-1}}{\sigma_{t-1}}$ is 0.132 with a p-value of 0.000. This implies that a positive shock of one percent (a one percent depreciation of NOK) leads to 0.132 higher variance the following day. In line with the models estimated above, the NOK is the opposite of a safe haven. Investors are escaping the krone in periods of higher volatility. Higher volatility is more likely to influence investors holding NOK, as opposed to investors holding USD. The coefficient on $\frac{|\varepsilon_{t-1}|}{\sigma_{t-1}}$ is 0.068 and the coefficient on $ln\sigma_{t-1}^2$is 0.725 with a p-value of 0.000 for both.

5.5.4 Interpreting the GARCH Models

The results from the EARCH model in column three in table 7 is similar to those obtained using the OLS model in column one in table 4 above. However, the variables explaining the conditional variance have changed. After taking into account that the variance might be conditional on previous variance, the variables $|LD.lnS\&P500|$, *ptax_*$|D.lnoil|$, *ptax_*$|D.lnS\&P500|$ and *ptax_*$|D.lnosebx|$ have all turned insignificant. The announcement date is significant with a coefficient of 0.380 and a p-value of 0.001. This implies that the conditional variance is 0.38 higher on announcement days prior to the change in taxation system. The coefficient on *ptax_ann* is -0.408 with a p-value of 0.040. The effect of the announcement date is therefore offset by the negative coefficient *ptax_ann*. For the ARCH- and model, the sum turns negative with about -0.3630, which once again is counterintuitive. It seems like Norges Bank caused the market to be more volatile due to the disclosure of their purchase plan, but only prior to the change in the petroleum tax-system. The coefficient on The coefficient on $|D.ln\frac{EUR}{USD}|$ is very high relatively to the other variables, this is not

Table 7: Autoregressive Conditional Heteroskedasticity Models

$D.ln\frac{NOK}{USD}$	ARCH(1)	GARCH(1,1)	EARCH(1,1)
D.lnoil	-0.024500***	-0.025103***	-0.025801***
	(0.003465)	(0.003520)	(0.003467)
D.lnidiff	-0.034638***	-0.031323***	-0.031176***
	(0.006802)	(0.005911)	(0.006020)
$D.ln\frac{EUR}{USD}$	0.934177***	0.944871***	0.946840***
	(0.012908)	(0.012529)	(0.012317)
D.lnghi	0.012752***	0.014053***	0.013795***
	(0.003110)	(0.003204)	(0.003186)
D.lns_p500	-0.014729*	-0.014350*	-0.013995*
	(0.007293)	(0.007288)	(0.007069)
LD.lns_p500	-0.026708***	-0.024115***	-0.023863***
	(0.006919)	(0.006844)	(0.006764)
D.lnosebx	-0.032274***	-0.033356***	-0.030683***
	(0.006140)	(0.006116)	(0.005967)
D.lnstl	-0.000044	-0.000042	-0.000016
	(0.000070)	(0.000069)	(0.000068)
HET			
ptax_ann	-0.785212**	-0.708331	-0.407656*
	(0.254343)	(0.452875)	(0.198439)
ann	0.422231**	0.744453***	0.380108**
	(0.156379)	(0.214331)	(0.116712)
ptax	0.060011	-0.093341	-0.032336
	(0.060658)	(0.083412)	(0.030134)
Tuesday	0.138616	0.661698**	0.244445*
	(0.074280)	(0.243594)	(0.096102)
Wednesday	0.348167***	0.738561***	0.269265**
	(0.075105)	(0.209342)	(0.083907)
Thursday	0.120926	0.002987	-0.018815
	(0.074085)	(0.269533)	(0.082878)
Friday	0.088814	0.386966	0.060479
	(0.078273)	(0.278826)	(0.097532)
$D.lnghi$	4.727521***	5.381810**	3.454180***
	(0.926653)	(1.646854)	(0.675669)
$\|D.lnidiff\|$	13.587490***	13.501691***	5.956510***
	(1.949123)	(2.435399)	(1.419676)
$\|D.ln\frac{EUR}{USD}\|$	36.339747***	48.689106***	22.547642***
	(5.796114)	(9.220661)	(4.570948)

Table 7 (Continued)

$\lvert LD.lnS\&P500 \rvert$	9.818246***	5.008856	0.791645
	(2.512328)	(4.693531)	(1.886640)
$ptax\_\lvert D.lnoil \rvert$	7.382923*	14.902840**	3.785771
	(3.076406)	(4.766351)	(2.014272)
$ptax\_\lvert D.lnS\&P500 \rvert$	14.789726***	9.877048	2.709201
	(4.142777)	(6.518360)	(2.813182)
$ptax\_\lvert D.lnosebx \rvert$	7.682700**	7.458562	3.116880
	(2.830553)	(5.690218)	(2.320505)
Constant	-11.841618***	-13.123058***	-3.380452***
	(0.066720)	(0.232100)	(0.432250)
ARCH			
ε_{t-1}^2	0.073027***	0.071534***	
	(0.016507)	(0.015151)	
$ln\sigma_{t-1}^2$		0.569836***	
		(0.049933)	
$\frac{\lvert\varepsilon_{t-1}\rvert}{\sigma_{t-1}}$			0.067988***
			(0.018273)
$\frac{\varepsilon_{t-1}}{\sigma_{t-1}}$			0.131609***
			(0.028419)
$ln\sigma_{t-1}^2$			0.724731***
			(0.036103)
N	3023	3023	3023

Standard errors in parentheses: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

surprising. A one percent change in the EUR/USD market is quit server. Thus, it should increase the variance in the NOK/USD market quite drastically.

6 CONCLUSION

In this paper it has been argued that the current petroleum taxation system creates an unnecessary cycle of purchases through foreign currencies. There has been done an empirical analyze over the period from March 29th, 2001 to May 6th, 2013. The emphasis has been on whether Norges Bank affects the volatility in the Norwegian krone – U.S. dollar market through announcements of their monthly purchase plan of foreign currency. Over the period as a whole, there is no evidence of higher volatility on those particular days. By including a structural change in the model, to account for the change in the petroleum tax system August 2008, we find a significantly larger volatility on the announcement days prior to the system change. However, another important factor, not picked up by the model, is the increased transparency in Norges Bank's operating market decisions through the period. The empirical research has revealed several important variables that affect the conditional variance in the Norwegian krone – U.S. dollar market. In comparison with these variables, the announcements prior to the structural change cannot be said to have been an important driver for volatility.

Even though the principles for the Norwegian petroleum taxation system create excessive currency operations, the research done in this paper does not provide evidence to support a change in the current system. On the contrary, it is likely that the excessive currency transactions help maintain liquidity of the Norwegian krone, and lower the overall volatility.

APPENDIX

A.1 EFFICIENT CAPITAL MARKETS

With efficient markets; all prices reflect all relevant information. Fama (1970, 1976) defines three types of efficiency, depending on what information that is understood to be relevant. Weak-form efficiency says that information about historical prices is not useful in making excess return. In other words, one cannot develop trading rules based on historical prices and returns in capital markets. Semistrong-form efficiency states that no investor can make excess return based on any publicly available information. All prices reflect all publicly available information. Strong-form efficiency states that no investor can earn excess return using any information, publicly or not. With this form of efficiency, not even insiders are able to earn abnormal returns (Copeland, Weston, & Shastri, 2005). In this paper, semistrong-form efficiency is assumed. Therefore, as Norges Bank announces new information, this will impact the prices of the Norwegian krone. With the strong assumption, the market would not react to the announcement, because the information would already been reflected by the prices, even though the information was not publicly available.

A.1.2 THE VALUE OF INFORMATION

The value of an information structure can be expressed as

$$V(\eta) \equiv \sum_m g(m) \underset{a}{MAX} \sum_e p(e|m)U(a,e) - V(\eta_0).$$

g(m) is the prior probability for receiving message *m*, *p(e|m)* is the conditional probability of event *e*, given message *m*, *U(a,e)*, is the utility from action *a* if event *e* occurs, $V(\eta_0)$ is the expected utility of the decision maker without the information (Copeland, Weston, & Shastri, 2005). The value of the Norwegian krone will therefore depend on the likelihood of receiving information, the likelihood of each particular event given that information, and the utility of the actions given those events, and of course, adjusted for the utility given no new information available. An important aspect of this formula, regarding this paper, is the probability for the announcement to be as the market anticipates. For example, if the market expects the announcement to be a 200 million daily purchase of foreign currency with a probability of 90 percent, and the announcement is as expected, the value of the Norwegian krone will not adjust much as opposed to an announcement which surprises the market. It is likely that for many of the announcement days, the market has already guessed the announcement, and the effect will be relatively small.

A.2 THE FLOOR SYSTEM

The liquidity policy is executed in order to implement the monetary decisions. The most common framework for liquidity policy is through a corridor system. In a corridor system the central bank offers two overnight facilities; a deposit rate and a lending rate. No bank is willing to lend money to another bank in the interbank market at a lower rate than the deposit rate offered overnight in the central bank. Similarly, banks will not loan to a rate higher than the lending rate offered by the central bank, as long as the bank is eligible for loans at the central bank[25]. The key rate determined by the central bank's monetary policy is normally in the middle of the deposit rate and the lending rate in a corridor system. The central bank is using supply and demand of liquidity in the banking system to adjust the overnight interbank money market rate, to be close to the key rate (Bernhardsen & Kloster, 2010).

Norges Bank is using a so-called floor system. An advantage of the floor system is its capability to distinguish the liquidity policy and the monetary policy. As the liquidity drained during the financial crisis (2007-2009), this was beneficial. The construction of a floor system is the same as the corridor system, with the same facilities offered by the central bank. However, in the floor system, the liquidity provided by the central bank is large enough for the interbank interest rate to approach the deposit rate. In other words, the deposit rate is set equal to the key interest rate. The floor system does have a drawback. The banks inside the system do not have as much incentives to trade with each other. The supply side of loans might dry up, as banks having excess liquidity might choose to use the deposit facility in the central bank opposed to lending out the excess liquidity in the interbank money market (Keister, Martin, & McAndrews, 2008). On October 3th, 2011, Norges Bank extended the liquidity system (Syrstad, 2012). The extended version of the floor system provides each bank with a limit of how much capital they are eligible placing at the deposit rate. The excess capital above this limit earns a rate lower than the deposit rate, called the reserve rate. This provides banks incentives to lend out excessive capital in the interbank money market. Norges Bank separates the deposit facility and the lending facility by one percentage point. The reserve rate is one percentage point lower than the deposit rate.

A.3 IMPLIED VOLATILITY AND THE GLOBAL HAZARD INDEX

Volatility is an unobservable value. Thus, a proxy for volatility is needed. Historical volatility does not live up to the task, as current and future volatility is not dependent upon former

[25] Banks need to provide collateral in order to use the central bank's lending facility. In addition, not all banks are eligible for the facility, such as foreign banks operating in Norway.

volatility (McDonald, 2006). An alternative is to use the implied volatility obtained directly from the derivative market. Implied volatility is obtained by observing the options prices on the underlying asset of interest. The Black & Scholes formula is frequently used to calculate the implied volatility. For a European call option, the Black & Scholes becomes what is called the Garman-Kohlhagen model:

$$c = xe^{-r_f T}N(d_1) - Ke^{-rT}N(d_2)$$

$$d_1 = \frac{ln\frac{x}{K} + \left(r - r_f + \frac{1}{2}\sigma^2\right)T}{\sigma\sqrt{T}}$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

c, is the call price, *x* is the current exchange rate (domestic currency per unit of foreign currency), K is the strike price, *r* and r_f are domestic and foreign interest rate, σ is the volatility, T denotes time and $N(x)$ is the cumulative normal distribution function (McDonald, 2006). All the inputs except volatility are easily observed directly from the market. Volatility can be found by solving the formula for σ. The implied volatility reflects the markets belief about the volatility. An option is more valuable when fluctuations are large. The higher the option price is, all else equal, the higher is the implied volatility. In other words, when market participations believe that there is a lot uncertainty in the market, they will price an option to buy or sell a future asset for a given price higher. The formula above can easily be extended to a European put option.

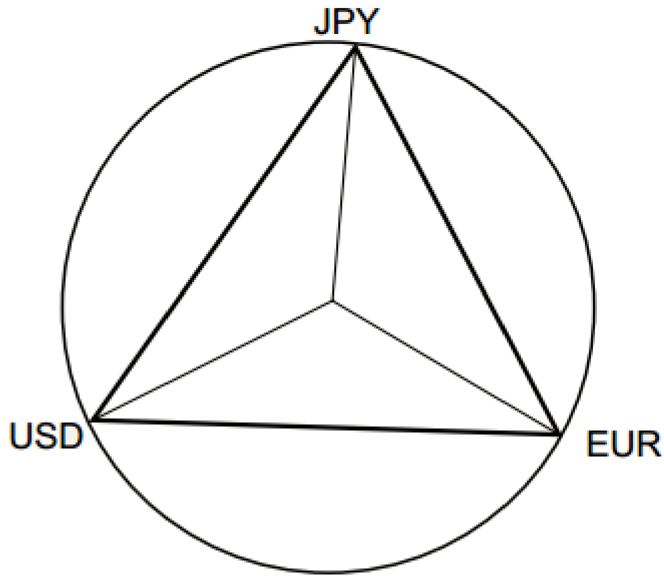
Brousseau and Scacciavillani (1999) suggested that a relevant indicator for international money market turbulence can be formed by the implied volatilities of the exchange rates among the dollar, the euro and the yen[26]. The global hazard index (GHI) is given by:

$$GHI = \frac{2\sigma_{U/E}\sigma_{J/U}\sigma_{E/J}}{\sqrt{\left(\sigma_{\frac{U}{E}} + \sigma_{\frac{J}{U}} + \sigma_{\frac{E}{J}}\right) * \left(-\sigma_{\frac{U}{E}} + \sigma_{\frac{J}{U}} + \sigma_{\frac{E}{J}}\right) * \left(\sigma_{\frac{U}{E}} - \sigma_{\frac{J}{U}} + \sigma_{\frac{E}{J}}\right) * \left(\sigma_{\frac{U}{E}} - \sigma_{\frac{J}{U}} - \sigma_{\frac{E}{J}}\right)}}$$

where $\frac{U}{E}$, $\frac{J}{U}$ and $\frac{E}{J}$ refer to $\frac{USD}{EUR}$, $\frac{JPY}{USD}$ and $\frac{EURO}{JPY}$, respectively (Brousseau & Scacciavillani, 1999). The formula is an expression of an orthocenter. Figure 8 illustrates this. The lines between the pars of currencies, in the figure, implicate the implied volatility in between them. In the illustration, the implied volatilities between the pars are at the same level. Thus, the lines are of equal length. The diameter of the circle is equal the orthocenter which is equal GHI. The

[26] When Brousseau and Scacciavillani (1999) published their paper, they suggested using the German mark.

Figure 8: Orthocenter



Notes: Figure obtained from Bernhardsen and Røisland (2000)

average implied volatility equal a third of the circumference of the triangle. The GHI is larger than the mean implied volatility. If the implied volatility off for example $\frac{JPY}{USD}$ is very low, the average volatility would be reduced by far. However, the GHI will not be reduced as much. The GHI will be close to the implied volatility between USD and EUR. This will reflect the international uncertainty. If we follow the same example, but Japan ties their currency to the dollar, the average implied volatility will increase by far, while the GHI will be reduced marginally (depending on the initial implied volatility between JPY and USD) (Bernhardsen & Røisland, 2000).

A.4 Spurious Regressions

A.4.1 Stationarity

A variable is strictly stationary if its properties are not affected over time. In other words, the joint probability distribution is not changed over time. For a weakly stationary variable, only the mean, variance and the covariance are needed to be independent of time (Verbeek, 2012). For instance, take the Oslo Stock Exchange index *osebx*. If the stock market is efficient, then the value of the index will represent all available information to the market. Changes to the index will occur only as new information becomes available. This can be written as a random walk model, $osebx_t = \beta osebx_{t-1} + e_t$. Today's value of osebx equals yesterday's value of *osebx* plus any newly available information to the market given by e_t. Thus, $\beta = 1$. Assuming efficient markets and that any new information is at random, $E(e_t) = 0$, then it can be showed that the variance of *osebx* increase linearly over time

$$var(y_t) = var(e_t) + var(e_{t-1}) + \cdots + var(e_1) = \sigma_e^2 t.$$

If $var(y_0) = 0$, the correlation between y_t and y_{t+h} is given by $corr(y_t, y_{t+h}) = \sqrt{\frac{t}{t+h}}$. The covariance is not stationary as, the covariance between two points with the same distance in between increases as *t* increases. The constant mean requirement is violated if *osebx* follows any trend. If *osebx* can be described by these properties, we can conclude that *osebx* is following a random walk and is non-stationary.

A.4.2 Definition of Spurious Regression

A spurious regression problem has its origin from a situation where two variables are correlated through their correlation with a third variable (Wooldridge, 2009). When dealing with two independent series that are both integrated of order one, the situation is more complicated. Even though the series have means without trends, the relationship between the two will often be significant. Granger and Newbold (1974) showed this through a regression of one variable integrated of order one on another variable integrated of order one, using ordinary least squares. They showed, by doing this, that a large percentage of the time the t-statistic was significant far more often than one could expect. Granger and Newbold (1974) called this the spurious regression problem. Davidson and MacKinnon showed that with a sample size of 50, the null hypothesis was rejected against the five percentage level about 66.2 percent of the time. The problem even got more severe when the sample size increased (Wooldridge, 2009).

If the residual follows a random walk, then the t-statistic does not have an asymptotic normal distribution (Verbeek, 2012). More formally it can be showed that the residual from a regression of one variable on the other follows a random walk. The two I(1) variables can be written as $y_t = y_{t-1} + a_t$ and $x_t = x_{t-1} + e_t$. The regression can then be written as

$$y_t = \beta_0 + \beta_1 x_t + u_t.$$

The residual needs to have zero mean, $E(u_t) = 0$, for the t-statistic for the estimated coefficient on x, $\hat{\beta}_1$ to be asymptotically normally distributed for large samples. The null hypothesis is given by $H_0: \beta_1 = 0$. Since the two variables are independent, the null should hold. We can then rewrite the equation as $y_t = \beta_0 + u_t$. For H_0 to hold, firstly β_0 needs to equal 0, but more importantly if $u_t = y_t = \sum_{i=1}^{t} e_i$.Then the residual, u, follows a random walk (Wooldridge, 2009).

A.4.3 Testing for Unit Roots

In order to formally test whether a variable is stationary or not, we can test for unit roots. We insert the variable we want to test in an autoregressive model of order one (AR(1)), $y_t = \alpha + py_{t-1} + e_t,\ t = 1,2, \ldots,$, where y_0 is the initial value of the variable. e_t is assumed to be independent identically distributed with zero mean and is independent of y_0 (Wooldridge, 2009). If $p = 1$ the variable has a unit root. Thus, it follows a random walk and is non-stationary. If, then in addition, $\alpha \neq 0$, the variable follows a random walk with a drift. We can now test whether $p = 1$. We test the null hypothesis, $H_0: p = 1$, against the alternative hypothesis, $H_1: p < 1$. When $|p| < 1$, y_t is a stable AR(1) process. By subtracting y_{t-1} from both sides of the AR(1) equation we obtain

$$\Delta y_t = \alpha + \theta y_{t-1} + e_t.$$

Where $\theta = p - 1$. It is now straightforward to test $H_0: \theta = 0$ against $H_1: \theta < 0$. A rejection of the null hypothesis implies that the variable y does not follow a random walk. If we keep the null hypothesis, the variable is an I(1) process and, as stated above, we cannot use the central limit theorem. Thus the t-statistic does not have an asymptotic standard normal distribution even for large samples. However, we can use the t-statistics, but they have to be compared with adjusted critical values. These critical values were first obtained by Dickey and Fuller (1979), and the test is called the Dickey-Fuller (DF) test (Wooldridge, 2009).

The test can easily be extended to include a time trend or to include lags of Δy_t. The latter is called an augmented Dickey-Fuller test. By including both a time trend and lags, the model will can be expressed as

$$\Delta y_t = \alpha + \theta y_{t-1} + \delta_t + \Delta y_t +, \ldots, \Delta y_{t-p} + e_t,$$

where δ_t refers to the time trend. When including these terms, the critical values for the t-statistic change (Wooldridge, 2009).

Table 8 below displays the results of a Dickey-Fuller unit root test on all variables in their level form. All variables do have unit roots for all lag options on the five percentage significance level. The maximum number of lags included in the test is determined by the Schwert criterion. Table 9 displays the results after taking first difference of the variables, with exception of $\Delta ln\frac{JPY}{USD}$, all variables passes the test for all lags, and reject the null hypothesis of having unit roots. $\Delta ln\frac{JPY}{USD}$ does not reject the null hypothesis on the five percentage significance level for 26, 27 and 28 lags. As it rejects a unit root for all other lags, the variable is used in the analysis.

A.5 MULTICOLLINEARITY

In a regression with highly correlated explanatory variables, we may experience multicollinearity problems. Multicollinearity drives up the variance of the coefficients, and might create problems establishing significant coefficients. The sample variance of the coefficients $\hat{\beta}_j$ is given by

$$var(\hat{\beta}_j) = \frac{\sigma^2}{SST_j(1-R_j^2)},$$

σ^2 is the error variance and represent white noise. SST_j is the total sample variation in variable *j*. R_j^2 is the R-squared of a regression of *j* on all other explanatory variables. Thus it explains how much of the variation in *j* that can be explained by the other explanatory variables. It is clear from the formula above that a higher R_j^2 will increase the variance of the coefficient $\hat{\beta}_j$. Wit R_j^2 equal one, the regression will suffer from perfect collinearity and the regression is not valid (Wooldridge, 2009).

Table 8: Dickey-Fuller test for stationarity

Lags	$ln\frac{NOK}{USD}$	$ln\frac{EUR}{USD}$	$ln\frac{JPY}{USD}$	$lnosebx$	$lns\&p500$	$lnstl$	$lnoil$	$lnidiff$	$lnghi$	$lnvol$	Critical Values		
											1 %	5 %	10 %
28	-1.626	-1.212	-1.766	1.781	-1.779	-1.388	-2.795	-1.056	-1.926		-3.480	-2.832	-2.545
27	-1.612	-1.217	-1.767	1.714	-1.723	-1.320	-2.723	-1.007	-1.941	-1.832	-3.480	-2.833	-2.546
26	-1.609	-1.212	-1.680	1.734	-1.719	-1.380	-2.750	-0.987	-1.989	-1.923	-3.480	-2.833	-2.546
25	-1.572	-1.211	-1.668	1.668	-1.713	-1.302	-2.607	-0.989	-1.932	-1.903	-3.480	-2.833	-2.547
24	-1.581	-1.221	-1.653	1.658	-1.736	-1.336	-2.593	-1.008	-2.040	-1.886	-3.480	-2.834	-2.547
23	-1.578	-1.259	-1.720	1.716	-1.811	-1.374	-2.626	-1.021	-2.166	-1.857	-3.480	-2.834	-2.547
22	-1.579	-1.225	-1.749	1.725	-1.802	-1.361	-2.641	-1.044	-2.208	-1.816	-3.480	-2.835	-2.548
21	-1.647	-1.282	-1.781	1.728	-1.758	-1.366	-2.746	-1.048	-2.212	-1.769	-3.480	-2.835	-2.548
20	-1.651	-1.356	-1.756	1.681	-1.751	-1.345	-2.770	-1.042	-2.231	-1.782	-3.480	-2.836	-2.549
19	-1.599	-1.326	-1.723	1.721	-1.745	-1.378	-2.750	-1.028	-2.252	-1.762	-3.480	-2.836	-2.549
18	-1.675	-1.363	-1.733	1.700	-1.762	-1.319	-2.729	-1.021	-2.247	-1.767	-3.480	-2.837	-2.550
17	-1.707	-1.334	-1.757	1.718	-1.865	-1.347	-2.658	-0.994	-2.298	-1.801	-3.480	-2.837	-2.550
16	-1.609	-1.266	-1.711	1.638	-1.778	-1.341	-2.707	-0.983	-2.219	-1.837	-3.480	-2.838	-2.550
15	-1.604	-1.255	-1.711	1.554	-1.712	-1.300	-2.714	-1.008	-2.143	-1.691	-3.480	-2.838	-2.551
14	-1.541	-1.206	-1.776	1.540	-1.772	-1.349	-2.644	-1.027	-2.090	-1.636	-3.480	-2.839	-2.551
13	-1.520	-1.175	-1.813	1.546	-1.809	-1.386	-2.511	-1.024	-1.971	-1.565	-3.480	-2.839	-2.552
12	-1.561	-1.200	-1.734	1.503	-1.752	-1.404	-2.402	-0.998	-1.945	-1.533	-3.480	-2.840	-2.552
11	-1.534	-1.129	-1.711	1.532	-1.781	-1.462	-2.456	-0.966	-1.935	-1.460	-3.480	-2.840	-2.552
10	-1.512	-1.118	-1.748	1.561	-1.758	-1.528	-2.413	-0.951	-1.918	-1.512	-3.480	-2.840	-2.553
9	-1.488	-1.139	-1.653	1.522	-1.727	-1.501	-2.345	-0.924	-1.862	-1.428	-3.480	-2.841	-2.553
8	-1.570	-1.183	-1.615	1.515	-1.736	-1.502	-2.332	-0.907	-1.929	-1.503	-3.480	-2.841	-2.554
7	-1.555	-1.121	-1.655	1.487	-1.653	-1.504	-2.426	-0.882	-1.949	-1.573	-3.480	-2.842	-2.554
6	-1.520	-1.052	-1.655	1.421	-1.695	-1.493	-2.404	-0.830	-1.987	-1.685	-3.480	-2.842	-2.554
5	-1.572	-1.088	-1.766	1.454	-1.741	-1.546	-2.467	-0.755	-2.057	-1.785	-3.480	-2.843	-2.555
4	-1.620	-1.108	-1.719	1.512	-1.809	-1.607	-2.503	-0.713	-2.120	-1.856	-3.480	-2.843	-2.555
3	-1.606	-1.058	-1.713	1.486	-1.847	-1.616	-2.438	-0.676	-2.164	-1.856	-3.480	-2.843	-2.556
2	-1.619	-1.060	-1.737	1.522	-1.817	-1.673	-2.428	-0.635	-2.219	-1.916	-3.480	-2.844	-2.556
1	-1.702	-1.095	-1.807	1.554	-1.962	-1.800	-2.374	-0.572	-2.229	-1.998	-3.480	-2.844	-2.556

Notes: The t-distribution is marginally different for lnvol. However, using the absolute correct critical values does not change the interpretation.

Table 9: Dickey-Fuller test for Stationarity, First Difference

Lags	$\Delta ln\frac{NOK}{USD}$	$\Delta ln\frac{EUR}{USD}$	$\Delta ln\frac{JPY}{USD}$	$\Delta lnosebx$	$\Delta lns\&p500$	$\Delta lnstl$	$\Delta lnoil$	$\Delta lnidiff$	$\Delta lnghi$	$\Delta lnvol$	Critical Values		
											1 %	5 %	10 %
28	-4.675	-3.074	-2.541	-8.310	-7.028	-4.237	-9.230	-6.694	-7.750		-3.480	-2.832	-2.545
27	-4.902	-3.129	-2.618	-8.729	-7.399	-4.453	-9.557	-7.150	-7.834	-5.313	-3.480	-2.833	-2.546
26	-5.084	-3.212	-2.689	-9.225	-7.797	-4.768	-9.954	-7.612	-8.016	-5.661	-3.480	-2.833	-2.546
25	-5.253	-3.319	-2.860	-9.272	-8.035	-4.772	-10.015	-7.898	-8.078	-5.589	-3.480	-2.833	-2.547
24	-5.528	-3.426	-2.967	-9.825	-8.295	-5.164	-10.733	-8.039	-8.571	-5.787	-3.480	-2.834	-2.547
23	-5.696	-3.524	-3.090	-10.079	-8.452	-5.264	-10.997	-8.046	-8.401	-5.991	-3.480	-2.834	-2.547
22	-5.915	-3.581	-3.117	-9.930	-8.416	-5.359	-11.073	-8.104	-8.177	-6.243	-3.480	-2.835	-2.548
21	-6.138	-3.771	-3.197	-10.073	-8.705	-5.622	-11.234	-8.082	-8.259	-6.552	-3.480	-2.835	-2.548
20	-6.160	-3.804	-3.279	-10.263	-9.168	-5.852	-11.030	-8.206	-8.482	-6.910	-3.480	-2.836	-2.549
19	-6.388	-3.804	-3.440	-10.782	-9.513	-6.205	-11.157	-8.411	-8.663	-7.116	-3.480	-2.836	-2.549
18	-6.831	-4.004	-3.635	-10.772	-9.895	-6.389	-11.465	-8.698	-8.844	-7.442	-3.480	-2.837	-2.550
17	-6.859	-4.082	-3.786	-11.165	-10.195	-6.974	-11.803	-8.943	-9.142	-7.718	-3.480	-2.837	-2.550
16	-7.039	-4.306	-3.932	-11.311	-10.082	-7.260	-12.407	-9.379	-9.233	-7.911	-3.480	-2.838	-2.550
15	-7.731	-4.655	-4.214	-12.197	-10.933	-7.740	-12.498	-9.708	-9.877	-8.110	-3.480	-2.838	-2.551
14	-8.155	-4.917	-4.461	-13.278	-11.817	-8.488	-12.796	-9.714	-10.612	-9.019	-3.480	-2.839	-2.551
13	-8.913	-5.328	-4.608	-13.878	-12.031	-8.858	-13.502	-9.787	-11.346	-9.732	-3.480	-2.839	-2.552
12	-9.584	-5.755	-4.824	-14.349	-12.395	-9.332	-14.667	-10.061	-12.627	-10.657	-3.480	-2.840	-2.552
11	-10.011	-6.050	-5.331	-15.402	-13.426	-9.994	-15.917	-10.597	-13.538	-11.546	-3.480	-2.840	-2.552
10	-10.885	-6.758	-5.813	-15.801	-14.004	-10.492	-16.257	-11.261	-14.479	-12.900	-3.480	-2.840	-2.553
9	-11.902	-7.371	-6.212	-16.234	-15.070	-10.986	-17.325	-11.817	-15.649	-13.658	-3.480	-2.841	-2.553
8	-13.160	-7.948	-7.092	-17.570	-16.418	-12.207	-18.814	-12.596	-17.463	-15.650	-3.480	-2.841	-2.554
7	-13.833	-8.502	-8.050	-18.733	-17.656	-13.513	-20.158	-13.344	-18.401	-16.759	-3.480	-2.842	-2.554
6	-15.424	-9.772	-8.966	-20.481	-20.221	-15.142	-20.764	-14.320	-20.050	-18.141	-3.480	-2.842	-2.554
5	-17.684	-11.544	-10.342	-23.436	-22.022	-17.414	-22.668	-15.999	-21.903	-19.405	-3.480	-2.843	-2.555
4	-19.699	-13.108	-11.540	-25.351	-24.274	-19.650	-24.166	-18.728	-23.855	-21.097	-3.480	-2.843	-2.555
3	-22.402	-15.366	-14.200	-27.377	-26.992	-22.568	-26.474	-21.579	-26.534	-23.664	-3.480	-2.843	-2.556
2	-27.315	-19.653	-18.083	-32.576	-31.483	-27.822	-31.234	-25.497	-30.742	-28.457	-3.480	-2.844	-2.556
1	-35.201	-26.378	-24.677	-39.313	-41.191	-35.911	-38.245	-31.925	-37.434	-35.601	-3.480	-2.844	-2.556

Notes: The t-distribution is marginally different for Δlnvol, as the shwerz criterion suggest 27 lags. Using the correct critical values does not change the interpretation.

BIBLIOGRAPHY

Aamodt, E. (2009). Valutakursmodellering av den norske kronen - en undersøkelse av informasjonsinnholdet i NOK/SEK-kursen. *Masteroppgave NHH*.

Aamodt, E. (2012). *Petroleumsfondsmekanismen og Norges Banks valutakjøp til SPU.* Aktuell kommentar, Norges Bank.

Aamodt, E. (2012). *Petroleumsfondsmekanismen og Norges Banks valutakjøp til SPU.* Aktuell kommentar, Norges Bank.

Akram, Q. F. (2004). Oil prices and exchange rates: Norwegian evidence. *Econometrics Journal* , 476-504.

Baillie, R. T., & Bollerslev, T. (1989). The Message in Daily Exchange Rates: A Conditional-Variance Tale. *Journal of Business & Economic Statistics, Vol 7, No. 3,* 297-305.

Bernanke, B. S. (2005, April 14). Remarks by Governor Ben S. Bernanke - The Global Saving Glut and the U.S. Current Account Deficit.

Bernhardsen, T., & Kloster, A. (2010). Liquidity management system: Floor or corridor? *Staff Memo no.4, Norges Bank*.

Bernhardsen, T., & Røisland, Ø. (2000). Hvilke faktorer påvirker kronekursen? *Penger og kredit*.

Bjørnstad, R., & Jansen, E. S. (2006). Renta bestemmer det meste. *Økonomiske analyser*, 42-47.

Brousseau, V., & Scacciavillani, F. (1999). A Global Hazard Index for the World Foreign Exchange Markets, Working Paper no.1. *European Central Bank Working Paper Series*.

Copeland, T. E., Weston, J. F., & Shastri, K. (2005). *Financial Theory and Corporate Policy, Fourth Edidition.* Pearson Addison Wesley.

Enders, W. (2010). *Applied Econometric Time Series.* John Wiley & Sons, Inc.

Evjen, S., & Kloster, T. B. (2012). Norges Bank's new monitary policy loss function - further discussion. *Staff Memo no.11*.

Flatner, A. (2009). Norske kroner ingen trygg havn. *Aktuell kommentar nr. 3 - Norges Bank.*

Flatner, A., & Tornes, P. H. (2002). Bankenes likviditet og Norges Bank likviditetstyring. *Norges Bank.*

Gjerstad, T., & Skard, K. (2013). Nektes Adgang. *Dagens Næringsliv, 16 mai 2013*, 6-7.

Hill, R. C., Griffiths, W. E., & Lim, G. C. (2012). *Principles of Econometrics - International Student Version, Fourt Edition.* John Wiley & Sons.

Holmsen, A., Qvigstad, J. F., Røisland, Ø., & Solberg-Johansen, K. (2008). Communicating Monetary Policy Intentions: The Case of Norges Bank. *Monetary Policy Department Working Paper*.

Juel, S., Haarberg, K. J., & Brice, E. (2002). *Sterk krone - fordi vi fortjener det.* BI Centre for Monetary Economics Working Papers.

Keister, T., Martin, A., & McAndrews, J. (2008). Divorcing Money from Monetary Policy. *FRBNY Economic Policy Review*, 41-56.

Klovland, J. T. (2012). FIE420 Pengemarkeder og bankvesen F-4 forelesning 30.08.2012. *Norwegian School of Economics,* (ss. 2-5). Bergen.

McDonald, R. L. (2006). *Derivatives Markets.* Pearson Education, Inc. .

NBIM. (u.d.). *Norges Bank Investment Management* . Hentet May 2013 fra http://nbim.no/no/

Norges-Bank. (2012). Pengepolitisk Raport nr.1 2012.

Norges-bank. (u.d.). *Norges*. Hentet May 18, 2013 fra www.norges-bank.no: http://www.norges-bank.no/valutakjop/

Oljeskattekontoret. (2013). *Petroleumssektoren og petroleumsskatten i tall og trender.* Oljeskattekontoret.

Oslo-Børs. (2013, May 14). *www.oslobors.no*. Retrieved May 15, 2013, from http://www.oslobors.no/Oslo-Boers/Om-oss/Presserom/Pressemeldinger/Endret-utvalg-i-Oslo-Boers-Hovedindeks-OSEBX8

Rogoff, K. (1996). The Purchasing Power Parity Puzzle. *Journal of Economic Literature*, 647-668.

Røisland, Ø., & Sveen, T. (2006). Pengepolitikk under et inflasjonsmål: en dynamisk analyse. *Norsk Økonomisk Tidsskrift 120*, 90-103.

Sollund, S., & Lystad, R. S. (2002, December 20). *http://www.regjeringen.no/en/dep/fin/Documents-and-publications/andre/Publications-in-English-or-translated-in/prinsipputtalelser_fortolkninger/2002/betaling-av-petroleumsskatt-med-utenland.html?id=102721*. Retrieved from www.regjeringen.no.

Syrstad, O. (2012). The daily liquidity effect in a floor system - Empirical evidence from the Norwegian market. *Working Paper, Market Operations and Analysis - Norges Bank*.

Thøgersen, Ø. (2011). Pengepolitikkens evolusjon. *Samfunnsøkonomisk analyse og debatt*, 23-32.

Verbeek, M. (2012). *A Guide to Modern Econometrics, Fourth Edition.* West Sussex, UK: John Wiley & Sons Ltd.

Wooldridge, J. M. (2009). *Introductory Econometrics* . South-Western CENGAGE Learning.