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The implications of global volatility on USD and NOK real interest rates and exchange rates.

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Abstract

This Master thesis investigates the impact of global volatility on exchange rates and interest rates for US-dollar and Norwegian krone (NOK) during global uncertainty. Due to the availability of data and for efficient calculations we have chosen to split the global uncertainty into three periods: Financial crisis (2000-2008), Oil crisis (2010-2015) and Covid-19 pandemic (2019-2023). Our study finds that oil price increase has a positive impact on the NOK relative to USD in the short, medium, and long-term. The real interest rate is also affected by oil price. So, the results imply that global volatility has a major impact on USD and NOK real interest rates as well as exchange rates. During Covid-19 pandemic, the Volatility Index (VIX) affects the exchange rate for the whole period. However, oil price shocks, interest rate difference and VIX does not have an immediate impact, but it will have a great effect in the long run. Real interest rates are also impacted by global volatility, which alters the cost of borrowing and lending. Further our findings show that there are several factors that should be explored to get the full understanding of the complex problem. To be summarized, this study helps our understanding of the intricate connection between global volatility, exchange rates, and real interest rates by giving us important new information on how the USD and NOK currencies behave in a volatile global financial environment.

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1. Introduction

The objective of our thesis is to determine the consequences of the exchange rates and interest rates of Norway and the USA (United States of America) in the short-run and long-run during the time of uncertainty. The conditions whereby the global financial system operates are dynamic and unpredictable. These factors have broad impacts particularly for exchange rates and interest rates which serve as vital indices of the overall state of the economy and investor attitude. We would like to provide light on the dynamic nature of these variables and their reaction to global uncertainty by examining this relationship in the short and long run. We aim to deliver an in-depth comprehension of the mechanisms through which global uncertainty influences exchange rates and interest rates, subsequently assisting in an increased awareness of international finance and the formulation of effective monetary policies. To accomplish this, we execute an extensive examination of economic indicators and analyze their behavior. We take into account different time periods in the dataset from 2000- 2008 (Financial crisis), 2010-2015 (Oil crisis) and 2019-2023 (Covid-19 pandemic) and how these affect the exchange rates and interest rates in Norway and the US.

The motivation for this thesis is to understand the current economic environment which has been fundamentally defined by global volatility. The effect on interest rates and currency rates can have significant impacts on monetary policy, investment choices, and economic stability. We are interested in finding out whether different variables have a significant effect on the exchange rate and interest rate. This is done through Granger-causality test, multiple linear regression, and VAR (Vector Autoregressive) models. Based on the literature included and our assumption, the research question read as follows:

"How does global uncertainty affect exchange rates and interest rates in Norway and the US in the short and long run?"

Norway is especially prone to changes in market conditions and price fluctuations for commodities because of its resource-rich economy and dependence on oil exports. The United States demonstrates its own distinct sensitivities to global uncertainty being the largest economy in the world with a variety of sectors and broad global interactions. Investigating how exchange rates and interest rates in these two economies get impacted by global uncertainty provides significant insights into the various reactions and policy implications in various economic circumstances.

This study seeks to add to the knowledge already available on the subject by using econometric tools and examining pertinent economic indicators. Insights into how long- and short-term effects of global uncertainty on exchange rates and interest rates in Norway and the US are sought. The findings of the study can help policymakers create efficient monetary and fiscal policies, educate investors about the financial markets, and contribute to broader discussions about the effects of global uncertainty on financial systems around the world and economic stability.

1.1 Research objectives

This thesis aims to examine the relationship between exchange rates and interest rates in Norway and the US during different crisis periods. The first goal of the thesis is to determine whether there is a relationship between exchange rates and interest rates, VIX and Oil price. The second goal is to explain this relationship in terms of long-run and short-run dynamics. The ultimate goal is to demonstrate how uncertainty affects interest rate differentials and exchange rates from 2000 to 2023 and their causality and long-run and short-run structures. This thesis examines the long-run and short-run dynamics between exchange rates, interest rates, the VIX and oil prices.

1.2 Hypothesis

We posit that at the time of uncertainty, the exchange rates will change in the short run which strengthens the USD and devaluate the NOK, but the relationship will revert back to equilibrium in the long run. It would be interesting to see how the interest rates and exchange rates will behave and what will be the relationship between them in the crisis periods.

1.3 Structure of this paper

The orientation of this thesis proceeds as follows. Firstly, we review theories and literature on subjects relevant to exchange rates and interest rates. Finding the theory that best explains how exchange rates and interest rates interact during times of crisis is one of the objectives of this thesis. Then, we study the prior literature to search for patterns and differences that can serve as a historical foundation for our research. After that, we present the data we'll be using and explain why we selected the variables we chose for the upcoming regression. We did ADF (Augmented Dickey-Fuller) tests to check for stationarity. We also use Cook's D method, VIF test, Run White test, QQ plot, histogram plot and Shapiro test. After an overview of the long-run and short-run dynamics, we demonstrate the outcomes for each crisis period (Financial crisis, Oil Crisis, the Covid-19 Pandemic, and the Financial Crisis period). We describe the implications of our research and reach conclusions at the end. The tables in this paper display the results of numerous tests, regressions, and graphs. As therefore, we decide to place the remaining tables in the appendices and only include key plots and tables in the main body of the thesis.

2. Literature Review

Global uncertainty is cited as a state of increased obscurity and unforeseeable situation in the global economic, financial, or geopolitical environment. Lack of agreement or understanding about potential future developments could have a consequence for a few facts about the global economy. Global uncertainty shocks relate to a significant reduction in the areas of global inflation, global growth and in the global interest rate (Kang, Ratti & Vespignani, 2020). In this study, we are considering the Financial crisis, Oil crisis and Covid-19 pandemic and its impacts on the exchange rates and interest rates for Norwegian krone (NOK) and US- dollar (USD) for the period from 2000 to 2023.

Global uncertainty can have an impact on both short-term and long-term on the exchange rates and interest rates. The uncovered interest rate parity (UIP) connects interest rates and exchange rates. Since it is anticipated that the exchange rate between the two nations will change, potentially profitable interest rate arbitrage will no longer be possible. Risk-neutral investors will not care which interest rates are offered in the two countries. There are minor departures from UIP in the short term, but the idea holds considerably more strongly in the long run, claimed by Lothian and Wu (2011). However, there is very little research on this connection. Therefore, to stop a long-term contagion between these markets, authorities do not need to respond to volatility shocks. This is crucial because rapid and severe interventions by central banks in the money markets during times of turmoil may result in significant losses in foreign exchange reserves, which would eventually have the same outcomes without the intervention. The dramatically modified correlations are anticipated to recover to their typical levels in the medium-long term, so investors with cross-hedged positions in these markets can keep their allocations (Sensoy & Sobaci, 2014). On the other hand, in the short-run, global uncertainty can increase the risk-averse investors. These kinds of investors will sell their riskier assets as well as currencies held by them.

2.1 Exchange rate

Exchange rate is considered to be the main economic relationship between the local economy and the rest of the world. If the exchange rate is floating, fluctuations in exchange rate movements are both expected and desirable as the exchange rate serves as a mechanism which can adjust and absorb macroeconomic shocks. On the contrary, uncontrolled exchange rate fluctuations can be harmful for the economic conditions of a country. For foreign exchange traders and investors, frequent changes in exchange rates can lead to enormous losses. The SDG (Sustainable Development Goal) target of reducing global imbalances and exchange rate conflicts may be jeopardized by frequent changes in exchange rates, which also have a negative impact on a nation's balance of payments and distort international comparisons. Essentially, it has been demonstrated in the literature that abrupt changes in exchange rates can result in high production costs, risky international transactions, and rising unemployment, among other things (Isah & Ekeocha, 2023).

Using a de facto exchange rate classification to capture policies implemented by countries regardless of the regime reported by the country's authorities. A study by Zumaquero & Rivero (2013) results shows that exchange rate volatility does increase with the global financial crises and that there is an inverse relationship between the degree of flexibility in the exchange rate regime and RER (Real exchange rate) volatility.

Additionally, mixed evidence from empirical studies supports the hypothesis that the Norwegian exchange rate and Oil price are correlated. The Norwegian krone (NOK) and Oil price have a statistically insignificant relationship, according to Bjørvik, Mork & Uppstad (1998) and Akram & Holter (1996).

2.2 Interest rate

Through low interest rates and a sharp rise in loan volumes globally, financial innovations, inflation targeting, and small inflation contributed to financial instability. The credit volume nearly doubled between 1992 and 2008. The result was the emergence of asset bubbles (Røed, Larsen & Mjølhus 2009, pp. 84–96). Even though the Norwegian stock market dropped by 64% in just six months, from May to November 2008, the effects on the country's economy were very minor. With little economic stagnation and lower unemployment than almost any comparable economy, Norway emerged as the winner. Bank losses were also kept to a minimum. This resulted from both Norway's less exposed financial sector and the country's economies generally had strong performance. Many nations are currently experiencing a budgetary crisis as a result of bailouts, tax cuts, and government crisis packages. Norway has escaped a similar predicament due to its high petroleum revenues, small financial crisis, and minor real economy spillovers (Grytten & Hunnes, 2014).

For Oil crisis periods, a study by Bjørnland (2009) found that the Norwegian economy grows its overall income and demand in response to higher oil prices. The result found is an unemployment rate decrease with a gradual increase in inflation rate. Also interest rates rise eventually with a connection to a rise in economic activity.

2.3 Purchasing Power Parity (PPP)

Majority of economists suggest Purchasing Power Parity holds over the long run. Though there are a lot of arguments behind this. Additionally, estimates of PPP exchange rates are crucial for practical reasons, such as figuring out the degree of the nominal exchange rate's misalignment and the best course of action, establishing exchange rate parities, and comparing national income levels across borders (Westerlund & Narayan, 2015).

2.4 Interest Rate Parity (IRP)

A key principle of international finance is interest rate parity. It claims that whether considering expected changes in exchange rate spot rates (uncovered parity) or current forward exchange rates (covered parity), debt yields are similar across currencies. The scholarly literature on interest rate parity is surprisingly extensive given its significance to international finance. However, despite having a deep understanding of how interest and exchange rates behave, market participants' reactions to cross-currency variation in interest rates are surprisingly poorly understood (McBrady, Mortal & Schill, 2010).

Market volatility and fear of risks typically develop throughout a financial crisis according to Mishkin & Eakins (2019). Because of this, investors frequently go for safe-haven assets like US Treasury bonds, which raises the demand for them. The increased demand causes the bonds' yields to decline which lowers interest rates. As a result, interest rate parity may not be maintained when the gap between nations' interest rates widens. Interest rate parity may be affected by an Oil crisis. Because of the higher oil prices, central banks may increase interest rates. This may go against interest rate parity and expand the gap between countries' interest rates (Hamilton, 2009).

2.5 Different crisis periods

2.5.1 The Global Financial crisis

The combination of the US mortgage problem in the autumn of 2007 and the bankruptcy of Lehman Brothers developed into a global financial crisis in the autumn of 2008 (Bank of Japan, 2009). As claimed by the report from the Bank of Japan, this resulted in a decline in the foreign exchange rate markets´ liquidity, as well as considerable fluctuations in the exchange rates because of market participants becoming more risk-averse. This crisis hit Norway too. A study by Grytten & Hunnes (2010) reveals that, most economists are astonished by the very negligible influence of the enormous international challenges on the Norwegian economy considering the tiny size and openness of her sector. While the overall output in our three neighboring countries—Denmark, Finland, and Sweden—fell by 5.5, 6.4, and 9.4 percent over the course of a year in the second quarter of 2009, the Norwegian loss was only 2.2 percent. Furthermore, Norway's financial markets appear to be handling the crisis better than most other Western nations. As a result, the overexpansion of authorized credits and the money stock appears to be the root cause of both the boom and the bust, at least in part. This resulted in a global meltdown along with terrible global financial instability, where some nations maintained significant current account surpluses while others continued to run persistent deficits. The tiny, open Norwegian economy was similarly impacted by the global financial crisis. However, the crisis in Norway was less severe than in most other nations due to superior internal financial stability than in most other countries and an early abolition of the gold standard. (Gamir, J., 1991).

According to Dominguez, Hashimoto & Ito (2011), the global financial crisis had a great impact on world markets and resulted in an increase in debt for growing markets. Additionally, the study stated that trade-oriented countries experienced a decline in exports and countries with high debt had to accept a depreciation in their currency.

2.5.2 The Oil Crisis

The increasing oil production from Saudi Arabia and Russia resulted in a collapse of the oil prices in 2014 (Baumeister & Kilian, 2016). Developments in the oil market after the Oil crisis brought debate regarding the connection between commodity prices and exchange rates (Kohlscheen, Avalos, & Schrimpf, 2017). According to Chen, Liu, Wang & Zhu (2016) the oil price shocks can explain approximately 10 to 20 % of the long-term variations in exchange rates. Furthermore, the studies found that there is a strong relationship between oil prices and exchange rates, primarily for countries that have an oil-dependent economy. Oil price declines may have a less detrimental impact on the Norwegian economy, at least in the short run, if monetary and fiscal policy become more expansionary during the recession than they have been on average in the past. This could temporarily boost domestic demand and expenditure. However, the long-term consequences of such expansive policy are less certain (Bjørnland, H., & Thorsrud, L., 2014).

Additionally, Lizardo and Mollick (2010) discovered that oil prices can explain movements in the exchange rate of the US dollar against major currencies. The study found that when the oil price increases, the currencies of other oil importers like Japan, depreciate compared to the US dollar (Lizardo & Mollick, 2010). The study also states that the relationship is opposite for oil-exporting currencies. Sujit and Kumar (2011) found that higher oil prices often result in an increase in the currency of oil-exporting countries and a decrease in the currency of oil-importing countries.

2.5.3 Covid-19 pandemic

The pandemic of Covid-19 has caused chaos and turbulence in all financial markets (Günay, 2020). The research Günay (2020) found that the exchange markets were not as badly affected as they were during the global financial crisis. It was examined from one of the studies by Mo, Yang & Chen (2023) that high yield currencies like NOK depreciated against the USD at the beginning of the Covid-19 pandemic in February 2020 and again started to appreciate following the next two months and beyond while gaining the lowest value prior to March 23, 2020.

The purpose of the theoretical and literature review was two-fold. Firstly, we considered to present workable theoretical topics of whether exchange rates and interest rates cause any changes in short run and long run during crisis periods. Secondly, we ought to study previous empirical research to find support for our research question. Since some answer to this question can be gathered from previous research, we also conducted some tests based on the secondary data. The remaining chapters of this paper are going to discuss the methodology, result and discussion.

3. Methodology

3.1 Data

Research data for this study consists of monthly data from Norway and the United States covering 2000 to 2023. Using monthly data made the calculation easier to understand and describe but leaves us with less observations then by using weekly or daily data. We divided uncertainty period into three parts. Financial crisis (2000-2008), Oil crisis (2010-2015) and Covid-19 pandemic (2019-2023).

The real interest rate data from US, VIX, CPI Norway, CPI US and Oil price all have been acquired from FEDERAL RESERVE BANK of ST. LOUIS (FRED database). The Exchange rate NOK/USD and Norwegian interest rate has been acquired from Statistisk sentralbyrå (SSB). To create the variable Interest rate difference, we subtract the Norwegian Interest rate from the Interest rate of the US. PPP exchange rate derived from the equation of CPI Norway/CPI US * Exchange Rate NOK/USD. We set 2000 as a starting year for CPI in both countries equal to 100.

To see how exchange rate is affected by the independent variables, we test for the full period 2000-2023, Financial crisis 2000-2008, Oil crisis 2010-2015 and Covid-19 pandemic from 2019-2023. This is to capture how the variables are affected by the different crisis periods and in times without crisis considering the reasoning of the crisis are different.

3.2 Choice of Variables

Our choice of variables in this paper is based on theoretical and empirical research. Previous theoretical research suggests that exchange rates are affected by multiple macroeconomic variables. However, we decided to pick the Global volatility Index (VIX), oil price, real interest rate and Norwegian/USD exchange rate to address the research question. Nevertheless, we include PPP exchange rate to complete the analysis. The crude oil price is usually believed to influence the Norwegian exchange rate, as 78% of the exported goods in Norway are derived from oil (Government Petroleum Revenues, 2012). Appreciation pressures in the currency during 1996/1997 followed by depreciation in 1998/1999 attributed to the rise and fall of the oil prices (Akram, 2004). The assumed link between oil price and krone is based on the size of the petroleum sector relative to GDP.

Real interest rates are a crucial factor in understanding exchange rate dynamics, as changes in one can impact the other. Engel and West (2005) argue that interest rate differentials are important in determining the exchange rates in the long run. Their findings suggest that the difference in interest rates explains a vast amount of the variation in exchange rates over long periods of time, especially for countries with open capital markets. Chinn and Meredith (2004) study also suggest the same, but they also investigate that interest rate differences have a significant impact in the short run as well. Particularly their results suggest the difference in interest rates are very important in times of crisis or uncertainty.

The real inflation captures the inflationary pressure in an economy and provides insights into the relative changes in prices over time. We choose to add real interest rate as done by Hoffmann & MacDonald (2009) instead of using nominal interest rate and adding CPI (Consumer price index) into our models.

We exclude CPI in our regression and VAR model as real interest rates and CPI capture information about inflation, but from different angles. Including both variables could lead to multicollinearity issues and make it difficult to disentangle their individual effects on the exchange rate. We use CPI (Consumer Price Index) however to calculate purchasing power parity (PPP) exchange rate which we compare with the nominal exchange rate in Figure 2.

While the research question focuses on exchange rates, it is important to consider the role of PPP exchange rates. PPP exchange rates can provide important information about the relative competitiveness of countries. Deviations from PPP exchange rates might reflect differences in factors affecting the relative price of goods and services within the countries, such as productivity and trade barriers. PPP exchange rates are very useful in order to understand exchange rate dynamics in the long run, as they reflect the underlying economic fundamentals of countries (Coakley et al., 2005).

While picking these variables we decided to be parsimonious in our selection due to the limited amount of time series observation, complexity, and potential overfitting of the model. The increase of variables will also reduce the degree of freedom. Adjusting our models, we have taken Akaike information criterion (AIC) to consideration and added parameters that result with the lowest AIC compared to other considered models.

3.3 Regression analysis

Multiple regression analysis has assumptions, testing for these assumptions is important as serious violations can result in biased estimates of relationships and untrustworthy confidence intervals and significance (Williams, Grajales & Kurkiewicz, 2013).

The regression model assumes normal distribution, heteroscedasticity, linear relationship, multicollinearity, and variables being measured without error. Testing for normal distribution, we use QQ-plot (Appendix 1,Figure 9), histogram-plot, and Shapiro test (Appendix 2,Table 7). We worked with Cook's D method to clean the data and remove extreme outliers which also increase accuracy of the model. We analyze the linear relationship by looking at the residuals in the plot of the regression (Appendix 1, Figure 8). To check for Heteroscedasticity, White test is used and the VIF test (Appendix 2, Table 7) is utilized to check for multicollinearity. Additionally, we also run PACF (Partial autocorrelation function) and ACF (Autocorrelation function) test to gain insight into the presence and strength of autocorrelation of different lags. The assumption of stationarity also comes with Time series data. So, an Augmented Dickey-Fuller (ADF) test (Appendix 2, Table 6) was conducted to look for non-stationarity, and the outcome decides whether or not the NULL hypothesis should be rejected. The p-value threshold is 5%. We have performed an ADF test for each crisis period (Financial crisis, Oil crisis and Covid-19 pandemic). Then, we define a NULL hypothesis and an alternative hypothesis in order to obtain precise findings from the ADF test. These are as follows:

H_o: The variables are non-stationary.
H_A: The variables are stationary.

We need to adjust non-stationarity for those variables in the multiple regression model. Since the majority of our data is non-stationary, we transform them to stationary by converting them to the change from month to month.

3.4 Var model

Due to the regression model having assumptions such as linearity and independent variables are affecting the dependent variable and not the other way around, we also used the VAR (Vector autoregressive) model to see how the variables affect each other over time.

Conducting the VAR model, we check for what lags are best for our model, resulting in 1 or 2 lags being optimal. To see whether our model is stable or not we look at the unit root (Appendix 2, Table 9). We also conduct the portmanteau test (Appendix 2, Table 11) to see whether there is autocorrelation and an Arch test (Appendix 2, Table 10) for heteroscedasticity. Assessing whether one time series variable can predict another we perform a granger- causality test (Appendix 2, Table 8). Different from the regression model the VAR model allows us to check how shocks in the independent variables affect the dependent variable by the help of the impulse response analysis. We also look for seasonal trends (Appendix 1, Figure 10) in order to see how different lags affects the variables.

4. Results and Discussion

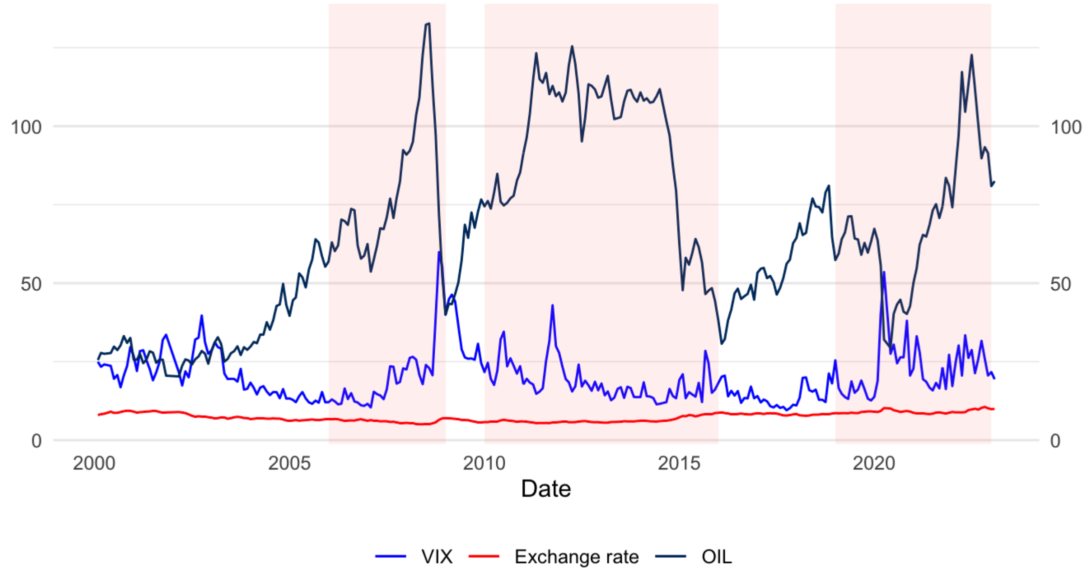

Figure 1:The trend of VIX's, Exchange rate and oil prices through the period 2000-2023 with highlighted crisis areas

Figure 1 provides an overview of how the different variables move in relation to each other, showcasing any notable patterns or extreme changes that occurred during the highlighted periods. By examining the graph, one can observe the dynamics and fluctuations of the VIX, exchange rate and oil price. These trends may reveal certain correlations or divergences between the variables, especially during the crisis periods.

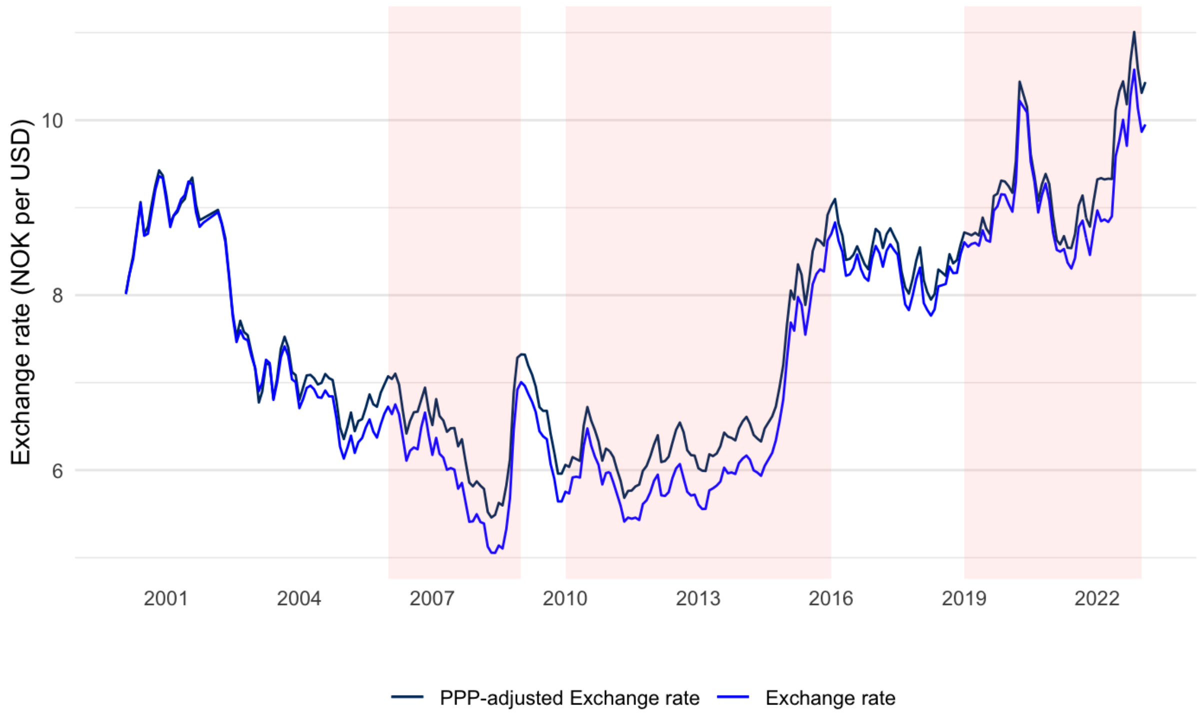

Figure 2: The trend of Exchange rate and PPP-adjusted Exchange rate

In Figure 2 it is observed that, when the PPP-adjusted exchange rate is higher than the actual exchange rate, it indicates that the local currency is undervalued compared to the reference currency. In this case, it means that the Norwegian Krone (NOK) is undervalued compared to the US dollar (USD) based on the relative price levels of goods and services between the two countries.

The exchange rate between the Norwegian krone and the US dollar is influenced by the relative purchasing power of the currencies in the short and the long run. The exchange rate movements adjust over time to maintain purchasing power parity and changes in the real economic fundamentals, such as inflation rates and productivity levels, play a crucial role in shaping the exchange rate dynamics between the two currencies. The exchange rate is moving towards its equilibrium level as implied by the theory of purchasing power parity.

The undervaluation can be explained by the "flight to quality" phenomenon, supported by Chaudhary, Shah, and Bagram (2012). As global uncertainty increases, the demand for smaller currencies decreases as the money flows into bigger currencies such as the USD. The depreciation of smaller currencies can also be attributed to the increase in risk aversion among investors. (Husted et al., 2018) finds a rise in risk aversion among investors during uncertain times. This risk aversion causes investors to favor low-risk assets such as US Treasury bonds over higher-risk assets. Political instability is also a driver of a currency being undervalued in uncertain times (López-Villavicencio & Mignon, 2017). However, both Norway and the US are both considered to be stable countries, but recent events in tax policy changes in Norway might have caused disruptions.

According to PPP theory, the difference in exchange rates and PPP exchange rate can be driven by various factors such as inflation, real income, and transaction cost. However, a study done by Lizardo & Mollick (2010) found that changes in oil prices had a significant impact on the exchange rates of several oil-importing and exporting countries. Another study by Mohaddes and Raissi (2018) found that fluctuations in oil prices significantly affected the exchange rates of several countries, including Norway.

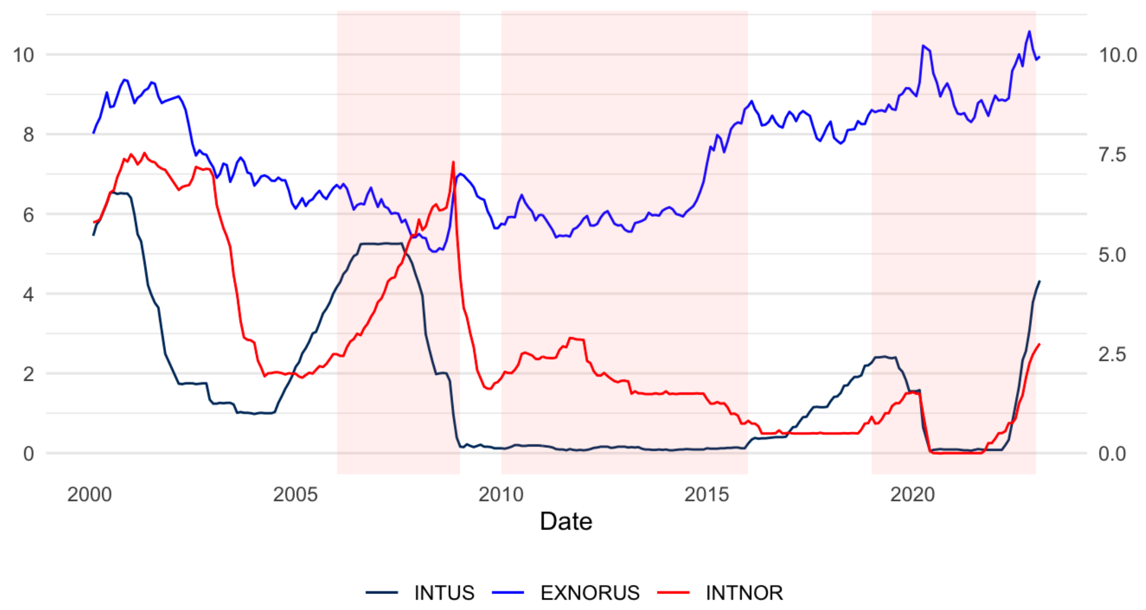

Figure 3:The trend of Exchange rate and Interest rates

Figure 3 provides an overview of how interest rates variations in the two different countries are potentially affecting the exchange rate between NOK and USD. One noteworthy observation from the graph is that the NOK on average exhibits higher interest rates compared to the USD throughout the entire period. The higher interest rate in Norway relative to the United States can have implications for the exchange rate between the currencies. Initially the NOK experiences an appreciation in value relative to the USD which in part can be attributed to the higher interest rates in Norway. The remaining 10 years however the NOK undergoes a devaluation relative to the USD. Various factors, such as changing economic conditions, market dynamics, and shifts in global capital flows, contribute to this devaluation. It is crucial to conduct a more detailed analysis and consider additional factors to understand the precise reasons behind this devaluation and its relationship with interest rates.

Regression results

	Dependent variable:			
	USD/NOK			
	(From 2000 to 2023)	(Financial Crisis)	(Oil Crisis)	(Covid-19)
ChangeIDIFF	0.0003	0.001	0.008	0.0004
	(0.0003)	(0.001)	(0.044)	(0.0004)
VIX	0.0003*	0.0005	0.0005	0.001*
	(0.0002)	(0.0003)	(0.0004)	(0.001)
ChangeOIL	-0.131***	-0.110***	-0.233***	-0.101**
	(0.017)	(0.030)	(0.032)	(0.040)
Constant	1.126***	1.099***	1.219***	1.083***
	(0.018)	(0.033)	(0.054)	(0.047)
Observations	270	107	60	43
R^2	0.246	0.196	0.498	0.346
Adjusted R^2	0.238	0.173	0.471	0.295
Residual Std. Error	0.024 (df = 266)	0.027 (df = 103)	0.018 (df = 56)	0.026 (df = 39)
F Statistic	28.948*** (df = 3; 266)	8.388*** (df = 3; 103)	18.532*** (df = 3; 56)	6.870*** (df = 3; 39)
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 1: Regression results Full period, financial crisis, oil crisis and covid-19.

Table 1 shows 0.246 of the changes in the exchange rate in the full period model is explained by the independent variables, 0.196 for the Financial crisis, 0.498 for Oil crisis and 0.346 for Covid-19 pandemic. The constants are significant at 1% through all the four measurements. For the full period the constant is 1.126 for the financial crisis 1.099, Oil crisis 1.219 and 1.083 for Covid-19 pandemic. The constant together with R squared indicates that there are other factors that explain the exchange rate which needs to be explored.

Oil Price changes are significant through the whole period at 1% level. Increasing exchange rate difference by one will cause a decline in oil price change by 0.131. For the financial crisis period the significance is at 1% level and one increase in exchange rate causes a decrease of 0.11 in oil price. During the Oil crisis, the exchange rate difference and oil price difference is significant at the 1% level with one increase in exchange rate difference causing a decrease by 0.223 in the oil price. During Covid-19 pandemic, the relationship is significant at the 5% level with one increase in exchange rate difference causing a decrease in oil price difference by 0.101. Overall if the oil price decreases the NOK will become weaker according to the findings of the Norwegian central bank who finds a correlation between the exchange rate and oil price, from oil prices above 14 USD.

VIX is significant during the full period at 10% level with one increase in exchange rate difference causing an increase of 0.0003 in VIX. During the Covid-19 pandemic, the relationship is significant at 10%, one increase in exchange rate will cause an increase in VIX by 0.001. These changes are small, but significant. During times of uncertainty and market stress such as the Covid-19 pandemic, investors tend to be more cautious and seek safer assets, which increases market volatility. Changes in exchange rates can be seen as indicators of market instability and economic uncertainty, which can have a stronger impact on the volatility index during such periods. Interest rates are also drivers of the exchange rates. During times of uncertainty, interest rates are often increased in the different countries by central banks in order to manage economic conditions and stabilize financial markets. These changes can add more complexity and risk for investors as they need to reconsider investments opportunities, borrowing cost and currency valuations causing further uncertainty.

It is possible that the Covid-19 pandemic had a larger global impact compared to the other crisis and therefore VIX is shown as significant during the full period and Covid-19 pandemic. The pandemic had far-reaching consequences across multiple sectors and countries. It brought global health emergencies and triggered widespread disruptions in economic activities leading to a severe global recession. The pandemic's impact on exchange rates was influenced by various factors, such as changes in trade patterns, shifts in investor sentiment, and government policy responses. The financial crisis also had a global impact but not at the same scale. The Oil crisis although significant might have had a more limited global impact compared to the other crisis. The specific dynamics of the oil market, geopolitical factors, and regional variations in economic dependence on oil might have influenced the relationship between oil prices and exchange rates during that period.

Exchange rate (dependent)	**Estimated**	**Std. Error**	**T value**	**P - value**	**Correlation**	**Covariance**
Oil price	9.347e-03	2.005e-02	8.7111	0.641	-0.4514	-0.001079
VIX	9.796e-05	2.038e-04	1.771	0.631	0.24520	0.03228
Interest rate difference	2.960e-04	3.033e-04	0.4389	0.330	0.14335	0.02043
Constant	-1.247e-03	4.429e-03	-0.281	0.779		
Residual standard error 0.0325	Multiple R-Squared 0.06019	Adjusted R-squared -0.04142	F-statistic 0.5924	p-value 0.6703		
Oil price (fin)	0.0167362	0.0326708	0.512	0.609581	-0.34828	-0.000888
VIX (fin)	0.0002967	0.0003123	0.950	0.344272	0.22799	0.02983
Interest rates diff (fin)	0.0008926	0.0008341	1.070	0.287080	0.17597	0.01694
Constant	0.6260442	0.1166330	5.368	5.1e-07***		
Residual standard error 0.02834	Multiple R-Squared 0.1539	Adjusted R-squared 0.1204	F-statistic 4.594	p-value 0.001892		
Oil price (oil crisis)	-0.0442846	0.0326708	-0.788	0.433933	-0.640758	-1.036e-03
VIX (oil crisis)	-0.0442846	0.0561730	-0.974	0.334325	0.32212	0.02821
Interest rates diff (oil crisis)	-0.0202006	0.0554919	-0.364	0.717259	0.025224	3.116e-05
Constant	0.7722004	0.2172621	3.554	0.000797***		
Residual standard error 0.02265	Multiple R-Squared 0.1713	Adjusted R-squared 0.1099	F-statistic 2.791	p-value 0.03522		
Oil price (covid)	-0.0109582	0.0527761	-0.208	0.836652	-0.5354	-0.002199
VIX (covid)	0.0003792	0.0007129	0.532	0.597933	0.35576	0.08637
Interest rates diff (covid)	0.0003042	0.0004621	0.0004621	0.514400	0.30917	0.1273
Constant	0.9028817	0.2206944	4.091	0.000223 ***		
Residual standard error 0.0325	Multiple R-Squared 0.06019	Adjusted R-squared -0.04142	F-statistic 0.5924	p-value 0.6703		

Table 2:VAR model results Exchange Rate as dependent

In Table 2, Fin refers to Financial crisis period 2000-2008, Oil crisis 2010-2015 and Covid-19 pandemic 2019-2023. Dependent variable is Exchange rate difference. All variables are measured by difference from one period to another except VIX.

Trying to predict the exchange rate with the other variables we find no other significance other than the constant. In contrast to our granger test which suggest the oil price highly affects the exchange rate between the Nok and USD. but further investigation is necessary to establish causality more conclusively. Using VAR (Basher et al., 2012) finds positive shocks to oil prices tend to depress the US dollar exchange rates in the short run.

Interest rates diff (dependent)	**Estimated**	**Std. Error**	**T value**	**P- value**	**Correlation**	**Covariance**
Exchange rates	26.04774	13.85542	1.880	0.0612*	0.14335	0.0204299
Oil price	8.99978	4.15048	2.168	0.0310 **	-0.2332	-0.115366
VIX	-0.03641	0.04220	-0.863	0.3891	0.24520	-0.36559
Constant	0.27869	0.91705	-0.304	0.7614		
Residual standard error 5.432	Multiple R-Squared 0.02544	Adjusted R-squared 0.01068	F-statistic 1.723	p-value 0.1452		
Exchange rates (fin)	-1.777788	12.204398	-0.146	0.884	0.1760	0.0169392
Oil price (fin)	3.733635	3.916338	0.953	0.343	-0.08615	-0.026338
VIX (fin)	0.006031	0.037431	0.161	0.872	0.10645	1.66925
Constant	-1.353382	13.981130	-0.097	0.923		
Residual standard error 3.397	Multiple R-Squared 0.01249	Adjusted R-squared 0.01068	F-statistic 0.3193	p-value 0.8645		
Exchange rates (oil)	0.120419	0.410178	0.294	0.770	0.02522	3.116e-05
Oil price (oil)	0.087407	0.135208	0.646	0.521	-0.003898	-1.517e-05
VIX (oil)	0.001029	0.001191	0.863	0.392	0.04789	0.01009
Constant	0.650754	0.522946	1.244	0.219		
Residual standard error 0.05453	Multiple R-Squared 0.04125	Adjusted R-squared -0.02977	F-statistic 0.5808	p-value 0.6778		
Exchange rate (covid)	144.25382	76.69433	1.881	0.0679 *	0.3092	0.127316
Oil price (covid)	30.64273	20.57606	1.489	0.1449	-0.4684	-0.750144
VIX (covid)	-0.19323	0.27793	-0.695	0.4912	-0.05105	-4.83247
Constant	-171.97994	86.04318	-1.999	0.0530 *		
Residual standard error 12.67	Multiple R-Squared 0.1102	Adjusted R-squared 0.01403	F-statistic 1.146	p-value 0.3503		

Table 3: VAR model results Interest rate as dependent

Here in Table 3 Fin refers to Financial crisis period 2000-2008, Oil crisis 2010-2015 and

Covid-19 pandemic 2019-2023. Dependent variable is Interest rate difference. All variables are measured by difference from one period to another except VIX.

We find significance between interest rate difference and change in exchange rates at the 10% level for the full period. Table 3 displays if the interest rate differential increases by one unit, then the exchange rate difference will also increase by 0.1434 units. We also identified the significance between interest rate difference and change in oil price at the 5% level. One unit change in interest rate differential will result in a -0.2332 change in oil price change. 0.1068 changes in the model with interest rate difference as dependent variable can be explained by the independent variables.

During Covid-19 pandemic, exchange rates are significant at the 10% level, one increase in interest rate difference causes an increase of 0.3092 in exchange rates. The constant is also significant during this period at the 10% level.

These findings are in accordance with the economic theory of exchange rates. Changes in the exchange rate can have an impact on interest rate differentials between two currencies. The movements in the exchange rate caused by monetary policy or capital flows could affect the relative attractiveness of investing in a specific country, which can influence the demand and supply of currencies and have an impact on the interest rate differential. This tend to be prevalent during time of crisis as investors flee to safe haven currencies such as the USD. Exchange rates can also be affected by interest rates. If interest rates in one country are higher than the other, investors might be attracted to the country's currency which will increase the demand and appreciate that currency's exchange rate in accordance with the interest rate parity theory.

It is fascinating to observe that the interest rate difference and exchange rates are significant only during the full period (2000-2023) and Covid-19 pandemic. This might be due to the full period encompassing a broader range of economic conditions and events, which allows a comprehensive assessment of their impact on the interest rate difference. The Covid-19 pandemic had a profound impact on global economies and financial markets. The significance due this time might have been caused by the heighten uncertainty and policy intervention in contrast to the Oil crisis. The disruptions caused by the pandemic might also have amplified the effects of these variables on the economic environment. During Oil crisis, other factors such as energy prices might have been more prevalent, while through the financial crisis banking sector stability and market liquidity may have dominated the economic landscape and diluted the influence of exchange rates on interest rates differential.

Interest rate differentials play a crucial role in influencing the currency values between Norway and the US. These findings highlight the importance of considering interest rate dynamics when analyzing and forecasting exchange rates and PPP movements. Levy-Yeyati & Sturzenegger, (2003) focused on the means by which various exchange rate regimes affect economic growth. They found a positive correlation between interest rates and exchange rates, which specified that higher interest rates are related to appreciation of the local currency of any country. Additionally, the effectiveness of empirical exchange rate models apart from samples is investigated in the study. It concludes that interest rate differences and changes in exchange rates are closely related (Meese & Rogoff, 1983). The interest rates affect investment flows, exchange rates and therefore might be affecting the demand and pricing for commodities such as oil through this mechanism.

Oil price (dependent)	**Estimated**	**Std. Error**	**T value**	**P - value**	**Correlation**	**Covariance**
Exchange rate	-0.5857196	0.2323366	- 2.521	0.0123***	- 0.4514	- 0.001079
Interest rate diff	- 0.0003414	0.0010529	- 0.324	0.7460	- 0.23317	- 0.11537
VIX	- 0.0009577	0.0007077	- 1.353	0.1771	- 0.20857	- 0.09532
Constant	0.0277257	0.0153777	1.803	0.0725 *		
Residual standard error 0.09109	Multiple R-Squared 0.07188	Adjusted R-squared 0.05782	F-statistic 5.111	p-value 0.0005553		
Exchange rate fin)	-5.347e-01	3.234e-01	-1.653	0.10134	-0.3483	-0.000888
Interest rate diff (fin)	4.361e-05	2.649e-03	0.016	0.98690	-0.08615	-0.02634
VIX (fin)	-2.747e-03	9.917e-04	-2.770	0.00668 ***	0.03496	0.01452
Constant	1.585e+00	3.704e-01	4.280	4.26e-05 ***		
Residual standard error 0.09	Multiple R-Squared 0.1356	Adjusted R-squared 0.1014	F-statistic 3.962	p-value 0.004991		
Exchange rate (oil)	-0.745348	0.536746	-1.389	0.1706	-0.64076	-1.036e-03
Interest rate diff (oil)	0.063112	0.174783	0.361	0.7194	-0.003898	-1.517e-05
VIX (oil)	0.001621	0.001559	1.040	0.3030	-0.23691	-0.06534
Constant	1.590041	0.684311	2.324	0.0239 **		
Residual standard error 0.099	Multiple R-Squared 0.03226	Adjusted R-squared 0.03226	F-statistic 1.483	p-value 0.2201		
Exchange rate (oil)	-0.3084894	0.7650401	-0.403	0.689	-0.5354	-0.002199
Interest rate diff (oil)	-0.0001805	0.0017971	-0.100	0.921	-0.46839	-0.7501
VIX (oil)	-0.0005304	0.0027724	-0.191	0.849	-0.36635	-0.34591
Constant	1.1721595	0.8582965	1.366	0.180		
Residual standard error 0.1264	Multiple R-Squared 0.06019	Adjusted R-squared -0.04426	F-statistic 0.5655	p-value 0.6892		

Table 4: VAR model results Oil price as dependent

In Table 4, Fin refers to Financial crisis period 2000-2008, Oil crisis 2010-2015 and Covid-19 pandemic 2019-2023. Here, the dependent variable is Oil price, and all variables are measured by difference from one period to another except VIX.

Having Changes in oil as the dependent variable the exchange rate is significant at 1% level and the constant is significant at 10% for the full period. One increase in oil price will decrease the Change in exchange rate by -0.4514. The explanation power for the full period model is 0.05782 which is quite low. During the financial crisis VIX is significant at the 1% level together with the constant. One increase in oil price will increase the VIX by 0.03496. The independent variable explains 0.1014 of the variations in oil price which is low. During the Oil crisis we have a constant which is significant.

Our long-term results are similar to the results in our linear model. Al-Mulali (2010) has similar results and finds Oil prices to appreciate in the NOK currency. Naranjan (2013) also finds appreciation in the currency, caused by oil prices in oil countries measured towards the USD. The independent variables in this model however have a very low explanation on the changes in Oil price. Testing for seasonal effect it seems the relationship between exchange rate and Oil price happens relatively immediately and fades after two lags.

VIX tends to rise when there is increased uncertainty in the stock market. Changes in oil prices can have broader economic implications and potentially affect market sentiment, but it does not necessarily translate into a consistent and predictable impact on the VIX. During 2006-2008 the Oil prices increased dramatically. The price increases were initially attributed to fundamental factors such as the rise in global demand, and disruptions of the supply of oil.

Bhar & Malliaris (2011) also proposes that the decline of the USD played an important role in the increase of oil prices as oil suppliers demanded compensation for the declining value of the dollar.

VIX (dependent)	Estimated	Std. Error	T value	P -value	Correlation	Covariance
Exchange rate	-10.88315	12.79794	- 0.850	0.396	0.2452	0.0322775
Interest rate diff	0.04106	0.05800	0.708	0.480	- 0.01341	- 0.36559
Oil price	- 0.81757	3.83370	- 0.213	0.831	- 0.2086	- 0.095318
Constant	4.08056	0.84706	4.817	2.46e-06 ***		
Residual standard error 5.017	Multiple R-Squared 0.6291	Adjusted R-squared 0.6235	F-statistic 111.9	p-value 2.2e-16		
Exchange rate (fin)	8.52164	16.58526	0.514	0.609	0.2280	0.0298252
Interest rate (fin)	0.00254	0.13588	0.019	0.985	0.10645	1.66925
Oil price (fin)	0.91994	5.32214	0.173	0.863	-0.03496	-0.014523
Constant	-6.91287	18.99976	-0.364	0.717		
Residual standard error 4.616	Multiple R-Squared 0.7773	Adjusted R-squared 0.7685	F-statistic 88.13	p-value 2.2e-16		
Exchange rate (oil)	-40.12086	29.07767	-1.380	0.173	0.32212	2.821e-02
Interest rate diff (oil)	12.70201	9.46870	1.341	0.185	0.047889	1.009e-02
Oil price (oil)	-13.18034	9.58491	-1.375	0.175	-0.236908	-6.534e-02
Constant	45.61729	37.07185	1.231	0.224		
Residual standard error 3.865	Multiple R-Squared 0.6117	Adjusted R-squared 0.5829	F-statistic 21.26	p-value 1.42e-10		
Exchange rate (covid)	-45.15531	45.21620	-0.999	0.32445	0.3558	0.086371
Interest rate diff (covid)	0.05718	0.10622	0.538	0.597933	-0.05105	-4.8325
Oil price (covid)	-0.73512	12.13090	-0.061	0.95201	-0.3663	-0.345906
Constant	57.59209	50.72794	1.135	0.26355		
Residual standard error 7.47	Multiple R-Squared 0.2297	Adjusted R-squared 0.1464	F-statistic 2.759	p-value 0.04199		

Table 5: VAR model results VIX as dependent

From Table 5, Fin refers to Financial crisis period 2000-2008, Oil crisis 2010-2015 and Covid-19 pandemic 2019-2023. Dependent variable is VIX. All variables are measured by difference from one period to another except VIX.

VIX shows no significance with any of the predictor variables through all the periods however the constant term is significant during the full period. The constant also has a statistically significant impact using the other variables during different time periods especially having exchange rate difference as dependent, the constant is significant in all periods. This significance indicates that there are other factors at play beyond the variables included in the model that contribute to explaining these variables. This could be due to market conditions, investor sentiment, macroeconomic factors or other variables that are not explicitly accounted for in our analysis. This is also highlighted by some of the low R squared that suggests our chosen variables explain few of the variations in the dependent variable. Some explanation could be other factors not included in the analysis, such as unmeasurable variables or random noise. The complexity of the Exchange rate and VIX warrants further investigation. Future research should consider incorporating additional variables or exploring alternative methodologies to capture and analyze these hidden factors accurately.

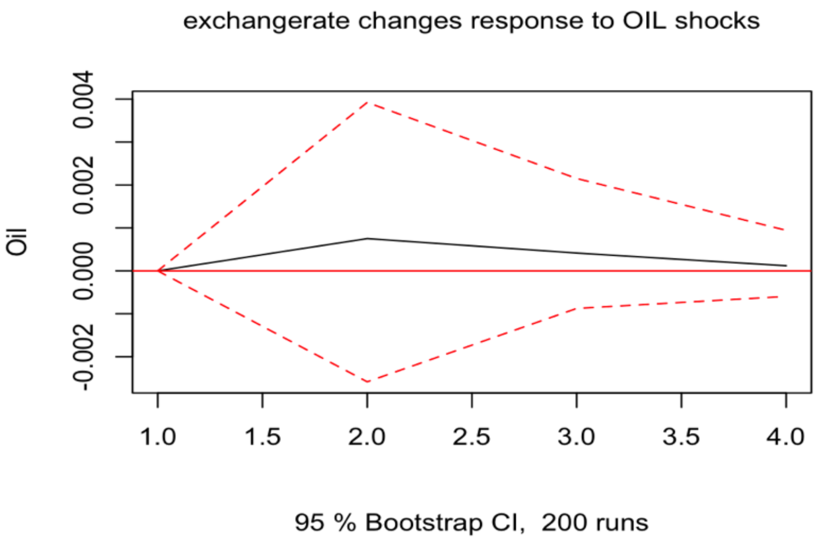

Figure 4: Impulse response

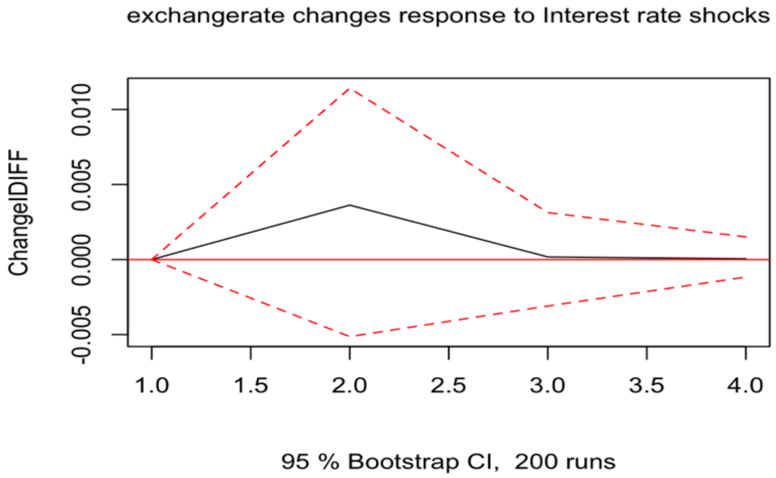

Figure 5: Impulse response

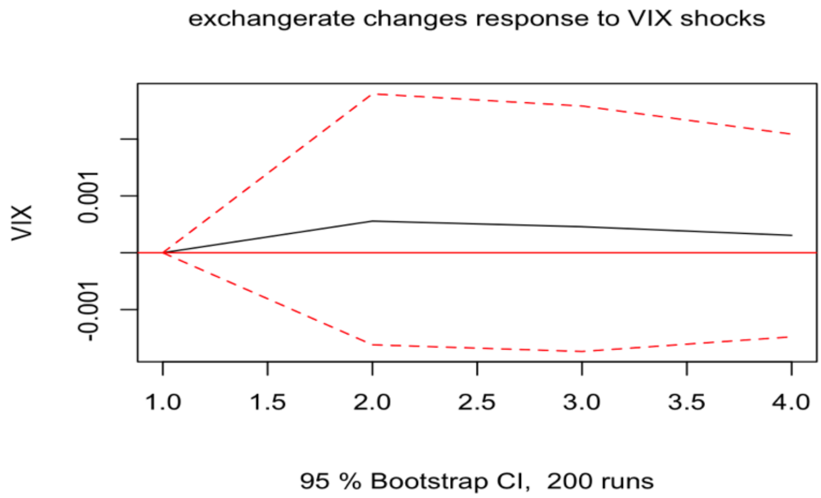

Figure 6: Impulse response

Analyzing Figure 4, Figure 5 & Figure 6, we find no significance in the short term between exchange and the various variables however the variables are positive. The lack of significance does not imply the absence of any relationship or effect, but it indicates that the observed responses are not statistically significant at the given confidence level. It is possible that other factors or dynamics not included in the model may play a more dominant role in driving the exchange rate movements in the short run. Other unaccounted variables or dynamics such as economic policies, geopolitical events, market sentiment and speculative activities might have a more dominant influence on driving short-term exchange rate movements. The short-term analysis does not capture the full complexity and of the interplay of the variables.

5. Limitations

The choice of lag length in the VAR model has a significant impact on our results. The optimal lags suggested were 1 and 2. These different lags gave us variations in the results. The differences indicate that the lag length choice affects the estimated coefficients, model fit, and the significance of the relationships among variables. When using a lag length of 1, we found that the coefficient estimates, and significance levels of some variables differed from the results obtained with a lag length of 2. This sensitivity to lag length highlights the importance of carefully considering the appropriate lag length for the VAR model. The variation in results based on different lag lengths highlights the importance of robustness checks and sensitivity analyses. It is crucial to evaluate the stability and consistency of the findings across different lag lengths in order to ensure the reliability and generalizability of the results.

Doing the analysis, we had to make the data stationary. In order to do this, we chose to look at the difference in the variables from one time to another. By taking the differences between consecutive observations there is a risk of losing some of the information since we are focusing on the changes rather than the actual levels of the variables. This can result in a loss of long-term trends or patterns in the data. Using this method also makes us susceptible to spurious relationships as the variables can seem to be stationary after differentiating, however this does not guarantee that the underlying relationships are meaningful or even causally linked. Furthermore, other factors such as politics should be considered in such an analysis, but for now we have tried to use theoretical justification for the relationships that we have observed.

The crisis periods we selected may have had a different timing or duration compared to the period selected. Some of the effects between the independent variables and the dependent might have been more immediate or short-lived and therefore not captured by the month-to-month difference of the independent variables. There is also a possibility that the impact of the independent variables on exchange rates manifested in a different way, such as through macroeconomic indicators or policy responses, rather than directly through changes in the independent variables.

In recent years the NOK exchange rate has weakened despite higher interest rates and lower inflation than the US and historically high oil and gas prices which should strengthen the currency as capital should flow into Norway. However, this has not been the case. An important and missing part in our research is how government policies' influence on exchange rate should be further explored as we think this might be a missing puzzle in explaining the devaluation of NOK in times of high oil prices and higher real interest rates than the US.

6. Conclusion

Both the linear regression and VAR analysis of the years 2000-2023 provides evidence of oil prices driving the NOK currency up in value against the USD. Using the linear model this seems to be true during all the different crises. The VIX does only seem to affect the exchange rates throughout the whole period and especially the pandemic. The results from both the linear model and Var also suggest adding more variables, as there are factors not accounted for in both models. Shocks in oil, real interest rate difference and VIX does not have an immediate impact on exchange rate however some of these variables such as oil and interest rate difference do in the medium to longer term. This paper contributes to the literature studying the effect of uncertainty, Oil price and real interest rate on exchange rate and the effect of shocks in these variables on exchange rate. Besides, this paper focuses on the US and Norway giving insight into the various factors affecting exchange rate between oil producing countries and countries considered smaller currency compared to big currency. For further research we suggest looking into how political events are affecting the exchange rate locally and globally in countries like US as we suspect a relationship between exchange rates and political stability. Further research should also incorporate daily and weekly data and see how the variables are affected.

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8. Appendix

8.1 Appendix 1

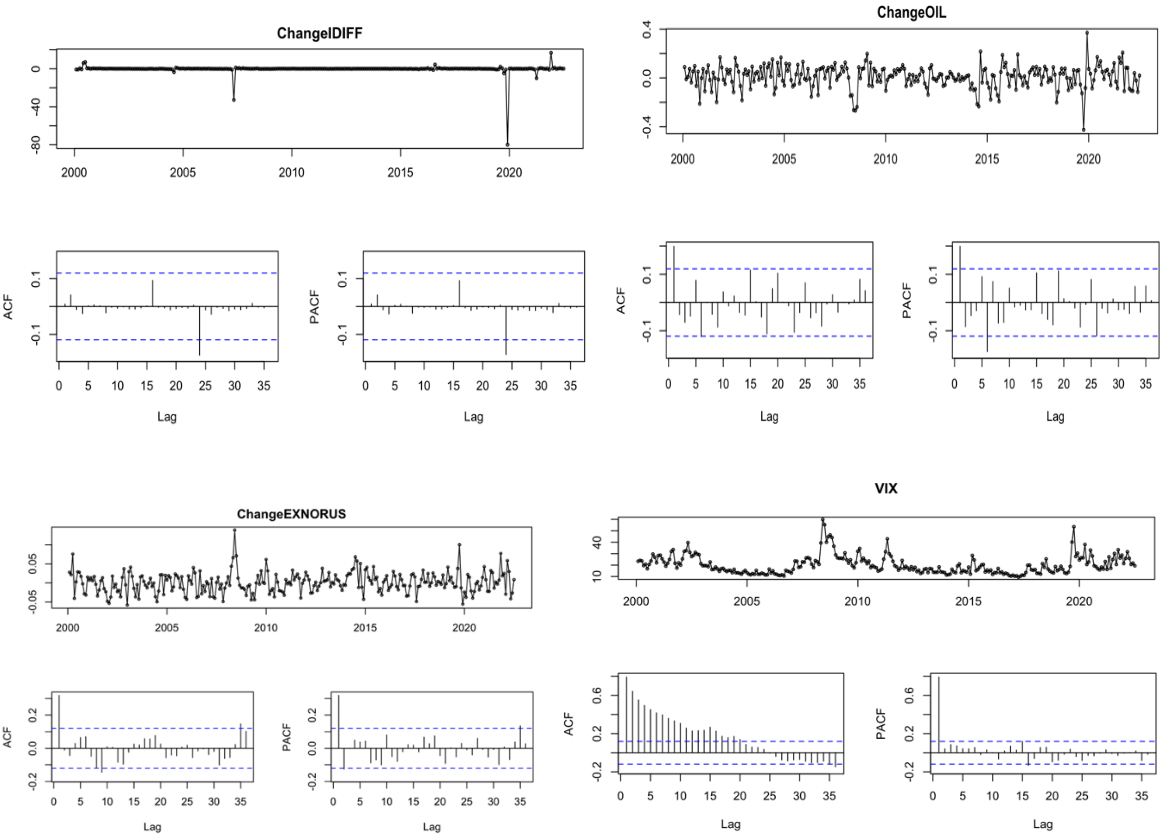


Figure 7: ACF and PACF tests

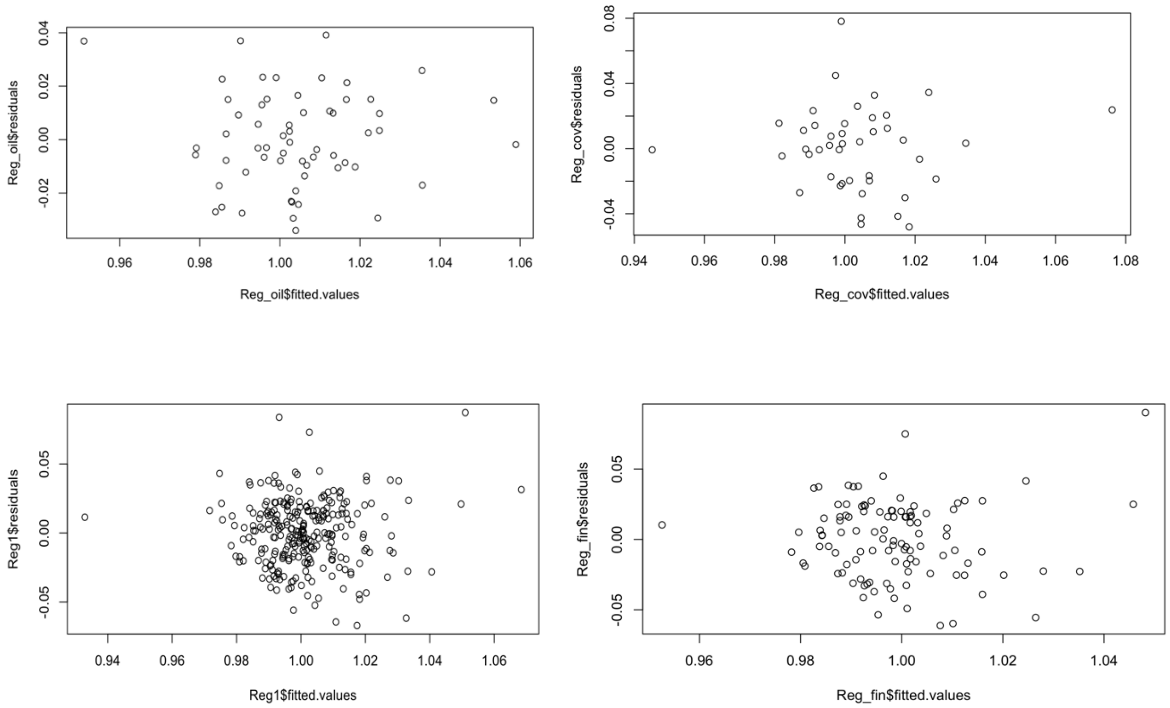


Figure 8:Residuals

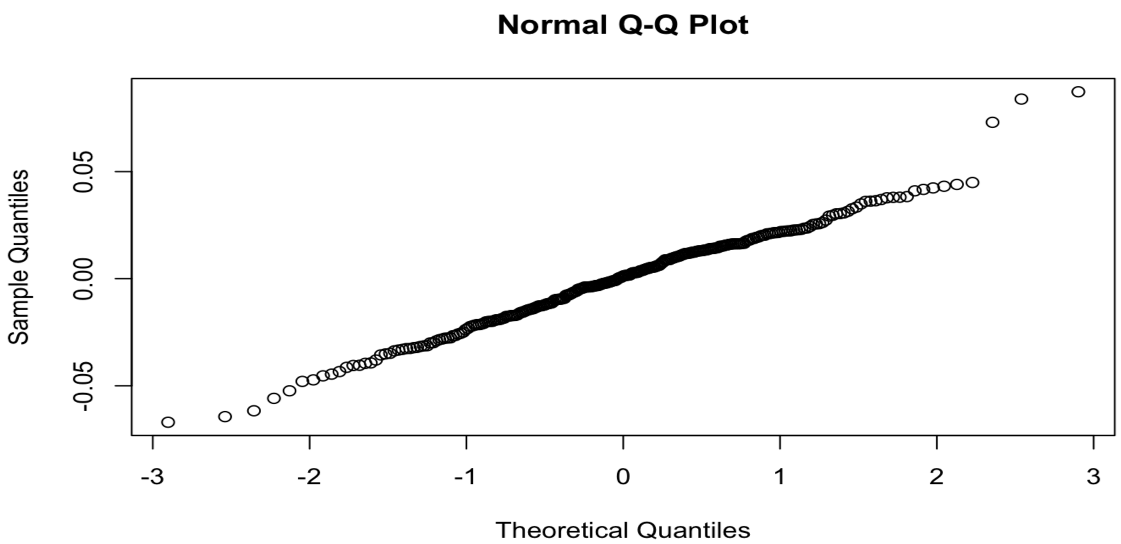
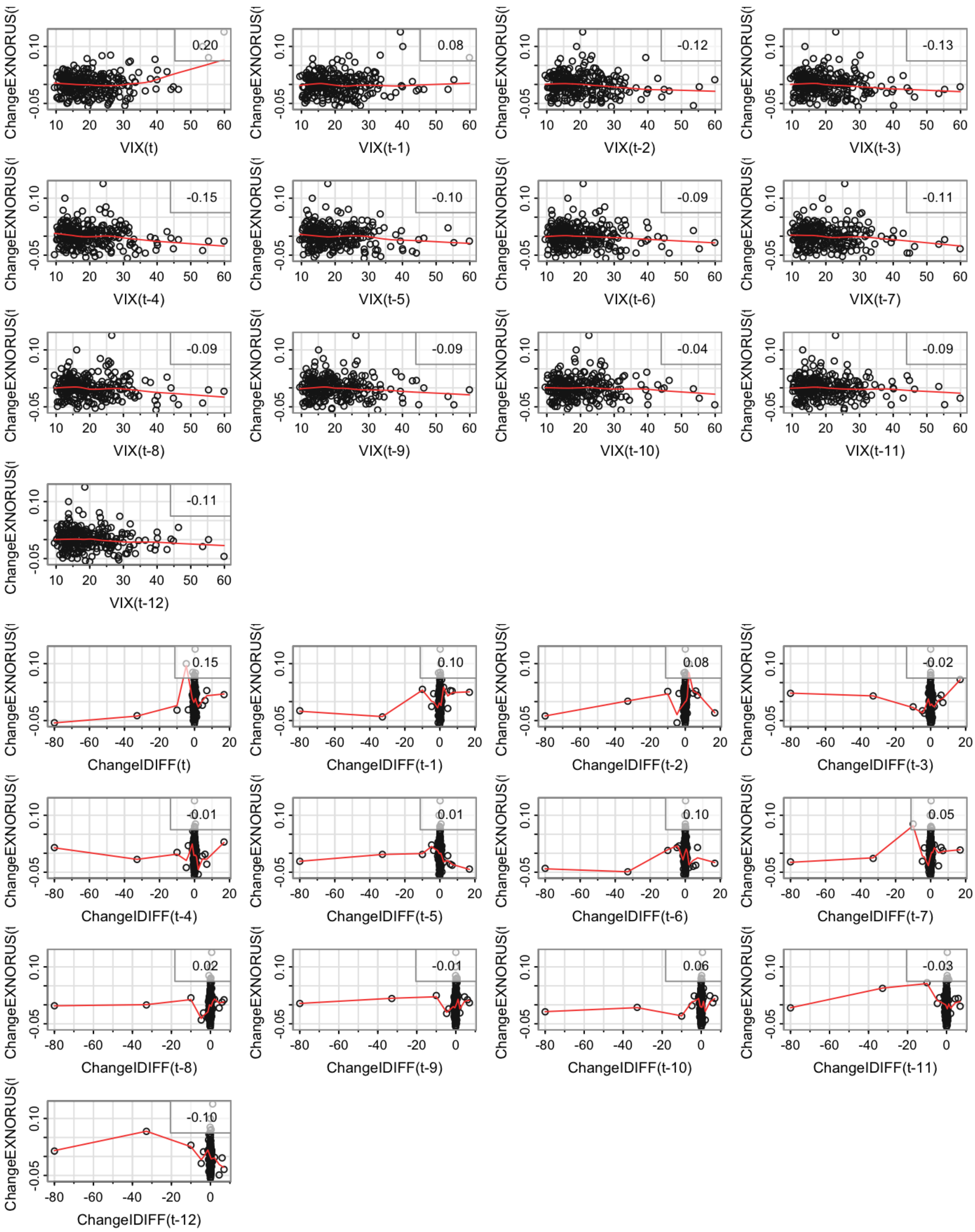


Figure 9:Normal QQ plot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0.20
VIX(t)
0.08
VIX(t-1)
-0.12
VIX(t-2)
-0.13
VIX(t-3)
-0.15
VIX(t-4)
-0.10
VIX(t-5)
-0.09
VIX(t-6)
-0.11
VIX(t-7)
-0.09
VIX(t-8)
-0.09
VIX(t-9)
-0.04
VIX(t-10)
-0.09
VIX(t-11)
-0.11
VIX(t-12)
0.15
ChangeIDIFF(t)
0.10
ChangeIDIFF(t-1)
0.08
ChangeIDIFF(t-2)
-0.02
ChangeIDIFF(t-3)
-0.01
ChangeIDIFF(t-4)
0.01
ChangeIDIFF(t-5)
0.10
ChangeIDIFF(t-6)
0.05
ChangeIDIFF(t-7)
0.02
ChangeIDIFF(t-8)
-0.01
ChangeIDIFF(t-9)
0.06
ChangeIDIFF(t-10)
-0.03
ChangeIDIFF(t-11)
-0.10
ChangeIDIFF(t-12)

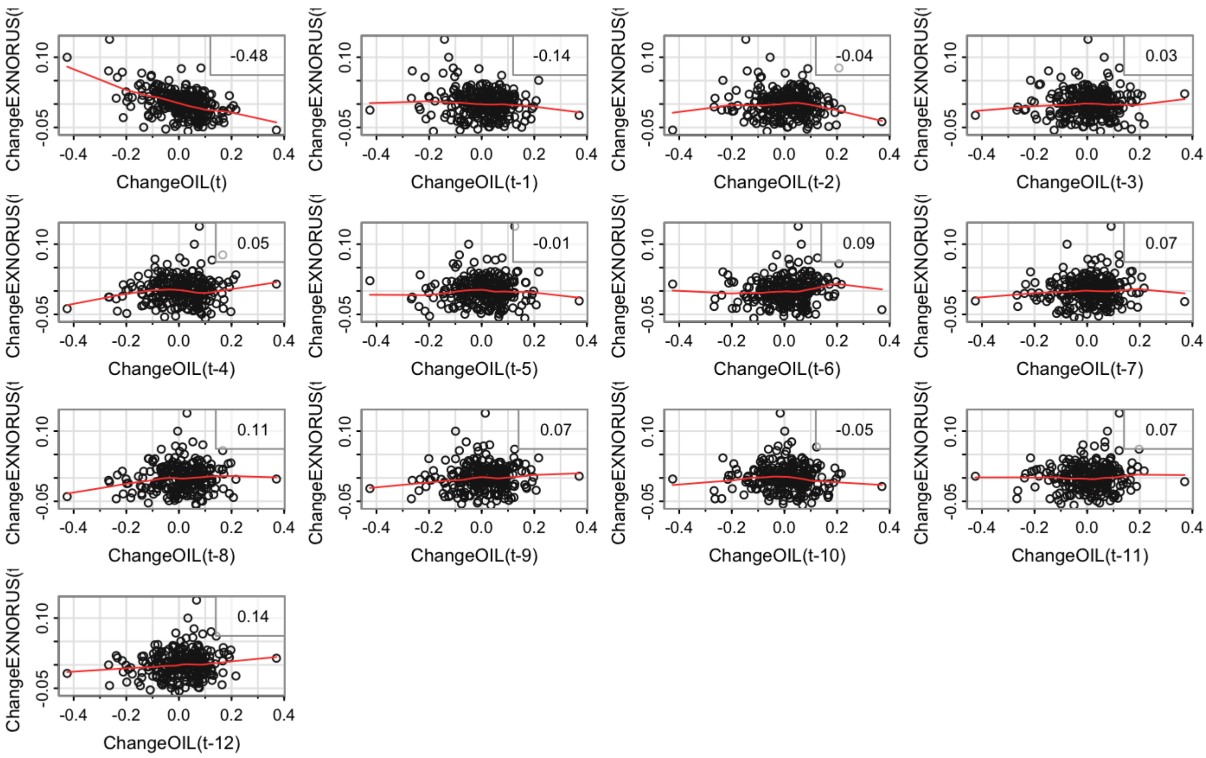

Figure 10:Seasonal effects

8.2 Appendix 2

Independent variable	Dickey fuller	Lag order	p-value
Interest rate diff	-1.4545	0	0.8058
Oil price	-1.9691	0	0.589
Exchange rate	-1.2838	0	0.8777
VIX	-5.5974	0	0.01 ***

Table 6: Augmented Dickey-Fuller (ADF) test

Period	w	p-value
Full period	0.98732	0.1809
Financial crisis	0.98002	0.1107
Oil crisis	0.9848	0.67
Covid-19 pandemic	0.96819	0.2867

Table 7: Shapiro-wilk Normality test

Independent variable	DF	F statistic	p-value
Oil price	268	8.7111	0.00344***
VIX	268	1.771	0.1844
Interest rate diff	268	0.4389	0.5082
Oil price (fin crisis)	103	0.0821	0.7751
VIX (fin crisis)	103	0.7142	0.4
Interest rate diff (fin crisis)	103	1.1292	0.2904
Oil price (oil crisis)	57	0.7273	0.3974
VIX (oil crisis)	57	1.2258	0.273
Interest rate diff (oil crisis)	57	0.3386	0.563
Oil price (covid crisis)	40	0.3199	0.5749
VIX (covid crisis)	40	0.1851	0.6694
Interest rate diff (covid crisis)	40	0.4649	0.4994

Table 8: Granger-causality test (Dependent variable exchange rate NORUS)

	Sample size	Log likelihood	Roots of the characteristic polynomial
Full period	269	-732.711	0.7961 0.2914 0.1586 0.01648
Financial crisis	106	-238.392	0.8877 0.2803 0.1497 0.02774
Oil crisis	59	165.622	0.7591 0.3838 0.09798 0.02893
Covid crisis	42	-169.831	0.4649 0.2378 0.2378 0.1427

Table 9: Root test

	Chi-squared	df	p-value
Full period	226.76	1200	0.12
Financial crisis	940	1200	1
Oil crisis	470	1200	1
Covid crisis	300	1200	1

Table 10: Arch test

	Chi-squared	df	p-value
Full period	269	176	0.15919
Financial crisis	169.04	176	0.6332
Oil crisis	135.71	176	0.9893
Covid crisis	156.3	176	0.8545

Table 11: Portmanteau test

9. R-codes

```
library(openxlsx)
library(quantmod)
library(xts)
library(lmtest)
library(tseries)
library(sandwich)
library(ggplot2)
library(dplyr)
library(readxl)
library(forecast)
library(stargazer)
library(tseries)
library(tidyquant)
library(lubridate)
library(sweep)
library(haven)
library(tibble)
library(broom)
library(margins)
library(pscl)
library(egg)
library(ISLR)
library(car)
library(latexpdf)
library(ggplot2)
library(zoo)
library(scales)
library(vars)
library(broom)
library(gridExtra)
library(ggplot2)
library(kableExtra)
library(webshot)
library(vars)
```

Importing data and cleaning

```
DataMaster2 <- read_excel("DataMaster.xlsx")

DataMaster2$VIX_NOM[DataMaster2$VIX>35] = 0
DataMaster2$VIX_NOM [DataMaster2$VIX<35] = 1

Data1 <- na.omit(DataMaster2)
# Convert tibble object to data.frame
Data1 <- as.data.frame(Data1)

Data1$IDIFFNORUS_modified <- Data1$IDIFFNORUS + 0.001

test1 <- shapiro.test(Data1$EXNORUS)

#Coocksd model for removing outliers
model <- lm(EXNORUS ~ VIX, OIL, CPINORUS, data = Data1)

# Calculate Cook's distances for the model
cooksd <- cooks.distance(model)

# Identify observations with high Cook's distances (e.g., greater than 4/n, where n is the sample size)
outliers <- which(cooksd > 4/nrow(Data1))
plot(outliers)
Data1 <- Data1[-outliers, ]
Data1$DATE <- as.Date(Data1$DATE)



# Extract year and month from the DATE column
year <- format(Data1$DATE, "%Y")
month <- format(Data1$DATE, "%m")
```

Checking for stationarity

```
adf.test(na.omit(Data1$IDIFFNORUS),k=0)#non stationary
adf.test(na.omit(Data1$OIL),k=0)#non stationary
adf.test(na.omit(Data1$EXNORUS),k=0)#non stationary
```

```
adf.test(na.omit(Data1$CPIDIFF),k=0)#non stationary
adf.test(na.omit(Data1$VIX),k=0)#stationary
adf.test(na.omit(Data1$CPINORUS),k=0)#non stationary


# Create time series objects
Data1$diff_exchange_rate <- Data1$EXNORUS - Data1$CPINORUS
exchange_ppp <- ts(Data1$diff_exchange_rate, start = c(year[1], month[1]), frequency = 12)
EXNORUS <- ts(Data1$EXNORUS, start = c(year[1], month[1]), frequency = 12)
IDIFFNORUS <- ts(Data1$IDIFFNORUS_modified, start = c(year[1], month[1]), frequency = 12)
OIL <- ts(Data1$OIL, start = c(year[1], month[1]), frequency = 12)
PPPEX <- ts(Data1$CPINORUS, start = c(year[1], month[1]), frequency = 12)
VIX <- ts(Data1$VIX [-1] , start = c(year[1], month[2]), frequency = 12)
CPIDIFF <- ts(Data1$CPIDIFF[-1] , start = c(year[1], month[2]), frequency = 12)


#Make it to the change in the non stationary variables

ChangePPPEX <- Delt(PPPEX)
ChangePPPEX <- na.omit(ChangePPPEX)

ChangeCPIDIFF <- Delt(CPIDIFF)
ChangeCPIDIFF <- na.omit(CPIDIFF)
ChangeCPIDIFF

ChangeOIL <- Delt(OIL)
ChangeOIL <- na.omit(ChangeOIL)

ChangeIDIFF <- Delt(IDIFFNORUS)
ChangeIDIFF <- na.omit(ChangeIDIFF)

ChangeEXNORUS <- Delt(EXNORUS)
ChangeEXNORUS <- na.omit(ChangeEXNORUS)

df <- data.frame(
        ChangeOIL = ChangeOIL+1,
        ChangeIDIFF = ChangeIDIFF+1,
```

```
              ChangeEXNORUS = ChangeEXNORUS+1,
              VIX=VIX,
              ChangeCPIDIFF= ChangeCPIDIFF)


adf.test(na.omit(ChangeIDIFF),k=0)
adf.test(na.omit(ChangeEXNORUS),k=0)
adf.test(na.omit(ChangeCPIDIFF),k=0)



#Auto correlation and partial autocorrelation
forecast::tsdisplay(ChangeOIL)
forecast::tsdisplay(ChangeIDIFF)
forecast::tsdisplay(ChangePPPEX)
forecast::tsdisplay(ChangeEXNORUS)
forecast::tsdisplay(VIX)
forecast::tsdisplay(ChangeCPIDIFF)
# How does lags in different variables affect the other one
astsa::lag2.plot(VIX,ChangeEXNORUS, 12)
astsa::lag2.plot(ChangeIDIFF,ChangeEXNORUS, 12)
astsa::lag2.plot(ChangeOIL,ChangeEXNORUS, 12)
astsa::lag2.plot(ChangeOIL,ChangeEXNORUS, 12) #change with 0 lags impacts the change in
Exchangerates imidiently -56 correlation
astsa::lag2.plot(ChangePPPEX,ChangeEXNORUS, 12)#change with 0 lags impacts the change in
Exchangerates imidiently 0.96 correlation
```

#Multiple regression model

```
#Running regression 2000-2023


Reg1 <- lm(ChangeEXNORUS ~ ChangeIDIFF + VIX + ChangeOIL + Delt(ChangeCPIDIFF),
data=df,na.action = na.exclude)
summary(Reg1)

Reg1_summary <- tidy(Reg1)
```

```r
shapiro.test(Reg1$residuals) #shapiro test acepted with log
qqnorm(Reg1$residuals) #not normal distributed looking at plot
vif(Reg1) # is fine
plot(Reg1$fitted.values, Reg1$residuals)#fitted
stargazer(Reg1, title="explaining", align = TRUE, no.space = TRUE, type="html", out ="Reg1.pdf")
#Running regression 2000-2008
ChangeIDIFF <- window(df$ChangeIDIFF, start = c(2000, 1), end = c(2008, 12))
ChangeEXNORUS <- window(df$ChangeEXNORUS, start = c(2000, 1), end = c(2008, 12))
ChangeOIL <- window(df$ChangeOIL, start = c(2000, 1), end = c(2008, 12))
VIX <- window(df$VIX, start = c(2000, 1), end = c(2008, 12))
ChangeCPIDIFF <- window(df$VIX, start = c(2000, 1), end = c(2008, 12))



adf.test(na.omit(ChangeEXNORUS),k=0)
adf.test(na.omit(ChangeIDIFF),k=0)
adf.test(na.omit(ChangeOIL),k=0)
adf.test(na.omit(ChangeCPIDIFF),k=0)
adf.test(na.omit(VIX),k=0)

Reg_fin <- lm(ChangeEXNORUS ~ ChangeIDIFF + ChangeOIL +VIX + Delt(ChangeCPIDIFF))

summary(Reg_fin)
shapiro.test(Reg_fin$residuals) #shapiro test acepted with log
qqnorm(Reg_fin$residuals) #not normal distributed looking at plot
vif(Reg_fin) # is fine
plot(Reg_fin$fitted.values, Reg_fin$residuals)#fitted
#Running regression 2010-2014
ChangeIDIFF <- window(df$ChangeIDIFF, start = c(2010, 1), end = c(2014, 12))
ChangeEXNORUS <- window(df$ChangeEXNORUS, start = c(2010, 1), end = c(2014, 12))
ChangeOIL <- window(df$ChangeOIL, start = c(2010, 1), end = c(2014, 12))
ChangeCPIDIFF <- window(df$ChangeCPIDIFF, start = c(2010, 1), end = c(2014, 12))
VIX <- window(df$VIX, start = c(2010, 1), end = c(2014, 12))

adf.test(na.omit(ChangeEXNORUS),k=0)
adf.test(na.omit(ChangeIDIFF),k=0)
adf.test(na.omit(ChangeOIL),k=0)
adf.test(na.omit(ChangeCPIDIFF),k=0)
```

```
adf.test(na.omit(VIX),k=0)

Reg_oil <- lm(ChangeEXNORUS ~ ChangeIDIFF + ChangeOIL +VIX + Delt(ChangeCPIDIFF))
summary(Reg_oil)
shapiro.test(Reg_oil$residuals) #shapiro test acepted with log
qqnorm(Reg_oil$residuals) #not normal distributed looking at plot
vif(Reg_oil) # is fine
plot(Reg_oil$fitted.values, Reg_oil$residuals)#fitted
#Running regression 2019-2023
ChangeIDIFF <- window(df$ChangeIDIFF, start = c(2019, 1), end = c(2023, 12))
ChangeEXNORUS <- window(df$ChangeEXNORUS, start = c(2019, 1), end = c(2023, 12))
ChangeOIL <- window(df$ChangeOIL, start = c(2019, 1), end = c(2023, 12))
ChangeCPIDIFF <- window(df$ChangeCPIDIFF, start = c(2019, 1), end = c(2023, 12))
VIX <- window(df$VIX, start = c(2019, 1), end = c(2023, 12))



adf.test(na.omit(ChangeEXNORUS),k=0)
adf.test(na.omit(ChangeIDIFF),k=0)
adf.test(na.omit(ChangeOIL),k=0)
adf.test(na.omit(ChangeCPIDIFF),k=0)
adf.test(na.omit(VIX),k=0)

Reg_cov <- lm(ChangeEXNORUS ~ ChangeIDIFF + ChangeOIL +VIX + Delt(ChangeCPIDIFF))
summary(Reg_cov)

shapiro.test(Reg_cov$residuals) #shapiro test acepted with log
qqnorm(Reg_cov$residuals) #not normal distributed looking at plot
vif(Reg_cov) # is fine
plot(Reg_cov$fitted.values, Reg_cov$residuals)#fitted
stargazer(Reg1, Reg_fin, Reg_oil, Reg_cov, type = "html", out = "Results_reg_PPP.html", title =
"Regression results", no.space = TRUE, column.labels = c("(From 2000 to 2023)", "(Financial
Crisis)", "(Oil Crisis)", "(Covid-19)"), model.numbers = FALSE, dep.var.labels = "USD/NOK")
#Var model
# Create a matrix with all variables
var_data <- cbind(ChangeEXNORUS,ChangeIDIFF,ChangeOIL,VIX)

#finding optimal lags
```

```
lagselect <- VARselect(var_data, lag.max = 12, type = "const")
lagselect$selection
# Estimate VAR model
var_model <- VAR(var_data, p = 1, type = "const", season = NULL)

summary(var_model)

#serial test (good)
serial1 <- serial.test(var_model, lags.pt = 12,type = "PT.asymptotic")
serial1
#hetero scedacity (negative)
Arch1 <- arch.test(var_model, lags.multi = 12, multivariate.only = TRUE)
Arch1
# Load the lmtest package

library(lmtest)
grangertest(var_data[, "ChangeEXNORUS"] ~ var_data[, "ChangeOIL"], data = var_data, order = 1)
grangertest(var_data[, "ChangeEXNORUS"] ~ var_data[, "VIX"], data = var_data, order = 1)
grangertest(var_data[, "ChangeEXNORUS"] ~ var_data[, "ChangeIDIFF"], data = var_data, order =
1)
grangertest(EXNORUS ~ OIL, order = 1)
grangertest(EXNORUS ~ IDIFFNORUS, order = 1)
shapiro.test(EXNORUS)
```

#testing for shocks

#plots

Plots crisis periods

```
Data1$DATE <- as.Date(Data1$DATE)
# Add rectangles for highlighting specific time periods
highlight_periods <- data.frame(
  start = c(as.Date("2006-01-01"), as.Date("2010-01-01"), as.Date("2019-01-01")),
  end = c(as.Date("2008-12-31"), as.Date("2015-12-31"), as.Date("2022-12-31")),
  color = c("pink", "pink", "pink")
)

# Create plot with three y-axes
```

```
p <- ggplot(Data1, aes(x = DATE)) +
  geom_line(aes(y = VIX, color = "VIX")) +
  geom_line(aes(y = EXNORUS, color = "Exchange rate")) +
  geom_line(aes(y = OIL, color = "OIL")) +
  scale_y_continuous(name = "", sec.axis = sec_axis(~ ., name = ""), breaks = pretty_breaks(n = 5)) +
  scale_color_manual(name = "", values = c("VIX" = "blue", "Exchange rate" = "red", "OIL" =
"#003366")) +
  labs(title = "", x = "Date", y = "",
       subtitle = "", caption = "") +
  theme_minimal() +
  theme(legend.position = "bottom",
        panel.grid.major.x = element_blank(),
        panel.grid.minor.x = element_blank()) +
  geom_rect(data = highlight_periods,
            aes(xmin = start, xmax = end, ymin = -Inf, ymax = Inf, fill = color),
            alpha = 0.1, inherit.aes = FALSE) +
  guides(fill=FALSE) +
  labs(
    title = "",
    caption = "",
    color = "",
    fill = "",
    VIX = "VIX",
    `Exchange rate` = "EXNORUS",
    OIL = "OIL"
  )

p
# Add additional values

# Display plot
```

Plots crisis periods

```
# Create plot with three y-axes
d <- ggplot(Data1, aes(x = DATE)) +
  geom_line(aes(y = INTUS, color = "INTUS")) +
```

```r
  geom_line(aes(y = EXNORUS, color = "EXNORUS")) +
  geom_line(aes(y = INTNOR, color = "INTNOR")) +
  scale_y_continuous(name = "", sec.axis = sec_axis(~ ., name = ""), breaks = pretty_breaks(n = 5)) +
  scale_color_manual(name = "", values = c("INTUS" = "#003366", "EXNORUS" =
"blue","INTNOR" = "red")) +
  labs(title = "", x = "Date", y = "VIX",
       subtitle = "", caption = "") +theme(legend.position = "bottom",
        panel.grid.major.x = element_blank(),
        panel.grid.minor.x = element_blank()) +
  geom_rect(data = highlight_periods,
            aes(xmin = start, xmax = end, ymin = -Inf, ymax = Inf, fill = color),
            alpha = 0.1, inherit.aes = FALSE) +
  guides(fill=FALSE)+theme_minimal()+ theme(legend.position = "bottom",
        panel.grid.major.x = element_blank(),
        panel.grid.minor.x = element_blank())

d
#exchange rate indicates that one USD can be exchanged for more NOK, while a lower exchange rate
indicates that one USD can be exchanged for fewer NOK.
# Create a vector of colors for the highlighted periods
colors <- c("pink", "pink", "pink")

# Create a data frame with the highlighted periods
highlight_periods <- data.frame(start = as.Date(c("2006-01-01", "2011-01-01", "2019-01-01")),
                                end = as.Date(c("2009-12-31", "2013-12-31", "2023-01-30")),
                                color = colors)

# Create the plot
ggplot(Data1, aes(x = DATE)) +
  geom_line(aes(y = CPINORUS, color = "PPP-adjusted Exchange rate")) +
  geom_line(aes(y = EXNORUS, color = "Exchange rate")) +
  scale_color_manual(name = "", values = c("PPP-adjusted Exchange rate" = "#003366", "Exchange
rate" = "blue")) +
  labs(x = "", y = "Exchange rate (NOK per USD)") +
  scale_x_date(date_breaks = "3 years", date_labels = "%Y") +
  theme_minimal() +
  theme(legend.position = "bottom",
```

```r
      panel.grid.major.x = element_blank(),
      panel.grid.minor.x = element_blank()) +
  geom_rect(data = highlight_periods,
            aes(xmin = start, xmax = end, ymin = -Inf, ymax = Inf, fill = color),
            alpha = 0.1, inherit.aes = FALSE) +
  guides(fill=FALSE)
#When the PPP-adjusted exchange rate is higher than the actual exchange rate, it indicates that the local currency is undervalued compared to the reference currency. In this case, it means that the Norwegian Krone (NOK) is undervalued compared to the US dollar (USD) based on the relative price levels of goods and services between the two countries.

Data1$diff_exchange_rate <- Data1$EXNORUS - Data1$CPINORUS

# create a linear regression model
model <- lm(diff_exchange_rate ~ VIX_NOM + OIL + IDIFFNORUS, data = Data1)
# print the summary of the model
summary(model)
```