BI Norwegian Business School – Thesis

The Impact of Foreign Financial Shocks on the Norwegian Macroeconomy – A quest for causal inference

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Abstract

In this master thesis, I evaluate empirically the importance of foreign financial shocks for explaining business cycle fluctuations and monetary policy stance in Norway. These shocks are a U.S. monetary policy shock and a U.S. based financial uncertainty shock, which in some of the literature are taken to represent the global financial cycle. To this end, I construct a set of structural VAR models, some of them identified recursively, some identified outside the model resorting to the literature of high-frequency identification of monetary policy shocks. The Norwegian responses of interest are in the GDP or industrial production index, inflation, interbank interest rate and the exchange rate. I find that the financial uncertainty shock has a limited and non-robust capacity to impact the macroeconomic performance of the Norwegian economy, while the monetary shock has potential to evoke notable and statistically significant short-term responses.

Acknowledgements

I am grateful for the thesis supervisor Gisle J. Natvik for valuable advice and criticism, as well as for Ph.D. candidate Vegard H. Larsen. I also owe a thank you to my fellow students Kim Myrvang, Momina Javaid Butt and Thomas Størdal Gundersen for inspiring conversations and solid support throughout our Master's studies.

Table of Contents

1. Introduction

‘‘When the U.S. sneezes, emerging markets catch a cold.” The claim has been extensively studied for emerging markets – but how well does it apply to a developed small open economy? In this master thesis, I strive to evaluate the importance of foreign financial shocks (FFSs) for explaining business cycle fluctuations and monetary policy stance in Norway. My research question is: To what extent can foreign financial shocks disturb macroeconomic conditions in Norway, and what does this suggest for monetary policy independence?

The FFSs are of two types: U.S. monetary policy shocks and U.S. based financial uncertainty shocks that are also called ‘market sentiment’ or ‘market fear’ shocks. I measure the monetary shocks first by a short-term interest rate that is presumably under the central bank’s strict control. Second, I measure them by the change in the short-term futures rate measured in a tight window around the Federal Reserve policy announcements, a measure that depicts the financial market’s surprise at the monetary action. Financial market uncertainty, in turn, is measured by the CBOE VIX index which summarizes investor risk aversion and expectations of short-term volatility in stock prices. The reason for selecting these particular FFSs is that, firstly, they are quantifiable with relative ease and thus suitable variables for an empirical analysis. Secondly, they are likely to be important for international capital flows and asset prices, and as such they potentially have a nontrivial impact on the financial and economic conditions of a small open economy.

Norway is a typical ‘periphery’[1] prone to influences from a ‘center economy’ like the U.S. Why study foreign financial shocks stemming from the United States? The United States is undoubtedly a realistic candidate for a center economy. The American economy is relevant for Norway through trade but also through financial flows given the country’s status within international finance. Moreover, the interpretation of financial shocks emanating from the United States has a wider scope. The finding that spillovers from U.S. monetary policy to the rest of the world are very large has led many researchers to support the hypothesis that the global financial cycle is driven by financial conditions in the United States

[1] In this context, a periphery, broadly defined, refers to an open economy, susceptible to influences from other economies while too small to self exert a wide-spread influence over the economies around it. Here, it does not have any meaning in terms of the degree of economic development. By contrast, a center economy signifies an economy that is large enough to dominate economic conditions within its region.

(Georgiadis 2015). Miranda-Agrippino and Rey (2015) additionally find the U.S. based VIX index a good candidate to proxy the global financial cycle. The VIX is shown to be (negatively) correlated with the global factor in risky asset prices, cross-border credit flows and regional credit growth. With this interpretation, the analysis of this master thesis regarding the impact of financial shocks from the U.S. to Norway relates to Norway's position in the global financial cycle. The topic is of relevance because the imported monetary- and other financial conditions may not be aligned with the macroeconomic conditions of the receiving country. Despite these concerns, financial spillovers are not regarded as uncontestedly adverse in the literature; for example, they can improve risk-sharing across economies. (Rey 2016, pp.24, Draghi 2016.)

In addition to impacting the trade balance which feeds directly into the economic activity of the periphery, FFSs matter because they can generate financial flows that change asset prices and credit availability in the periphery. Here the theoretical framework of international spillovers of monetary policy more or less divides into two: first, the traditional channels of impact that work through the trade balance (the foreign demand and the exchange rate channel) and second, the 'financial spillover' channel that works through integrated global capital markets.

Financial spillovers are not a new phenomenon, but they have been given more place in the open macro theory in the 2000s and 2010s, quite naturally along with the development towards deeper financial integration. The topic of international monetary spillovers in the academic literature dates at least to Hume (1742), Meade in the 1950s and the Mundell-Fleming model of the 1960s (Ammer et al. 2016, Obstfeld 2001). Financial integration and events such as the global financial crisis, the emergence of unconventional monetary policy measures in its aftermath and alleged competitive devaluations have more recently merited a re-examination of the topic (Frankel 2016, Draghi 2016). More interconnected financial markets allow undoubtedly also other type of financial shocks to spread than monetary shocks, such as financial market sentiments. Economic uncertainty is neither a new phenomenon, but it has been more carefully conceptualized and quantified in academic research during the past decade or so, although the pioneering work for the theory dates at least to Bernanke (1983).

Nonetheless, the brief theoretical treatment of FFSs in this master thesis is meant only to provide a backdrop for the ensuing empirical assignment. I add to the literature mainly by empirically evaluating and quantifying the macroeconomic impact and relevance of these shocks. To do this, I employ a set of structural VARs. I follow Rey (2016) and the high-frequency identification literature of monetary shocks in the methodology. I begin by estimating a recursive structural VAR (the 'baseline SVAR') which is identified using the Cholesky decomposition. The results are not robust in general. For the uncertainty shock's part I conclude that foreign financial uncertainty has limited capacity to disturb the macroeconomic performance of the Norwegian economy and the results are, for the most part, not statistically significant. The most notable impact is on the Norwegian short-term interest rate, NIBOR, which rises statistically significantly on impact (from 5 up to 20 basis points, depending on model specification). Variance decompositions reveal that the relevance of the VIX in explaining variation in the NIBOR is about 6% at its highest.

For the foreign monetary shock, I have the opportunity to utilize data on high-frequency identified monetary shocks. Hence, for the second main VAR model (the HFI SVAR) I use monetary policy shocks that have been identified outside the model. This model provides the most transparent identification of monetary shocks, and the most reliable one in terms of genuine exogeneity of the shock. Therefore, I consider the results of this model as the main results for the foreign monetary shock.

I find that an above-average U.S. monetary shock can have a substantial and statistically significant near-term impact on the Norwegian variables under research: For unobvious reasons, a contractionary U.S. monetary shock appears to have a stimulating effect on the Norwegian GDP in the short run, which turns into a downturn later on. Moreover, the puzzling near-term boost in the GDP is statistically significant (at 68% confidence level) and very robust across different model specifications. The NIBOR rises too, at highest about 5-20 basis points, although less statistically significantly so. The exchange rate depreciates in the short run and the variance decompositions show that the U.S. monetary shock has the most relevance for variation in the exchange rate: between 10% and 20%, depending on the model specification. As for the uncertainty shock, the effect on the Norwegian variables is passing and they mostly revert to their trends at the end of the horizon of inspection. All in all, a U.S. monetary shock is more potent for producing reactions in the Norwegian macroeconomy than a U.S. based uncertainty shock.

Lastly, the influence of FFSs over peripheral economies has implications for the theory of how economic policy can deal with them. The widespread spillovers of U.S. monetary conditions, despite the general adoption of flexible exchange rate regimes, has raised the question of whether domestic monetary policy in non-U.S. economies has been undermined by financial globalization (Georgiadis 2015). Perhaps the most provocative assertion is Rey's (2015) according to which the 'Mundellian trilemma' is not an accurate description of the tradeoffs that monetary policymakers face today. The final part of the thesis addresses the implications of the monetary response to these foreign shocks. The results suggest that monetary policy in Norway cannot remain passive in the face of a U.S. monetary shock. Nevertheless, the trilemma holds in the sense that the central bank has room for maneuver to focus on the variables that are its announced priority: inflation and output.

The thesis proceeds in the following way. Section 2 outlines the institutional setting of the Norwegian economy and presents the data. Section 3 provides an overview of the theoretical work on foreign monetary and uncertainty shocks. Section 4 presents the empirical methodology used to yield the results that are presented in Section 5. Section 6 reviews the implications from a domestic monetary policy perspective. Lastly, Section 7 concludes.

2. Institutional setting and data

2.1. Institutional setting

Norway is a small open economy. Its top industries are: petroleum and gas, seafood, shipping, and pulp and paper products, while the main export products are: oil and mineral fuels, seafood, and industrial machinery. In 2014, exports accounted for 38.7% of GDP. The main trade partners by exports are: the UK, Germany, the Netherlands, France, Sweden and the United States. (OECD 2016.) As a small open economy, productivity has been maintained by concentrating labor and other production inputs in the few leading industries. For example, the petroleum-related industry comprised on average 36.4% of value creation in 2000-2013 and 29.3% in the latest years (IMF 2016, pp. 9). This makes Norway's terms of trade volatile in comparison to larger, more dispersed economies.

Norway is a wealthy economy with sound external balances. The country's sovereign debt holds the highest credit rating from all the largest rating agencies. Real mainland (i.e. non-petroleum) GDP growth has averaged about 2.9% in the last two decades, with unemployment at 3.5% in 2014 (IMF 2015). According to the OECD (2016), in 2014 the country's GDP per capita was 64.9 USD, the current account surplus was 9.7% of GDP, the general government gross financial debt was 32.7% of GDP, while net financial debt amounted to -242% of GDP.

The high net foreign asset position is primarily due to the policy since 1996, that the excess proceeds of oil- and gas extraction are placed in the Government Pension Funds Global (GPFG)[2]. It is a public fund governed by Norges Bank Investment Management whose value per today is approximately 7000 billion NOK. The wealth transfers come from the Ministry of Finance after the ministry has taken its share to balance the state budget. It does so by the *fiscal rule* ('*handlingsregelen*') which instructs that approximately 4% of the fund's value (equal roughly to the annual real rate of return of the fund) is used for the annual state budget in order to phase the petroleum revenues into the Norwegian economy. Importantly, the budgetary rule is not a law and the government is able to use discretion in the use of the petroleum funds. Thus, the fund also performs as a fiscal buffer to shield the macroeconomy from adverse shocks. Also, with a low public debt ratio, the Norwegian government has fiscal policy space to counter adverse shocks to the economy.

Norway has its own currency, the krone. During the years 1993-2000 the krone has been more or less under a managed float: The krone was left to float in December 1992, after a period of speculative attacks against its peg to the ECU (European currency unit). By the government's proposal to the parliament ('*Melding til Stortinget'*) of May 1994, the krone was again to be managed within a trading band against the ECU. Volatile global capital flows from the onset of the Asian currency crisis in 1997 to the Russian and Latin American crises in 1998 made managing the external value of a peripheral currency again exceedingly costly. Norges Bank, the central bank of Norway, had to raise the policy rate continuously and to higher levels than the domestic macroeconomy had called for. Finally, in March 2001 an inflation target of 2.5% was formally adopted. (Isachsen 2001.)

[2] NBIM's webpage www.NBIM.no.

Norges Bank has a flexible inflation targeting framework. The central bank's announced policy priority is to promote price stability, but with consideration for output and employment as well as mitigating the build-up of financial imbalances. The latter "is not an objective in itself, but is included because it may yield improved performance in terms of inflation, output and employment over time" (Norges Bank 2016a, pp. 32). Since June 1993, Norges Bank's key policy rate has been the sight deposit rate.

Some financial imbalances have emerged over the protracted economic upturn with low interest rates and high oil prices. These imbalances concern the private credit and the housing sector. Total household and corporate debt in the mainland economy has been rising faster than GDP for a long period (Norges Bank 2016b). The IMF (2015) reports that household debt to disposable income in Norway, at 220%, was among the highest in the world at end-2014. They additionally report that the housing market is estimated to be overvalued by 25-60%.

Besides the credit-to-GDP ratio and developments in property prices, Norges Bank's assessment of financial imbalances is based on Norwegian banks' wholesale funding ratio (Norges Bank 2016b). While the Norwegian public sector is a major creditor to the rest of the world, the banks (including mortgage companies) and corporations have a net debtor position equivalent to about 85% of GDP (IMF 2015). Banks have relied extensively on wholesale (market-) funding to finance the credit boom, and a major share of it has come from foreign sources (principally in foreign currency). About one-third of the foreign currency funding is used to finance domestic currency assets, equivalent to about 10% of banks' total assets (IMF 2015). Figures 1 and 2, borrowed from the IMF (2015, pp.13) and Norges Bank (2016a, pp.40) respectively, illustrate the situation. Figure 2 reveals that the phenomenon is mostly relevant for the 2000s and 2010s, hence financial spillovers from abroad through this particular channel have likely increased in significance over time.

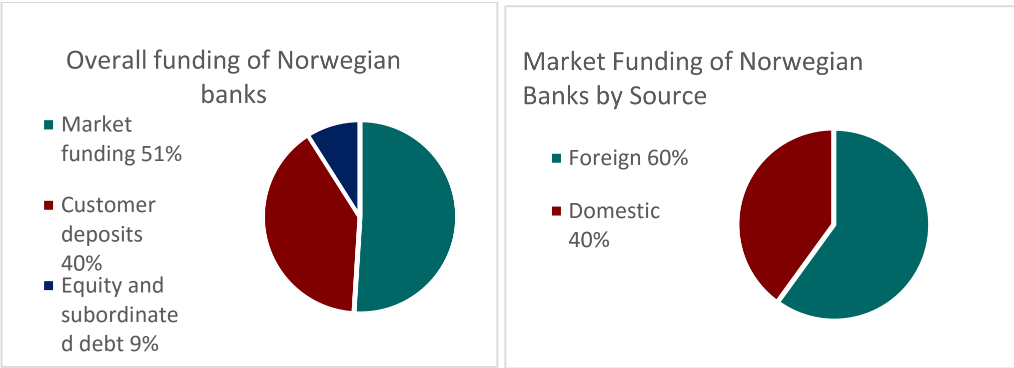

Figure 1. Funding of Norwegian banks. Source: IMF (2015, pp.13).

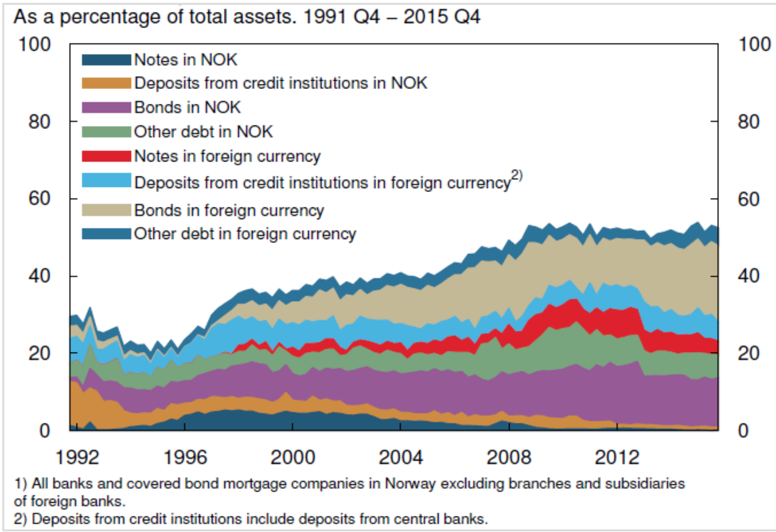

Figure 2. Decomposition of banks[1)] wholesale funding. Source: Norges Bank (2016a, pp.40).

2.2. Data

2.2.1. Measures of foreign financial influences

Foreign monetary policy indicators

There exists a wide array of methods for measuring monetary policy shocks. Research sometimes uses a short-term interest rate that is presumably under the central bank's strict control, although distinguishing between demand and supply shocks for money is a challenge (Obstfeld, Shambaugh and Taylor 2005). To overcome the problem of capturing monetary policy actions and them only, research has also resorted to externally identified shocks. In this master thesis, both types of measure are deployed.

The Federal funds rate – an overnight foreign interbank rate:

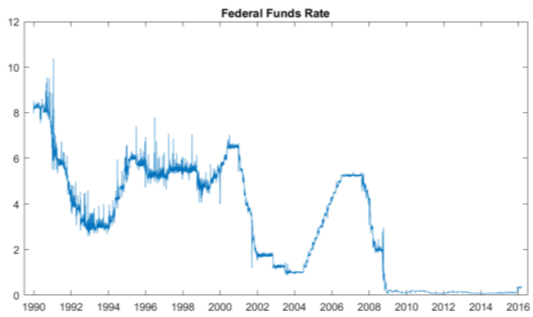

Figure 3. Effective federal funds rate in percent. Daily data 01/01/1990-22/03/2016. Source: Federal Reserve Bank of St. Louis.

The federal funds rate (FFR hereafter) is the interest rate at which depository institutions trade federal funds (balances held at the Federal Reserve Banks) with each other overnight. The rate that the borrowing institution pays to the lending institution is determined between the two banks; the weighted average rate for all of these types of negotiations is called the effective federal funds rate[3]. The effective federal funds rate is essentially determined by the market but is influenced by the Federal Reserve through open market operations to reach the federal funds rate target[4]. It is the effective FFR that is included as a foreign monetary policy indicator in the recursive VAR models of later sections.

Surprise in the Federal funds futures rate:

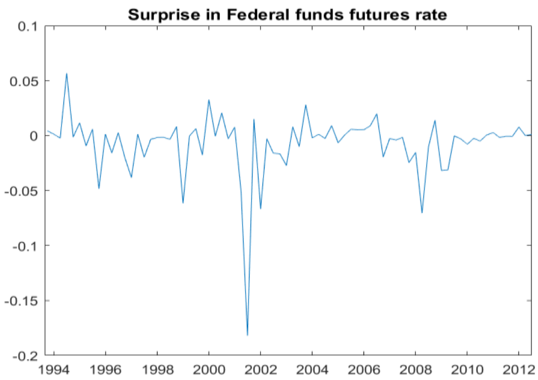

Figure 4. Surprise in the three-month ahead Federal funds futures rate in percentage points. Quarterly data 1993:Q2-2012:Q2. Source: American Economic Review website/ Gertler and Karadi (2015).

The high-frequency identification method of monetary shocks is described in section 4.3. Figure 4 displays one such series. It is interpreted such that a spike upwards signifies the market's upward revision of the interest rate on the banks'

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[3] Throughout this master thesis, I use the abbreviation FFR of the U.S. money market rate, although strictly speaking it is the *effective* FFR.

[4] This description is from Federal Reserve Bank of St. Louis webpage.

federal funds holdings – a contractionary monetary shock. The opposite holds for the spikes downwards.

The VIX index – a measure of market sentiments

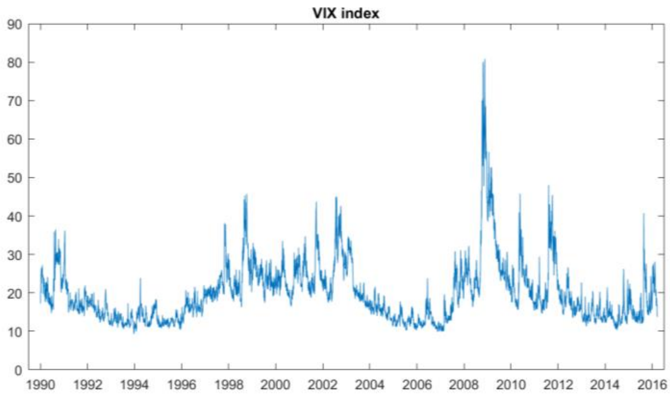

Figure 5. The Chicago Board Options Exchange SPX Volatility Index; the VIX index. Daily data 02/01/1990-22/03/2016. Source: Bloomberg.

The CBOE VIX index (VIX henceforth) reveals markets' expectations of the next 30-day volatility in the S&P 500 index, calculated from put- and call options written on the S&P 500[5]. An index value of 30 is often regarded as the threshold for high volatility expectations. It serves as a proxy for uncertainty and it is also named 'market fear' or 'market sentiment' indicator. Bekaert, Hoerova and Lo Duca (2013) decompose it into uncertainty and risk aversion among investors. One can observe from Figure 5 above that the VIX succeeds in capturing major financial and political events that have provoked market reactions, such as: Asian currency crisis in 1997, Russian crisis and LTCM default in 1998, 9/11 terrorist attack in 2001, Enron auditing scandal and bursting of the dotcom bubble all post 2000, Lehman brothers bankruptcy in 2008, European sovereign debt crises in 2010 and 2011 and the Chinese stock market plunge in 2015.

There are less straight-forward and readily-available measures of uncertainty than the VIX that also indicate economic uncertainty. Other potential measures for uncertainty are: the actual stock market volatility, newspaper coverage of economic uncertainty, confidence surveys to households and businesses, spreads in professional economic forecasts etc. (see for example Gudmundsson and Natvik 2012 or Bloom 2009, pp. 6). For my purposes the VIX index is convenient as it

[5] See Chicago Board Options Exchange webpage.

represents precisely financial market uncertainty abroad, thus potentially an important foreign financial shock.

As Furlanetto and Ravazzolo (2014, pp. 49) have documented, the VIX is driven by factors other than mere uncertainty. They estimate that going from short to medium horizon, 40-70 percent of its variation can be attributed to financial and macro shocks, which challenges the usual assumption that the VIX can be taken as an exogenous proxy for uncertainty. In my study, I allow the VIX to represent the financial and political events; the VIX is still a measure of financial market turmoil, regardless of the original source for turmoil. My concern, nonetheless, is that the VIX may reflect macroeconomic shocks like a shock to the U.S. GDP or oil prices which bear a significance of their own to the Norwegian economy. To clear some of the problematic macroeconomic shocks from the VIX, I include oil price and the U.S. GDP as controls into the baseline VAR in section 4.2.1.

2.2.2. Measures of Norwegian macroeconomic and financial conditions

Norwegian GDP

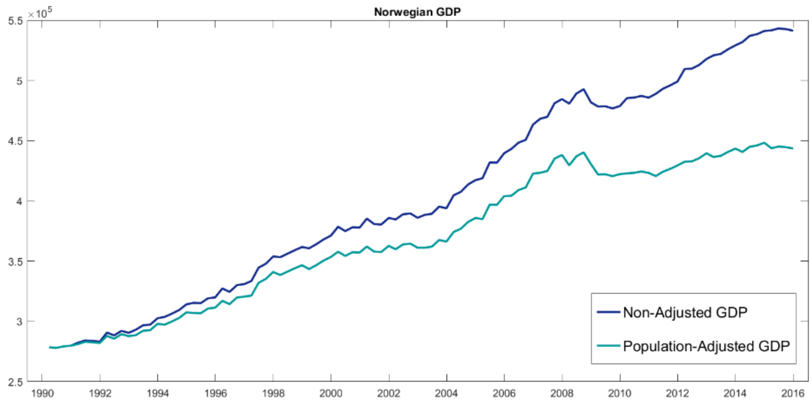

Figure 6. Gross Domestic Product Mainland Norway in millions of Norwegian kroners (NOK). Quarterly data 1990:Q1-2015:Q4. Source: Statistics Norway.

GDP series provide a comprehensive measure of economic activity that allows for the exclusion of other closely related activity measures from the model, such as employment (presumably GDP and employment are connected through Okun's Law about the relationship between unemployment rate and the GNP). GDP mainland Norway series is seasonally adjusted quarterly volumes from the national accounts, measured in fixed year-2013 prices (the upper blue line in Fig. 5). I further adjust the series for population growth with population series that are also retrieved from Statistics Norway (the lower green line in Fig. 5). The effect of population growth that was accelerating from the mid-1990s until early-2010s is apparent from the divergence of the two lines. Even after accounting for population growth, one can observe that growth in the GDP has been robust since the early-1990s when Norway started to recover from the previous banking crisis. It is the population adjusted GDP series that is employed in the upcoming models.

Norwegian Industrial Production Index

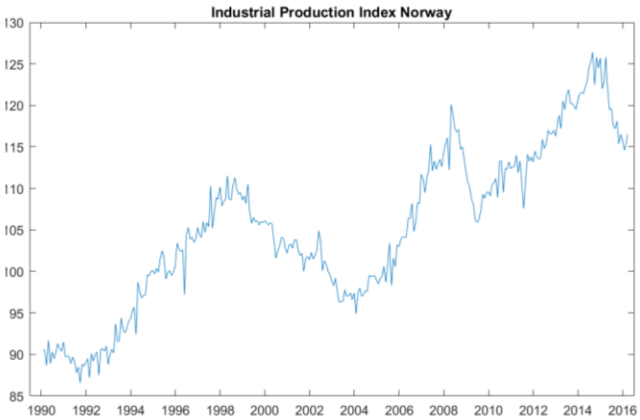

Figure 7. Industrial production index for Norway. Monthly data 1990:M1-2016:M3. Source: Statistics Norway.

The industrial production index (IP hereafter) is an alternative measure for economic activity. Fortunately, it is available at monthly frequency permitting a monthly VAR, which is the main motivation for using this series. The series is seasonally adjusted and includes only manufacturing[6], leaving out the volatile mining and oil and gas extraction series, as well as services. Hence, the IP represents only a part of the value creation in the Norwegian economy: Between 1990 and 2015, manufacturing has accounted for about 7-12% of total value added in Norway[7]. It is therefore not to be interpreted as a monthly version of the GDP series. One can observe that the IP series is upward sloping, as is the GDP, but the IP is more volatile (the higher data frequency likely being only part of the reason). Arguably, the IP series is built of more volatile components than the GDP since the IP contains mostly tradable goods that are susceptible to changes in foreign demand and exchange rate fluctuations.

[6] Manufacturing comprises: food, beverage and tobacco, refined petroleum, chemicals and pharmaceuticals, basic metals, machinery and equipment, ships, boats and oil platforms.
[7] See OECD webpage: data.oecd.org/natincome/value-added-by-activity.htm

Prices in Norway

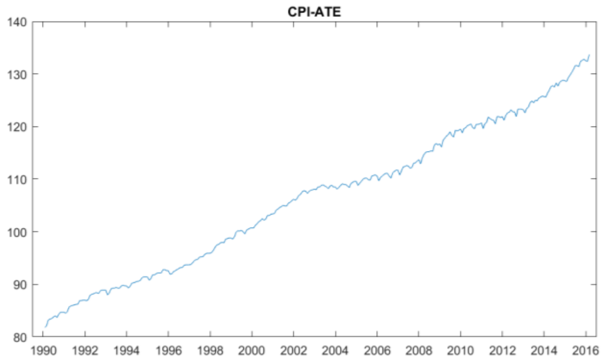

Figure 8. CPI-ATE. Monthly data 1990:M1-2016:M2. Base period is July 1999. Source: Statistics Norway.

CPI-ATE is a seasonally adjusted CPI that is adjusted for tax changes on goods and cleared of energy products. CPI-ATE represents core inflation better than the raw CPI. Norges Bank like other central banks tend to target the core inflation instead of headline inflation. Hence, the VAR should rather include this measure of inflation to incorporate the monetary policymaker's response to fluctuations in inflation. It should be noted, however, that several other inflation measures could have been considered in the VAR that also proxy core inflation and are thus used in policy making (Johansen, Rodriguez and Sandberg 2006).

Norwegian interest rates

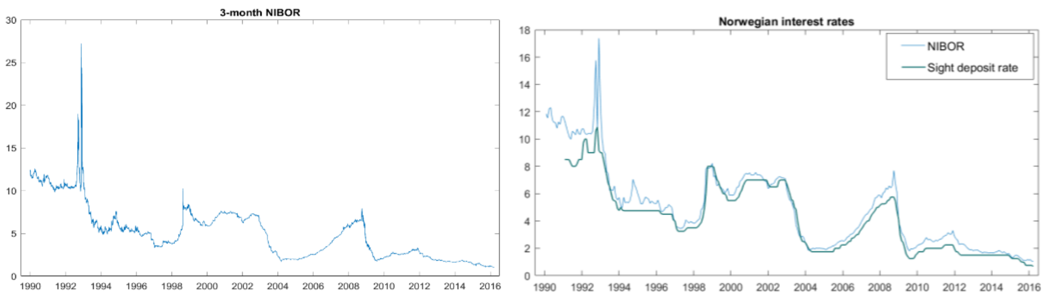

Figure 9. Left panel: 3-month Norwegian Interbank Offered Rate (NIBOR) in percent. ***Daily*** *data 02/01/1990-22/03/2016. Source: Oslo Børs through Bloomberg. Right panel: 3-month NIBOR and the sight deposit rate in percent.* ***Monthly*** *data 1991:M1-2016:M3. Source: Norges Bank.*

A short-term interest rate is included in the VARs to represent credit conditions that are known to be central also for macroeconomic activity. Furthermore, short-term rates are strongly influenced by policy rates, hence they reflect the monetary stance as illustrated in Equation (1) and the right panel in Figure 9. I use the three-month money market rate, NIBOR, as the Norwegian interest rate.

(1) *3-month NIBOR = 3-month key policy rate expectations + risk premium*

where only the 3-month NIBOR rate is observable.

NIBOR's function is "to reflect the interest rate level that lenders require for unsecured money market lending in NOK"[8]. Yet, few transactions actually take place in the Norwegian interbank market beyond the very shortest maturities. Thus, the interbank rate is constructed as a foreign exchange swap rate from the USD by utilizing the covered interest parity -relationship between domestic and foreign interest rates. Prior to the global financial crisis, the NIBOR panel banks based their calculations of the NIBOR directly on a foreign exchange (FX) swap into the eurodollar rate, the USD LIBOR (such that the USD LIBOR replaced the Kliem rate in Eq. 2). As this was not thought to reflect accurately the true borrowing costs that the Norwegian banks were facing in USD, since August 2008 the NIBOR has been derived from the 'Kliem rate', a USD interest rate published by the brokerage house Carl Kliem in Frankfurt. The Kliem rate is approximately the rate that one achieves by using the three-month EURIBOR and swapping to USD in the forward market. (Norges Bank 2013.) The full derivation of NIBOR is illustrated in Equations (2) and (3) (Tafjord 2015).

$$NIBOR = \mathit{Kliem\ rate} + \mathit{forward\ premium\ (USDNOK)} \quad (2)$$

where:

$$\mathit{Kliem\ rate} = \mathit{Overnight\ Index\ Swap\ (USD)} + \mathit{risk\ premium\ in\ EURIBOR} + \mathit{Overnight\ Index\ Swap\ basis\ (EURUSD)} \quad (3)$$

In Equation 3, the expectations of U.S. policy rates are embedded in the 'Overnight Index Swap (USD)'- term since the OIS-rate is normally very close to the key policy rate, due to USD LIBOR being a close substitute to the FFR (Norges Bank 2013, pp.14). The significance of this is that the USD LIBOR has been reflected in the Norwegian money market rate both before and after 2008. This means that the "Norwegian" interest rate NIBOR in the VAR models of this thesis reflects conditions (monetary policy as well as risk and term premia) in the U.S. money markets. The implications of it are brought up in section 4.2.1. Other candidates for Norwegian interest rates that come to mind are the Norges Bank sight deposit rate

[8]See webpage of Finans Norge, the institution that lays down the rules for NIBOR submissions: https://www.finansnorge.no/en/interest-rates/nibor---the-norwegian-interbank-offered-rate/. The six panel banks that submit their respective rate are: DNB Bank ASA. Danske Bank, Handelsbanken, Nordea Bank Norge ASA, SEB AB and Swedbank AB.

(key policy rate) or Nowa (Norwegian overnight weighted average) that reveal only the part of the prevailing credit conditions that is strictly under central bank's control. Alternatively, yields on Norwegian Treasury bills could be used, although they reflect the sovereign debt market and to a lesser degree the broader credit markets that are relevant for lending to the public. The right panel in Figure 9 above displays the sight deposit rate plotted against the three-month NIBOR. The sight deposit rate is the key policy rate and the interest rate on banks' overnight deposits with Norges Bank based on the banks' individual quotas. It is apparent that the policy rate is influential for the NIBOR.

Krone Exchange Rate

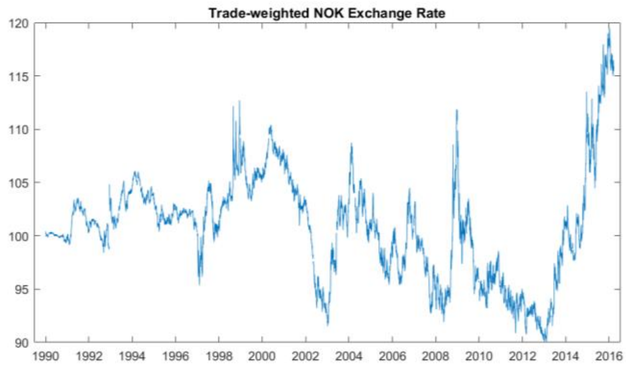

Figure 10. Trade-weighted currency basket. Daily data 02/01/1990-22/03/2016. Source: Norges Bank.

The trade-weighted index (TWI) is the nominal value of Norwegian krone against a basket of Norway's 25 most important trade partners. The index is determined such that higher values indicate a depreciated krone. Alternatively, I could simply use the NOK/USD-exchange rate in the model since both of the foreign financial shocks of the VARs are U.S. based (I do this for some models to check if the results differ). The TWI in turn measures Norway's position against the "rest" of the world. Given the interpretation that these U.S. originated shocks are representing the global financial cycle, it can be appropriate to measure the domestic currency's value against the "world" currencies.

3. Literature review and a theoretical discussion

3.1. A theoretical discussion of a foreign monetary policy shock

The discussion of this section reviews some of the theoretical frameworks that incorporate international transmission of monetary policy. The literature that studies international monetary transmission empirically, using VARs or other models, is massive, thus I will not review the previous empirical tests and results here. I consider the monetary policy shock to be a shock to the conventional policy instrument, the target for a short-term interbank interest rate. I use the short-term interbank rate as a measure for U.S. monetary policy stance, thus the theoretical framework excludes unconventional monetary policy measures such as forward guidance and quantitative easing that have become increasingly important in the recent years[9]. To notify the reader, I will consistently refer to the economy that receives a foreign shock as 'home economy', 'domestic economy' or 'periphery' which in my empirical exercises in the later sections is synonymous to Norway. I will refer to the economy where the monetary shock originates as the 'center economy', 'foreign economy' or 'abroad' which in the empirical exercises is the United States.

Traditional channels for international monetary spillovers

The political understanding is often that expansionary monetary policy actions abroad has a 'beggar-thy-neighbor' type of impact on the domestic economy through expenditure-switching effects (Frankel 2016). From a theoretical point of view, the outcome of foreign monetary stimulus might as well be of 'prosper-thy-neighbor' kind: foreign monetary stimulus also works as to boost the foreign economy, benefitting its trade partners alike the domestic economy (expenditure-increasing effect). (Ammer et al. 2016.)

Most traditional open economy models, such as the Keynesian Mundell-Fleming, the Mundell-Fleming-Dornbusch, the intertemporal current account models, as well as the neoclassical models acknowledge at least two key channels of impact for a foreign monetary shock. Their prediction is that an interest rate hike in a center economy has two opposing influences on a periphery economy (Rey

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[9] Ammer et al. (2016) review the literature of unconventional monetary policy impact on foreign asset prices.

2016, pp. 3). Let us assume that the periphery's currency is freely floating and the center economy raises its interest rate. Firstly, demand in the center economy weakens because saving in the center provides now a higher return, so consumers save more and consume less. Moreover, consumers and firms face a higher cost of capital which dis-incentivizes investment. In sum, this suggests a lower demand in the center, also towards peripheral goods. In the context of a foreign interest rate hike, this is an *expenditure-decreasing effect* (also named an *income-absorption effect*) with respect to the home economy through the 'foreign demand' channel.

Secondly, the return on the center's bonds is now greater than before the interest rate hike, which causes financial investment to flow from periphery to center. To keep foreign investors content holding the bonds of either economies, the currency of the center appreciates relative to that of the periphery, such that the poorer return in the periphery is compensated by a higher chance of a future capital gain from a peripheral currency appreciation in the periods ahead. This, in turn, boosts demand in the center for the relatively cheap imports from the periphery, and so the floating exchange rate has counteracted the fall in demand and functioned as an absorber of a foreign shock to the periphery. Hence, the foreign monetary shock induces *expenditure-switching effects* through the 'exchange rate' channel.

Yet, if the two forces described above do not perfectly balance, the foreign monetary shock can put pressure on the periphery's exports and GDP. The periphery's monetary policymaker may then respond to the shock by adjusting its interest rate, such that output and inflation remain within the desired path. It remains theoretically an unsettled issue which of the two opposing effects finally dominates, that is, what is the sign of the impact of a foreign monetary shock on trade balances at home and abroad. As the relative strength of the channels differs from economy to economy, the net effect is ultimately an empirical issue (Ammer et al. 2016, Georgiadis 2015). The effects depend, for instance, on the sensitivity of exchange rate to interest rate movements; models that impose uncovered interest parity[10] to

[10] The uncovered interest parity (UIP) provides an explanation for how a monetary policy action leads to a move in the exchange rate. According to the UIP, the following condition holds:

$$(4) \qquad 1+r_t = 1/s_t \times (1+r_t^*) \times E_t[s_{t+1}]$$

where r is the domestic risk-free interest rate, r* is the foreign risk-free rate, s_t is the spot exchange rate (units of domestic currency per units of foreign currency) and subscripts denote the time period. When a foreign monetary shock hits and raises r_t^*, investors will increase their holdings of foreign assets until Equation (4) balances again, putting upward pressure on r_t, s_t and/or downward pressure on $E[s_{t+1}]$, i.e. a current-period depreciation and future-period appreciation of the domestic currency such that investors are compensated for holding the lower-yielding domestic asset.

hold tend to give a greater impact of a foreign monetary shock through the exchange rate channel (Boivin, Kiley and Mishkin 2010).

Kim (2001) studies the international transmission mechanism of expansionary U.S. monetary shocks to other G7 countries in the flexible exchange rate era, using both recursive and non-recursive VARs. He finds that the trade balance overall bears less significance as a transmission channel than what the traditional theory posits (see also Georgiadis 2015). His findings are more consistent with monetary spillovers from integrated world capital markets: A U.S. interest rate change induces a parallel movement in interest rates internationally, which ultimately has an impact on the macro variables in each individual country. Notably, this channel is distinct from an endogenous domestic policy reaction to a U.S. monetary shock, that is, domestic replication of the Federal Reserve's monetary actions. Controlling for the domestic macroeconomic conditions that the non-U.S. monetary policymakers might react to within their mandate, the policy responses to the U.S. monetary actions are, in general, not strong or statistically significant. In addition, the initial responses of monetary aggregates are small, suggesting *less of a direct reaction* of non-U.S. monetary policy to a U.S. monetary shock.

Neo-Keynesian models

International transmission of monetary policy is also modelled in neo-Keynesian models. New Open Economy Macroeconomics (NOEM) started developing in the 1990s from Obstfeld and Rogoff's *Redux* model (1995). The framework developed as a synthesis of the Keynesian open economy models of the 1960s and the intertemporal current account models of the 1980s in attempt to better fit the open macro theory with data (Obstfeld 2001). Key features of the NOEM framework are nominal rigidities and imperfect competition in the markets for goods and/or labor, which has implications for the transmission mechanism for shocks. (Corsetti 2007, Lane 2001.)

NOEM's predictions about the impact of a foreign monetary shock are sensitive to the assumption of which currency is used for pricing tradable goods. With the assumption that exports are priced in the producer currency ('producer currency pricing'; PCP) and producer prices are sticky, nominal import prices move in parallel with the exchange rate such that import prices at home fall when domestic currency appreciates, spurring demand for foreign goods. In this set-up, the predictions are much like in the traditional Keynesian models that place much importance on the expenditure-switching effects that give the flexible exchange rate its stabilizing role.

Assuming PCP, foreign monetary expansion has ambiguous effects on the expanding foreign economy: it raises demand and thus output which due to monopolistic distortions is below the potential level. On the downside, the expansion reduces foreign welfare by deteriorating the foreign economy's terms of trade (foreign currency depreciates); the real income of foreign consumers declines due to the monetary expansion. As a result, optimal monetary policy trades off stabilization of the output gap (that tends to be nonzero due to monopolistic distortions) and improvements in the terms of trade (Rey 2016, pp. 4). For the same reasons, monetary expansion abroad has *unambiguously* a positive welfare spillover to the home economy. Firstly, cheaper imports reduce inflation and raise aggregate domestic demand for a given domestic monetary stance. (Corsetti 2007, Corsetti and Pesenti 2001 pp. 438-439.) Secondly, the appreciation of home currency improves home's terms of trade, benefitting domestic consumers by raising their real income.

The question of the currency that is used for pricing the tradable goods has launched a debate within the NOEM literature regarding the international transmission mechanism of foreign shocks. The 'received wisdom' of expenditure switching effects that are inherent in the traditional open macro models is questioned when it is assumed that tradable goods are priced in the currency of the importer ('local currency pricing', LCP). Likewise, the received wisdom is put into question when confronting the traditional theory with the empirical observation that pass-through from exchange rates to import prices is virtually zero in the short-run at the consumer level, while for example the Mundell-Fleming model assumes a unitary pass-through (Obstfeld 2001, pp. 20). Given these qualifications, foreign currency depreciation has a lesser influence on the price of foreign goods outside the foreign economy and there are smaller expenditure switching effects from foreign monetary expansion. (Corsetti 2007, Obstfeld 2001.)

In sum, the expenditure-switching and -reducing effects are strongly present in the NOEM literature as well, but the predictions are sensitive to the pass-through of the foreign monetary shock to domestic import prices. Generally, monopolistic distortions cause monetary expansion to have beneficial effects at home and abroad because the stimulus from increased demand reduces the perennial output gap.

The financial spillovers channel

Ammer et al. (2016) classify international monetary transmission into three main channels. In addition to the traditional exchange rate (expenditure-switching effect) and foreign demand (expenditure-reducing effect) channels already presented above, they include a third channel that they refer to as the 'financial spillovers' channel, akin to the capital market spillovers brought up in Kim (2001, see also Bruno & Shin 2015 and Feldkircher & Huber 2014). This channel has attracted more active research in the recent years. Rey (2016) elaborates on the financial spillovers channel and assigns the international transmission of monetary shocks to the 'international credit' channel and to the 'risk-taking' channel where the shock can be amplified through capital market frictions.

The credit channel, broadly defined[11], (also referred to as the 'balance sheet channel') works in the following way. Monetary tightening tends to deteriorate the balance sheets of households, firms and financial intermediaries: Asset values fall along with the risen discount rate, while funding costs increase in particular for those who hold liabilities with either a short maturity or a flexible interest rate; interest rates that are most swiftly impacted by policy rate changes. The effect of the credit channel is more potent when there prevail frictions in the credit market (here the theory departs from neoclassical channels).

Agency costs that arise from asymmetric information between borrowers and lenders introduce an external finance premium in lending. Lenders require a compensation for risk due to not knowing the true credit-worthiness of the borrower or the profitability of the undertaken investment. The issue is mitigated in times when borrowers can demonstrate a high net worth and collateral values, namely in times of expansionary monetary policy. It is in these times that the external finance premium is low. The friction of asymmetrical information in the credit market may thereby propagate the initial monetary shock to balance sheets through the external finance premium that fluctuates with the policy stance. (Boivin, Kiley & Mishkin 2010 and Rey 2016, pp. 4.)

The credit channel, with or without market frictions, operates also internationally: a federal funds target rate increase will tend to reduce the value of all dollar denominated assets. Given the scope of international dollar finance, a U.S.

[11] Boivin et al. (2010) treats bank lending channel separately.

monetary shock has the potential to deteriorate balance-sheets internationally. The U.S. dollar is the main currency of global banking. More than a third of global dollar lending by banks to non-banks now takes place outside the U.S. borders (Obstfeld 2015, pp. 31-32). The dollar is the currency used for invoicing, pegging exchange rates, issuance of financial assets, a vehicle currency in the FX market and in commodity trade (Rey 2016).

The international credit channel is relevant also for Norway, given the banks' foreign operations as outlined in section 2.1. Operating in the U.S. money markets naturally means that the Norwegian banks partly adopt the credit conditions prevailing in the U.S. that are governed by policies of the Federal Reserve. A shock to the dollar component of an international bank's balance-sheet has potential to spread over to the rest of the balance sheet. For example, a decline in dollar funding rates improves the bank's lending margin and raises profits, which likely spurs asset expansion in other currencies as well (Obstfeld 2015, see also section 2.1). As mentioned earlier, about one-third of the Norwegian banks' foreign currency funding is used to finance domestic currency assets, equivalent to about 10% of banks' total assets (IMF 2015). It should be noted that this is a channel for transmission of financial shocks in general, not restricted to monetary shocks.

Borio and Zhu (2012) propose a 'risk-taking' channel of monetary policy. A key element in it is that time-varying risk tolerance (or more precisely, monetary stance-varying risk tolerance) of economic agents generates time-varying pricing of risk, compressing risk premia procyclically. The international aspect of the risk-taking channel relates in particular to the 'search for yield' behavior of portfolio investors. In the international monetary transmission context, search for yield effect emerges when investors' target for a rate of return diverges from the prevailing rate of return that is set by policy rates. Monetary easing hence pushes investors to riskier markets or asset classes in attempt to reach a yield parallel to what was attainable at a lower risk before monetary easing took place. The reasons why investors may not adjust their return targets have to do with contractual obligations or behavioral reasons, such as 'money illusion' or 'irrational exuberance'[12]. (Borio and Zhu 2012.)

Although the 'search for yield'/'search for safety' behavior is connected to international monetary transmission through the risk-taking channel, this type of

[12] It is noteworthy that the risk-taking channels departs in many respects from the assumption of rational agents, distinct from the more classical and uncontested monetary transmission channels.

investor behavior also propagates other FFSs than merely monetary shocks, most likely financial market sentiments that are brought up in the next section.

It has been suggested that Norway is a safe haven for investors due to the country's stable economic growth and sound external balances. This is not necessarily the case as Lund (2011) points out. The EUR/NOK market, for example, is relatively small and illiquid and sensitive to oil price fluctuations. Moreover, the Scandinavian economies are exposed to the European financial conditions, despite being outside the euro area. This suggests that other, more robust currency markets make a better safe haven. Consequently, the flows of funds in and out of Norway as a response to the global financial cycle is less clear-cut than for emerging economies on the one end of the scale and the major industrialized countries on the other. Be that as it may, the Norwegian banks' potentially time-varying ability to draw on short-term credit abroad may be disturbing for the Norwegian credit markets and bank lending, hence affecting the real economy as well (see also Bruno and Shin 2015).

Domestic monetary response

The potency of the foreign monetary shock naturally depends on the domestic monetary response. The 'fear-of-floating' channel is similar to endogenous monetary policy responses to foreign monetary shocks where foreign monetary actions are written in the domestic monetary rule. In the fear-of-floating channel, however, the domestic central bank actively manages its exchange rate despite the announced policy target, the inflation rate. For instance, the central bank may not be able to peg credibly, which makes a fixed exchange rate regime unattainable; the central bank may still wish to continue pegging in a less open and formal manner (Calvo and Reinhart pp. 5-8). Also, large movements in the exchange rate have ultimately a bearing on output and inflation, which makes the exchange rate an object of interest also for an inflation-targeting central bank. Either way, if the domestic central bank tightens its policy when the center economy is tightening, the domestic economic activity is additionally impacted through the well-known domestic channels of monetary policy transmission (Jannsen and Klein 2011). For example, the domestic credit channel causes a fall in the asset values of domestic currency denominated assets while the international credit channel reduces the value of foreign denominated assets (Rey 2016).

Rey (2016) points out that the existence of foreign debt may complicate the implementation of domestic monetary policy in a setting of floating currency: contractionary foreign monetary shock has the perhaps favorable effect of weakening the domestic currency and boosting exports, yet the currency depreciation has the adverse effect of raising the value of foreign debt. Inaction of domestic monetary policy comes at a higher cost (or benefit, depending on the net foreign debt position). In this context, in order to reduce the swings in the balance-sheet effect it may be desirable for the economy to avoid large fluctuations in the exchange rate and to follow more closely the monetary stance of the center country. For Norway, the picture is two-sided: the country has large public holdings of foreign assets through the petroleum fund, while the banking sector has large private holdings of foreign liabilities.

Figure 11 below summarizes the preceding theoretical framework for foreign monetary shocks. Broadly defined, there are (i) the traditional channels that work through the trade balance and (ii) the channels that bring about a domestic interest rate and credit response: either through financial spillovers or because domestic monetary policy responds directly (out of fear of floating or by the announced exchange rate targeting). In the latter channels, the domestic interest rate response is towards the same direction as the interest rates in the center economy, causing the domestic absorption of the two economies to move in parallel, thus not necessarily prompting a trade balance change, although other macroeconomic changes are possible nonetheless (Kim 2001, pp.354). Yet, a modest reaction of the trade balance could equally indicate that the expenditure-switching and -reducing effects of the traditional channels do function but are mutually offsetting, which makes it difficult to discern empirically which channels are most influential.

In the empirical tests of the later sections, I do not fully disentangle the different channels from each other: firstly, this is difficult to do with a small-scale VAR and secondly, the interactions of some channels (e.g. the risk-taking channel with the credit channel) are obscure and difficult to summarize with some tangible variables. The frameworks were presented here rather to cast some light on how these channels might work in theory to yield a certain observed impact on the Norwegian economy.

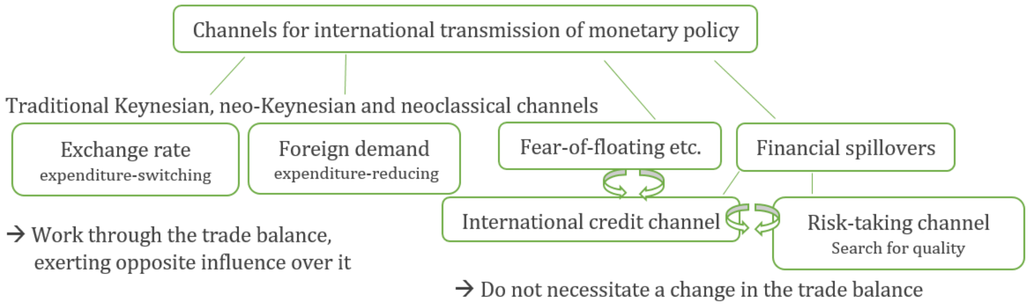

Figure 11. A summary of the main international channels of transmission of monetary policy.

3.2. A theoretical discussion of an uncertainty shock

The theoretical work on economic uncertainty dates at least to Bernanke (1983)[13]. Bloom (2009) provides a contribution to the uncertainty literature and relates his line of research to the critique in real business cycle theories regarding the absence of negative productivity shocks. He proposes an uncertainty approach to modelling business cycles by asserting that recessions could simply be periods of high uncertainty without any negative productivity shocks (see also The Economist, February 1, 2007: *Momentous modelling*).

Bloom argues that uncertainty shocks tend to have a depressing effect on economic activity in the following way: Firms may want to wait out the uncertainty before taking irreversible investment and hiring decisions. Additionally, the reduction in investment and recruitment hampers the process of capital and labor reallocation from low to high productivity firms – productivity falls along with investment. Bloom deduces that disruptions in investment and efficient input allocation in firms should create a pattern of a rapid slow-down in economic activity after the uncertainty shock, followed by a bounce back to normal levels when the uncertainty dissolves and pent-up activity revives (due to uncertainty shock being a temporary second moment shock, i.e. a shock to the variance of stock returns). Hence, the pattern is quite different from a persistent decline in economic activity from a first moment productivity or demand shock (shock to the mean).

Bloom's analysis arrives at an interesting conclusion that heightened uncertainty, by creating a real option value to waiting which incentivizes firms to cease investment and recruitment, makes the economy temporarily insensitive to

[13] Aastveit, Natvik and Sola (2013) provide a review of previous empirical research on uncertainty's macroeconomic effects.

changes in factor prices. This has implications for fiscal and monetary policy measures: responses to policy measures only occur with a lag when the economy is hit by an uncertainty shock, suggesting that policies targeted directly at diminishing the underlying uncertainty are likely to be the most effective. Aastveit, Natvik and Sola (2013) employ a recursive SVAR to see if U.S. based economic uncertainty could reach a dampening effect on policy effectiveness also outside the U.S. borders. Quite remarkably, monetary policy in Norway is found to be statistically significantly less effective for investment when U.S. stock market volatility (measured by the VXO index and the realized volatility when VXO is not available) is at its uppermost decile.

Bloom builds a theory-based structural partial equilibrium model, but also tests his theories empirically by running a set of recursive SVARs where he estimates uncertainty shocks' impact on standard real macroeconomic variables. He utilizes monthly data (from 1963:M7 to 2005:M7) on economic activity variables for the U.S. and finds that the pattern of responses in industrial production and employment to an uncertainty shock indeed fits the description above (the 'drop and rebound' pattern)[14] but also an overshoot in the longer run.

Gudmundsson and Natvik (2012, GN henceforth) follow Bloom, among others. They also conduct a recursive SVAR study on the impact of uncertainty shocks, but the response of their interest is consumption in Norway. They use three different types of uncertainty measures. Their measures of uncertainty in the financial markets are the CBOE VXO index (a U.S. based index comparable to the VIX index) and implied/realized volatility in the Oslo stock exchange. They use the frequency of newspaper quotes on economic uncertainty as their third measure of uncertainty. The reasoning is that the general public is more apt to respond to news coverage of economic uncertainty than the more financial type of measures, which makes the newspaper quotes a more relevant variable for studying consumption decisions. Different from mine, their study also considers domestic Norwegian uncertainty shocks (the Oslo stock exchange volatilities) and focuses on the response of consumption alone, whereas I look at the wider macroeconomy and financial conditions in Norway in response to a foreign financial uncertainty shock. They find that durable goods consumption in particular, but not alone, is responsive

[14] More specifically, the uncertainty shock used in the SVARs is stock market volatility at *selected turbulent events* (such as wars, economic crises or terrorist attacks). Stock market volatility series are the CBOE VXO, continued with actual volatility where the VXO series is not available.

to uncertainty shocks (a fall in consumption when uncertainty hits). Of the shocks, the news coverage has the most robust influence on consumption.

GN attribute the impact of uncertainty on consumption to two channels:

(i) **Precautionary behavior**. Consumers fear that their future consumption might become lower, which induces them to reduce consumption and increase labor supply today in attempt to smoothen their consumption paths.

(ii) **Delays of irreversible decisions**. In the spirit of Bloom but with an application to consumption decisions: delays arise from a concern that an investment cannot be recovered after the decision has proven to be wrong in a certain state of the world. This is due to the fixed cost nature of a durable goods investment and a rapid loss of value of the good once purchased (the market for lemons phenomenon). Thus postponing a decision has a real option value for consumers, and the higher the uncertainty, the higher the option value. Consumption is delayed because waiting is relatively cheap.

Lastly, there is a specific literature devoted to the effects of policy uncertainty on economic activity. More specifically, this can be either monetary, fiscal or regulatory policy uncertainty. Baker, Bloom and Davis (2015) adhere to this literature by conducting a panel VAR study on the effects of policy uncertainty on macroeconomic performance in the U.S. and twelve other major economies. To do this, they too utilize newspaper coverage as their chosen measure of uncertainty since it is perhaps successful in filtering out precisely *policy* uncertainty.

First, they exploit firm-level data to uncover a specific channel of uncertainty regarding government purchases of goods and services that can hamper investment and employment in certain firms; firms in defense, healthcare and construction sectors are presumably more exposed to the government's purchase decisions and disturbed by uncertainty around them. On the one hand, this firm-level exercise yields a better causal identification of an important link, but on the other hand it does not provide much guidance about the magnitude of the aggregate effects of policy uncertainty. Second, and in a similar vein with this thesis, they use macro data that captures multiple channels of impact but offers a weaker identification of separate causal links at work. Their findings from both of the exercises are in line with the common theoretical predictions: uncertainty has an adverse impact on investment, output and employment, or at the very least it foreshadows declines in these variables.

Before looking at what the data suggests in the form of VAR impulse responses, I hypothesize that the response of real economic activity to uncertainty in my case is most likely to come as a reaction to the changed exchange rate and credit conditions that a shock to the second moment brings about. In other words, I expect the foreign financial uncertainty shock (the VIX shock) to propagate the shocks to the first moment of NIBOR and krone exchange rate rather than to constitute an independent influence on the Norwegian GDP or CPI. As GN documented, the response of consumers to the financial uncertainty indicators (domestic and foreign) is less robust, implying that consumers react to a lesser degree directly to financial uncertainty than, for example, news coverage on economic uncertainty. For financial intermediaries this is not the case, so a change in their behavior in the interbank and FX market prompted by uncertainty should be immediately reflected in the price of krone and NIBOR. Nonetheless, it is not excluded that the Norwegian GDP could react directly to implied stock volatility in the U.S. For instance, economic turbulence in the U.S. (as represented by the VIX) could cause American firms to delay their decision to purchase goods from Norway, lowering exports from Norway to the U.S. and the Norwegian GDP with it.

4. Methodology

To study the effects of the foreign financial shocks on the Norwegian macroeconomic variables, I will employ a set of structural vector autoregressions (SVAR). This master thesis aims to study the effects of shocks that are (i) exogenous and (ii) financial[15]. Only after achieving this, I can make causal inference of the impact of these shocks on the Norwegian macroeconomy. Accordingly, structural shocks to the VIX and to the Federal funds rate and the subsequent responses of the Norwegian variables are the main objects of interest for the research question of this master thesis. I start with a 'simple SVAR' containing only the main variables (results of which are presented in Appendix A)

[15] In this thesis, the shocks are broadly defined as 'financial' when they manifest themselves as shocks to financial variables. Market sentiment shocks, for instance, do not have to be *originated* by economic events only, as long as they are exogenous to Norway, i.e. not reflecting some macroeconomic events that bear a significance of their own to the Norwegian economy.

to have a comparison point to the latter, more elaborate SVARs that more credibly can be considered incorporating structural shocks. More specifically, the simple SVAR is created to see whether the SVAR results are very sensitive to inclusion of some control variables.

4.1. Why a structural vector autoregression?

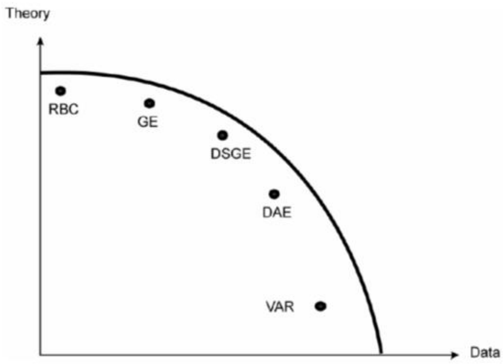

Figure 12. Pagan-diagram for model classification. RBC: Real Business Cycle models; GE: General Equilibrium models; DSGE: Dynamic Stochastic General Equilibrium models; DAE: Dynamic Aggregative Econometric models; VAR: Vector Autoregressive models. Source: Bårdsen, Lindquist and Tsomocos (2006, pp.15).

Vector autoregressions (VARs) provide a useful alternative to large-scale macroeconometric models. The Pagan-diagram[16] of Figure 12 compares VARs to other potential economic models in two dimensions: theoretical coherence and data congruence. Calibrated dynamic stochastic general equilibrium macroeconomic models are explicit about causal links, which makes their logic more tractable (Stock and Watson 2001). On the downside, their common defect is that they often fail to fit the data. Theories can lack in explaining the true data generating process entirely; direct translation of theoretical relationships to econometric specifications likely generates misspecified models (Lütkepohl 2005 pp.400, Bårdsen, Lindquist and Tsomocos 2006).

Figure 12 makes apparent that VARs are a more empirical approach to economic modelling. As Bårdsen, Lindquist and Tsomocos (2006, pp.33) put it, "where calibrated models emphasize theory replication, VARs emphasize data replication". VARs are better-suited to capture rich dynamic properties of data than the models that are more confined to theory. Congruence with data makes VARs good instruments for forecasting as well as describing and summarizing data

[16] The diagram is borrowed from Bårdsen, Lindquist and Tsomocos (2006, pp.15) but was first introduced in Pagan (2003).

(nowcasting). Furthermore, VARs supply a statistical toolkit that is relatively "light" in terms of the complexity in constructing a model.

Nonetheless, VARs have limitations in enabling causal inference which entails a move from unrestricted (reduced form) VARs to structural VARs (SVARs). The identification problem in structural VAR analysis refers to the inability to identify the structural parameters of the VAR since the parameters might reflect other influences than what they are thought to represent (biased parameter estimates). To put it more formally, for the reduced form VAR the problem is that the errors are likely correlated. This means that shocks in the different variables will not occur independently – movement in one variable is accompanied by movement in another variable in the system, so that the parameter for the first variable actually represents the joint effect of both of the variables; disentangling the individual impact of each shock cannot be done.

Structural inference requires in essence differentiating between correlation and causation. In the VAR setting, the task is done by solving the identification problem: first, by assuming that the reduced form residuals can be expressed as linear combinations of the structural shocks and second, using either economic theory (in a strict or loose manner) or institutional knowledge to restrict the distribution of residuals in the system. One can identify all the shocks, a subset of the shocks, or a single shock in the VAR. SVARs are subsequently more controversial than VARs because restricting the VAR model requires going from a purely statistical tool to using more discretion and economic reasoning. With successful restrictions, one can identify structural shocks and their transmission mechanisms in the form of impulse responses. This is a challenge because economically plausible restrictions are hard to come by. Yet, any structural implications are only as sensible as their identification schemes. (Stock & Watson 2001 and 2012, Bårdsen, Lindquist & Tsomocos 2006). I experiment with two different identification schemes in this master thesis. They are brought up in detail later on.

Even structural VARs are susceptible to endogeneity and omitted variables bias. A major limitation in the methodology is that SVARs have to be estimated to low-order systems that are bound to leave information outside the model (Bjørnland and Thorsrud 2015). Subsequently, the effects of omitted covariates (both other explanatory variables or lagged values) are left in the residuals and are a concern if they display themselves as distortions in the impulse responses, invalidating structural inference. Hence, one should be aware of what the "structural" shock genuinely captures. Due to the limited number of variables and the aggregate nature of the shocks, Bjørnland (2000, pp. 10) recommends viewing a VAR model rather as an approximation to a larger structural system.

Methodological development towards larger-scale state-of-the-art Bayesian VARs has been made, although these have not become full substitutes to smaller-scale VARs that benefit from lightness in terms of complexity. The criticism reviewed here is not to convey that VARs and structural VARs are useless or obsolete. At their best, SVARs can both fit the data and provide sensible estimates of causal connections, provided that credible economic reasoning is used in specifying the system. (Stock and Watson 2001.) For my purpose, which is to quantify the impact of a foreign financial shock on Norwegian macroeconomic data, the data-driven vector autoregression is effective.

Other specification issues may also arise. Given the length and frequency of the data available, it is possible that the VAR will be overly parameterized; there are too few observations to estimate the large number of parameters, especially if also the lag number is large. My quarterly SVARs are subject to this concern, which is why also a monthly version is estimated, although it is not a perfect substitute to the quarterly one (monthly IP does not equal a monthly GDP). Once the model appears to be correctly specified, the impact of a shock can be interpreted from each variable's impulse responses and the overall importance can be assessed by the variance decomposition, which is the general procedure for reporting VAR results. Appendix C gives a brief technical description of the methodology.

4.2. Cholesky identification

First proposed by Sim (1980), Cholesky identification of the parameters implies a recursively identified SVAR which have become very common in the literature. This is done by exploiting an algebraic result, the Cholesky decomposition, as is shown next[17]. To start with, one can transform the reduced form VAR of Equation (12) (in Appendix C) into its moving average (MA) representation:

[17] The mathematical description in this section follows Bjørnland and Thorsrud (2015) and the computations in between stages therein.

(5) $$\boldsymbol{y}_t = \boldsymbol{\mu} + \sum_{j=0}^{\infty} \boldsymbol{\Upsilon}_j \boldsymbol{u}_{t-j}$$

where $\boldsymbol{\mu}$ is a vector of constants, $\Upsilon_j = \boldsymbol{B}^j$ is a matrix of the reduced form MA coefficients for the reduced form shocks vector $\boldsymbol{u}$.

The Cholesky decomposition holds that every positive definite symmetric matrix, such as the variance-covariance matrix $\boldsymbol{\Sigma_u}$, can be written as the product $\sum_{\boldsymbol{u}} = \mathbf{PP}`$ where $\mathbf{P}$ is the Cholesky decomposition of the variance-covariance matrix. We know that $\mathbf{P}$ is a *lower triangular* matrix with positive diagonal elements and $\mathbf{P}`$ is its conjugate transpose. As $\mathbf{PP}^{-1} = \mathbf{I}$, we can insert it into the reduced form MA of Equation (5) to obtain:

(6) $$\boldsymbol{y}_t = \boldsymbol{\mu} + \sum_{j=0}^{\infty} \boldsymbol{\Upsilon}_j \boldsymbol{P}\boldsymbol{P}^{-1} \boldsymbol{u}_{t-j} \quad \text{i.e.} \quad \boldsymbol{y}_t = \boldsymbol{\mu} + \sum_{j=0}^{\infty} \mathbf{F}_j \boldsymbol{e}_{t-j}$$

where $\boldsymbol{y}_t$ and $\boldsymbol{\mu}$ remain as in Equation (5), $\boldsymbol{F}_j = \Upsilon_j\boldsymbol{P}$ and $\mathbf{e}_{t-j} = \boldsymbol{P}^{-1}\mathbf{u}_{t-j}$.

Importantly, for the variance-covariance matrix of the VAR this yields:

(7) $$\mathrm{E}[\mathbf{e}_t\mathbf{e}_t`] = \mathbf{P}^{-1}\mathrm{E}[\mathbf{u}_t\mathbf{u}_t`](\mathbf{P}^{-1})` = \mathbf{P}^{-1}\boldsymbol{\Sigma_u}(\mathbf{P}^{-1})` = \mathbf{P}^{-1}\mathbf{PP}`(\mathbf{P}^{-1})` = \mathbf{I}$$

That is, one has achieved a variance-covariance matrix that is an identity matrix. Hence, covariances between the different error terms are zero; a shock to one variable is likely *not* accompanied by a shock to another variable.

What is more, in Equation (6): $\boldsymbol{\Upsilon}_0 = \mathbf{B}^0 = \mathbf{I} \xrightarrow{yields} \mathbf{F}_0 = \mathbf{P}$. Thus, the first coefficient matrix for the error terms, the contemporaneous one, is a *lower triangular* matrix. The notable implication of "lower triangularization" of the matrix of contemporaneous coefficients is a recursive structure in the SVAR. This means that a variable is restricted from reacting contemporaneously to a shock to any variable that is ordered below it in the system, although it still allows a response after the first period has elapsed. The resulting identification scheme is thus short-run (first-period) time restrictions by imposing a recursive structure. It is evident that the ordering of variables in the VAR system matters, but the ordering is not always obvious from theory or experience. At times, a partial identification suffices if not all of the shocks in the system are under research; only some of the ordering is relevant.

It should be noted that a VAR that is identified by some scheme (and subsequently labeled a 'structural VAR' in the empirical literature) should not without reservations be treated as truly *structural*. All that the Cholesky identification does is that is forces the variance-covariance matrix to be an identity matrix (error terms to be orthogonal) and thus supplies certain values for the parameters through OLS. We still cannot ascertain what influences the 'structural shock' captures – only those of the variable where the innovation occurs or bearing influences of variables left out of the system? For this reason, Stock and Watson (2001) in fact make a distinction between structural VARs and recursive VARs; in their view "recursive VARs use an arbitrary mechanical method to model contemporaneous correlation in the variables, while structural VARs use economic theory to associate these correlations with causal relationships". In this context, the 'Wold causal chain' refers to mathematically identifying the VAR recursively and conjuring up a suitable economic theory that justifies the ordering, such that the structural VAR in fact simplifies to a recursive VAR. In its most superficial form this signifies "repackaging a recursive VAR and selling it as structural" as Stock and Watson phrase it.

My approach with the 'simple SVARs' and the 'baseline SVARs' in the following sections is indeed to identify the VAR recursively. Nevertheless, my task is simpler in the sense that I do not study the impacts of all the shocks but only the impacts of the FFR and the VIX shocks. That is, I do not need to identify the entire system: the ordering of the **bottom variables** with respect to each other does not affect the impulse responses of interest, generated by shocks in the **top variables**. Hence, I need only to argue for the ordering of the top variables with respect to each other since the bottom variables' contemporaneous reactions remain unrestricted with respect to the top ones.

4.2.1. Introducing controls – the baseline SVAR

For the 'baseline SVAR', the following structural moving average is estimated:

$$(8) \quad \begin{pmatrix} USGDP(t) \\ FED(t) \\ BRENT(t) \\ VIX(t) \\ NORGDP(t) \\ INFL(t) \\ NIBOR(t) \\ FX(t) \end{pmatrix} = \begin{pmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \\ \mu_5 \\ \mu_6 \\ \mu_7 \\ \mu_8 \end{pmatrix} + \begin{pmatrix} \theta_{11,0} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \theta_{21,0} & \theta_{22,0} & 0 & 0 & 0 & 0 & 0 & 0 \\ \theta_{31,0} & \theta_{32,0} & \theta_{33,0} & 0 & 0 & 0 & 0 & 0 \\ \theta_{41,0} & \theta_{42,0} & \theta_{43,0} & \theta_{44,0} & 0 & 0 & 0 & 0 \\ \theta_{51,0} & \theta_{52,0} & \theta_{53,0} & \theta_{54,0} & \theta_{55,0} & 0 & 0 & 0 \\ \theta_{61,0} & \theta_{62,0} & \theta_{63,0} & \theta_{64,0} & \theta_{65,0} & \theta_{66,0} & 0 & 0 \\ \theta_{71,0} & \theta_{72,0} & \theta_{73,0} & \theta_{74,0} & \theta_{75,0} & \theta_{76,0} & \theta_{77,0} & 0 \\ \theta_{81,0} & \theta_{82,0} & \theta_{83,0} & \theta_{84,0} & \theta_{85,0} & \theta_{86,0} & \theta_{78,0} & \theta_{88,0} \end{pmatrix} \begin{pmatrix} \varepsilon(USGDP,t) \\ \varepsilon(FED,t) \\ \varepsilon(BRENT,t) \\ \varepsilon(VIX,\ t) \\ \varepsilon(NORGDP,t) \\ \varepsilon(INFL,t) \\ \varepsilon(NIBOR,t) \\ \varepsilon(FX,t) \end{pmatrix} + \textstyle\sum_{i=1}^{L} \Theta_i \varepsilon_{t-i}$$

where USGDP is GDP in the U.S., FED is the Federal funds rate, BRENT is the oil price, VIX is the VIX index, NOGDP is GDP in Norway, INFL is inflation in Norway, NIBOR is the Norwegian money market rate and FX is the krone exchange rate. For a closer description, see section Data.

Table 1 in Appendix D presents information criteria tests for lag length. To obtain a somewhat consistent monetary regime throughout the sample used in the VAR, I set the sample to start from the third quarter of 1993. Having quarterly data, less than 90 observations are available, which restricts the lag length that can be chosen (over-parameterization of the model is a concern). Also, I assume that a foreign financial shock should not have a very persistent direct impact. Hence, I set the maximum allowed lag length to six periods in the lag length testing. As a result, two lags are chosen to be included in the quarterly baseline SVAR as it is the second most recommended lag length among all the criteria. Using two lags means that I allow the direct impact of the foreign financial shocks on the Norwegian economy to last a maximum of six months[18]. For comparability, I set the lag length of the monthly SVAR to six so that, again, the direct impact of the shock can last six months at most.

As for the simple SVAR, a recursive ordering (see Equation 8) is imposed in order to identify the shocks. I place the four foreign variables on top since, by the assumption of being exogenous to the Norwegian economy, they should not respond *at all* to the four Norwegian variables on bottom[19]. By this ordering, I assume that BRENT, FED and USGDP cannot react immediately to VIX. The U.S. GDP is assumed not to react on impact to anything since it is a slowly moving real economic aggregate. The assumption is more questionable, however, for the BRENT and FED which are asset prices that are updated in the financial markets on a daily basis. One could argue that the FFR mostly moves when the Federal funds target rate is adjusted, thus in about every six weeks if actions are taken, which would place the FFR below the U.S. GDP. Hence, in Appendix F, I conduct some robustness checks on the ordering of the top variables. The ordering is more of an issue for the quarterly SVARs; the ordering in the quarterly SVARs that predict a three-month delay in the reactions of the restricted variables is naturally more questionable than for the monthly SVARs.

The Norwegian variables' response in Equation 8 is thus not restricted at all with respect to shocks to the top variables. Moreover, the bottom four variables'

[18] There is some residual autocorrelation at the lag length of two, although statistically significantly only for the VIX residuals at the lags of 5 and 14, see Appendix D. The required assumptions for statistical inference are still largely valid.

[19] That is, Norway is a small enough economy to not have an impact on the top variables. For the very first period, I implicitly assume a structure of two blocks: an exogenous block of the top variables and a block of the Norwegian variables that can respond to the top block, taking output of the top block as its input.

ordering with respect to each other does not affect the results for the VIX (uncertainty) and FFR (monetary) shocks which are the only shocks under research. A distortion to the Norwegian variables' response could arise, however, when there is a shock to the VIX: U.S. GDP, the FFR and oil price are restricted from responding to it immediately, which signifies that the Norwegian variables' impulse responses in the near term do not incorporate the first-period response of the top three variables that is forced to zero. That is, the recursive ordering is mostly likely to cause distortions in the impulse responses in the near term from the shock.

How controls may enhance the simple SVAR

The simple SVAR that only contains the main variables (see specification in Appendix A) likely has defects related to simultaneity. To improve the simple SVAR, U.S. GDP and oil price are added as control variables. This is to clear the VIX and the FFR from the most important real variables that perhaps influence the foreign and the Norwegian variables simultaneously. Additionally, the FFR is included in the same VAR together with the VIX in the baseline SVAR.

Since the VIX is derived from the American stock market index S&P 500, and the American stock market certainly reacts to oil prices, the VIX is likely to react to oil prices as well. It is also known that the oil price has a substantial impact on the Norwegian economy. This is one potential issue in the simple SVAR. As oil price is correlated both with the VIX and with the Norwegian variables, not including it in the SVAR could render the model to omitted variable bias[20]. A similar reasoning applies to the U.S. GDP. Economic growth in the United States can stimulate the Norwegian GDP by boosting Norwegian exports to the United States. Economic growth can also reduce risk aversion and volatility expectations which the VIX represents. Thus, U.S. GDP is another potential source of omitted variable bias in the simple SVAR.

The Federal funds rate, in turn, is included in the baseline together with the VIX due to its correlation with the VIX as shown by Bekaert, Hoerova and Lo Duca (2013); I want to disentangle the effect of the VIX and the effect of the FFR from each other. Given that Norway is a small economy and that the VIX is derived from American stock market conditions, the VIX is ex ante assumed to be a completely

[20] Although, I already use series for Norwegian GDP and CPI-ATE that are largely cleared of oil price, which weakens the correlation link between oil and Norwegian macrovariables.

exogenous variable in the simple SVAR. Considering NIBOR's construction as clarified in section 2.2. (Equations 2 and 3), it also partly represents foreign money market conditions. As such, the ex ante exogeneity assumption of the VIX index is not reasonable because the VIX can be influenced by U.S. money market conditions that are also reflected in the NIBOR (through the U.S. interest rate therein); a shock to the VIX connected with interest rate fluctuations in the U.S. money market impacts the Norwegian economy directly through the VIX and indirectly through the NIBOR. The inclusion of the FFR into the baseline SVAR mitigates this issue since it is no longer a potential source of simultaneity.

In addition to **clearing the VIX**, inclusion of the oil price and the U.S. GDP potentially has the effect of **clearing the FFR** of supply shocks that compel the Federal Reserve to (preemptively) react and change their Federal funds target rate[21]. For example, if the Federal Reserve observes (forecasts) an adverse development in the oil price, it tries to counteract this real shock by adjusting the federal funds target rate lower, bringing the FFR also down (Romer and Romer 2004). This introduces a simultaneity problem in the simple SVAR which does not contain the oil price. An oil price shock has a direct impact to the Norwegian economy and an indirect impact through the Fed reaction to adjust the target rate. If this is the case, I get biased estimates for the impact of FFR shock on the Norwegian macrovariables, because the estimates partly reflect the influence of an oil shock to the Norwegian economy. What I am after, is the pure impact of a Federal funds rate shock (an (i) exogenous and a (ii) financial shock) to the Norwegian variables.

To summarize, the interpretation of the VIX shock and the FFR shock is closer to that of a true structural shock after the inclusion of U.S. GDP, Federal funds rate and the oil price as controls to the model (although the FFR is, of course, relevant due to its own significance as a foreign financial shock; I can equally well consider the VIX as a control variable for the FFR).

[21] New economic data – such as GDP and oil price realizations – have also the potential for changing the Fed's forecasts and induce a countercyclical target rate adjustment, even though their current levels might not call for the adjustment (Romer and Romer 2004).

4.3. High-frequency identification of U.S. monetary policy shocks – the HFI SVAR

In this section, I construct a structural VAR by utilizing monetary policy shocks that have been identified outside the model. I build two SVAR variants of the external identification method: first, a SVAR in which the externally identified monetary shock is included in the VAR *as such* as a monetary policy indicator variable (HFI SVAR) and second, a SVAR in which the externally identified monetary shock is *only used as an instrumental variable* in two-staged least squares to make another variable, a one-year government bond rate, exogenous. The exogenous one-year government bond rate is then included in the SVAR as a U.S. monetary policy indicator (IV SVAR). The second VAR, the IV SVAR is presented in Appendix G.

The purpose of this new method is to (i) address the identification issue in monetary policy shocks that is difficult to settle with the usual recursive identification strategy and (ii) secure that the monetary shock is truly exogenous. As explained earlier, having several financial variables in the baseline VAR at the same time, like the VIX and the FFR, means that I have to argue that one of them does not react on impact when the other is shocked. This is implausible as both the VIX and the FFR are based on prices that are updated daily in the financial markets and can potentially cause distortions in the impulse responses.

The high-frequency identification (HFI) literature abstracts from the recursive identification strategy of monetary shocks which often shocks the policy rate or a short-term interest rate in the SVAR and treats it as a monetary shock (in the baseline SVAR this would correspond to the FFR shock). For the SVARs in this section, I utilize HFI identified monetary shocks to attain monetary policy shocks that can be considered exogenous with respect to the other economic and financial variables in the SVAR as well as variables outside the SVAR. It follows that I can assume that the monetary shock is orthogonal to the error terms of all the other variables in the SVAR and I do not need to restrict any of the variables' contemporaneous response to a U.S. monetary shock [22]. Additionally and more

[22] Thus, I do not identify any of the other shocks in the SVAR, but this is not of interest to me. Partial identification suffices. The recursive ordering was not a major issue in the former recursive SVARs since the foreign variables were always on top, allowing Norwegian variables to react unrestrictedly to the top variables (and I only wanted to study reactions from top to bottom). Robustness checks on the baseline SVAR additionally affirmed that the ordering was not a major concern (see Appendix F).

importantly, I do not need to include control variables for the policy indicator due to influences left outside the model. I am safer in assuming that the other variables in the HFI SVAR react only to a U.S. monetary shock and not to some third variable that is absent from the model. In other words, I am more confident that I can make causal inference about the impact of a foreign financial shock to Norwegian macrovariables.

The literature that applies the HFI method in a VAR setting takes advantage of an approach that combines the strengths of two different methods; an event study that allows to extract exogenous policy movements and a structural VAR that, unlike event studies, allows to trace the dynamic responses to a monetary shock within the system. The event study extracts a shift in the short-term futures rate during a 30-minute time frame around a Federal Open Market Committee (FOMC) policy announcement. This established high-frequency identification method ensures that the measured change in Federal funds futures rate reflects only the policy change and not any other news that could move the futures rate. (Gertler and Karadi 2015, Mertens and Ravn 2013.)

Using information from outside the VAR to construct exogenous components of specific shocks was pioneered by Romer and Romer's (1989) narrative approach. It used "narratives" (outside information) to identify exogenous shocks: shocks that, typically with an error, measure the exogenous component of an endogenous shock and can replace the endogenous shock that it is correlated with. (Stock and Watson 2012, pp.16). In a regression this means that one can regress the dependent variable of interest directly on a proxy for the independent variable that is suspected to suffer from a simultaneity problem, assuming of course that the proxy itself is exogenous to the system. In the context of the HFI literature, this has meant regressing changes in asset returns directly on futures rates surprises that proxy a monetary policy indicator. This is also my approach for the first SVAR, labeled as the 'HFI SVAR'. I set the surprise in a three-month Federal funds futures rate ('Surprise in FF4', $\Delta FF4$) as the foreign financial variable of the SVAR; the specification is shown in Equation 9.

For the 'HFI SVAR', the following structural moving average is estimated:

$$(9) \quad \begin{pmatrix} \Delta FF4(t) \\ NORGDP(t) \\ CPI(t) \\ NIBOR(t) \\ FX(t) \end{pmatrix} = \begin{pmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \\ \mu_5 \end{pmatrix} + \begin{pmatrix} \theta_{11,0} & \theta_{12,0} & \theta_{13,0} & \theta_{14,0} & \theta_{15,0} \\ \theta_{21,0} & \theta_{22,0} & \theta_{23,0} & \theta_{24,0} & \theta_{25,0} \\ \theta_{31,0} & \theta_{32,0} & \theta_{33,0} & \theta_{34,0} & \theta_{35,0} \\ \theta_{41,0} & \theta_{42,0} & \theta_{43,0} & \theta_{44,0} & \theta_{45,0} \\ \theta_{51,0} & \theta_{52,0} & \theta_{53,0} & \theta_{54,0} & \theta_{55,0} \end{pmatrix} \begin{pmatrix} \varepsilon(\Delta FF4,\ t) \\ \varepsilon(GDP, t) \\ \varepsilon(CPI, t) \\ \varepsilon(NIBOR, t) \\ \varepsilon(FX, t) \end{pmatrix} + \sum_{i=1}^{L} \Theta_i \varepsilon_{t-i}$$

where ΔFF4 is the surprise in the three-month Federal funds futures rate, NORGDP is Norwegian GDP, CPI is Norwegian inflation, NIBOR is the Norwegian money market rate and FX is the krone exchange rate.

Accordingly, in Equation (9) only the coefficients in the first column are determined. The ordering of variables is arbitrary in this setting.

5. Empirical results

5.1. Impulse responses for the baseline SVAR

The graphs below show impulse responses to a one standard deviation change in the shocked variable, either the FFR or the VIX, with 68% confidence bands. Compared to the simple SVAR (see Appendix A), over-parameterization is a more serious issue in this quarterly VAR specification that includes eight variables with two lags: on the negative side, there is greater uncertainty regarding the parameter estimates which, on the positive side, are now perhaps more consistent (bias-variance trade-off). This possibly bloats the confidence bands around the median impulse responses, leading to less statistically significant estimates. Bootstrapped confidence intervals are computed using 200 replications. Impulse responses for inflation are cumulated because the series are differenced. Variance decompositions are presented in Appendix E[23].

[23] I am thankful to Ambrogio Cesa-Bianchi for sharing his superb Matlab code at his website which yielded the results.

5.1.1. Impulse responses for the uncertainty shock

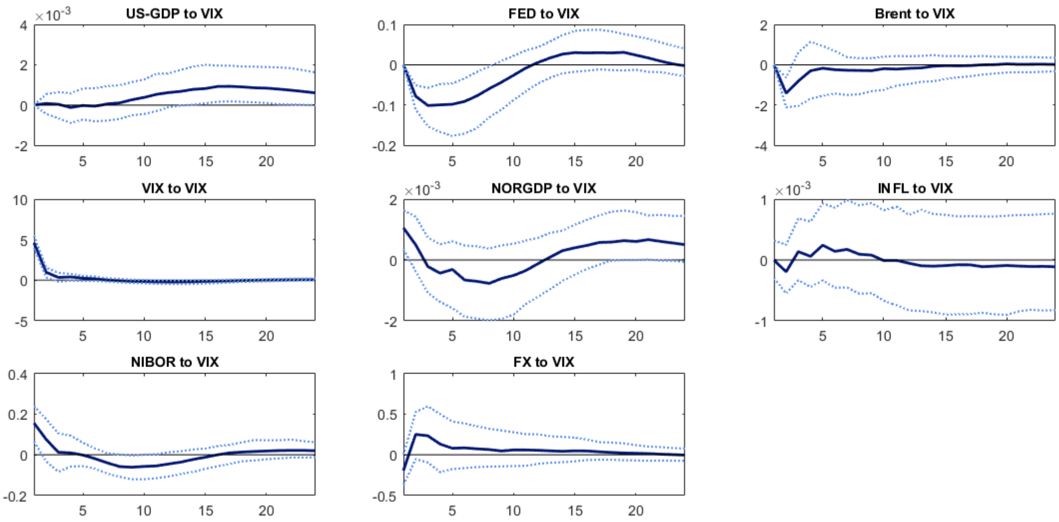

Figure 13. Quarterly baseline SVAR impulse responses for a shock to the VIX index. The FX rate is determined such that higher values indicate a depreciated krone. The time horizon is 24 periods (6 years) ahead. Quarterly data spans 1993:Q4-2015:Q4. Notation: USGDP is GDP in the U.S., FED is the Federal funds rate (FFR), BRENT is the oil price, VIX is the VIX index, NORGDP is GDP in Norway, INFL is inflation in Norway, NIBOR is the Norwegian money market rate and FX is the krone exchange rate.

Figure 13 above displays responses to a VIX shock that is about five units' increase in the index value. I focus on the response of the Norwegian variables, the last four ones, that are the most relevant for the (first part of the) research question of this master thesis: To what extent can foreign financial shocks disturb macroeconomic conditions in Norway? Not many statistically significant movements appear among the Norwegian variables (overfitting of the model is likely to be part of the reason), yet some patterns can be discerned from the point estimates.

Financial disturbances abroad (as represented by the VIX) lead the NIBOR to rise immediately about 20 basis points, perhaps due to heightened risk premia (see 'NIBOR to VIX'). This remains the maximum effect on NIBOR which reverts to the original after 3.75 years from the shock. The exchange rate ('FX to VIX'), in turn, depreciates in the short-term, indicating a lack of demand either for Norwegian goods and services or for krone-denominated assets; at least not pointing to the direction that investors treat Norway as a safe haven. I run the same SVAR again, only replacing the trade-weighted exchange rate with NOK/USD-rate (Fig.14 below) and the results remain: krone depreciates in the short-term.

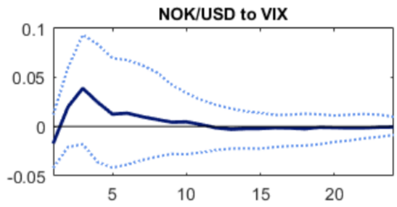

Figure 14. Impulse response of the NOK/USD exchange rate to a shock to the VIX index. The FX rate is determined such that higher values indicate a depreciated krone.

It is quite surprising that the Norwegian GDP rises on impact (see 'NORGDP to VIX'), given that the VIX shock signifies financial disturbance abroad that is likely to dampen foreign demand (although *U.S.* GDP is controlled for)[24] and one might have expected the effect to come with a lag through the NIBOR or the exchange rate – is it really plausible that Norwegian economic agents (or U.S. importers of Norwegian goods) *precipitate* their investment and consumption decisions based directly on the VIX, thus boosting the GDP? This seems hardly credible. It is also somewhat unexpected that Norwegian GDP reacts within a quarter to the VIX, considering that the GDP, in general, is a rather slow-moving economic aggregate.

Nonetheless, after the first period has elapsed, the system allows the variables to respond to the same- and past-period values of all the other variables. We observe that (i) the NIBOR rises on impact, (ii) the oil price, the price of Norway's main export article, falls and (iii) financial disturbances abroad (proxied by the risen VIX) likely reduce foreign demand. All this should work as to depress economic activity in Norway and the GDP does decline after the very beginning. The contraction of GDP together with a weak krone points to low demand for Norwegian goods besides petroleum.

Additionally, after the very short term we see a pattern that is more consistent with Bloom's (2009) and Gudmundsson & Natvik's (2012) hypothesis of investment and consumption postponements: a drop, a rebound and an overshoot in economic activity following an uncertainty shock; Norwegian economic agents (or foreign importers of Norwegian goods) delay investment and consumption decisions because they wish to wait out the uncertainty, creating pent-up demand for capital and consumption goods that accelerates economic activity after the turbulence has passed.

[24] The VIX reacts also to events that occur outside the U.S. and can be used as a proxy for a global financial factor in risky asset prices (Rey 2015), thus the scope of financial disturbance that the VIX measures has a scope beyond the United States.

Finally, the response of inflation to a VIX shock is negligible and varies around the zero-impact level ('INFL to VIX'). This occurs despite the fluctuations in the other Norwegian variables that should impact the prices. Although, the NIBOR and the FX rate exert somewhat opposing influence over the prices that could be mutually offsetting: interest rate hike dampens inflation while currency depreciation generates imported inflation.

All in all, the only barely statistically significant responses of Norwegian variables to a VIX shock (albeit at the 68% confidence level) are in the NIBOR and GDP. It seems that the Norwegian variables more or less revert to their trend at the end of the horizon of six years, which signifies that foreign financial uncertainty shocks have limited capability of disturbing economic conditions in Norway. The variance decompositions (in Appendix E in Fig. 38) point to the same direction: the relevance of the VIX in explaining variation in Norwegian variables is indeed small: the VIX explains up to about 6% of the variation in NIBOR, about 1.5-2% of Norwegian GDP and around 1% of inflation and the FX rate.

Still, the VIX shock was not of very large magnitude: only five index units which corresponds to the standard deviation of the quarterly VIX series. Figure 5 in the section 2.2.1, plotted on daily data, illustrates that much larger short-term changes have occurred historically. Like this one, bouts of uncertainty also tend to be short-lived (Bloom 2009). Hence, the shock did not supply any strain to the Norwegian economy after about six months, which might be part of the reason that the Norwegian reactions were so modest.

The most notable difference to the simple SVAR is in the response of Norwegian GDP to a VIX shock (Fig.13 compared to Fig.25 in Appendix A). The simple SVAR gave the impression that a VIX shock would unambiguously depress the Norwegian GDP. Adding the oil price and U.S. GDP as controls changed the image. This alludes to the interpretation that part of the downturn that we observed in the simple SVAR was generated by other factors than uncertainty, probably the oil price that covaries with the VIX index. The relevance of the VIX in explaining variation in Norwegian GDP has dropped after the inclusion of control variables. In the simple SVAR, the VIX explained about 3-5% of the longer-term variation in NORGDP, which fell to 1.5-2% in the baseline SVAR (compare Fig.34 to Fig.38 in Appendix E). This supports the suspicion that simultaneity might be an issue if not controlling at least for oil price, U.S. GDP and the FFR when studying the response of the Norwegian GDP to a VIX shock.

The main differences between a monthly baseline SVAR (Fig.15 below) and a monthly simple SVAR (in Fig.27 in Appendix A) is that the Norwegian IP lies rather flat, slightly above the normal level. Inflation is strikingly lower in the baseline SVAR and the fall in NIBOR is delayed. Much of the statistical significance is gone. Hence, there is less action in the Norwegian economy after the addition of controls. Therefore, one does not reach as substantial and clear-cut conclusions from the baseline SVAR as one would have from the simple SVAR.

Monthly

The results of a VIX shock for the monthly VAR in Figure 15 below differ substantially from the quarterly ones in Figure 13. Only the result for the NIBOR still holds. Most notably, Figure 15 below reveals that now the exchange rate has a distinct period of appreciation before it gradually reverts to the usual level. Keeping in mind that the industrial production (IP) index here only represents the manufacturing sector and not the entire value creation, the path of the IP rather suggests an upturn in the Norwegian economy, unlike the quarterly SVAR which predicts a more varied response in economic activity. Variance decompositions (Fig.40 in Appendix E) are similar to the quarterly ones, except that the relevance of the VIX has increased for the path of the FX rate.

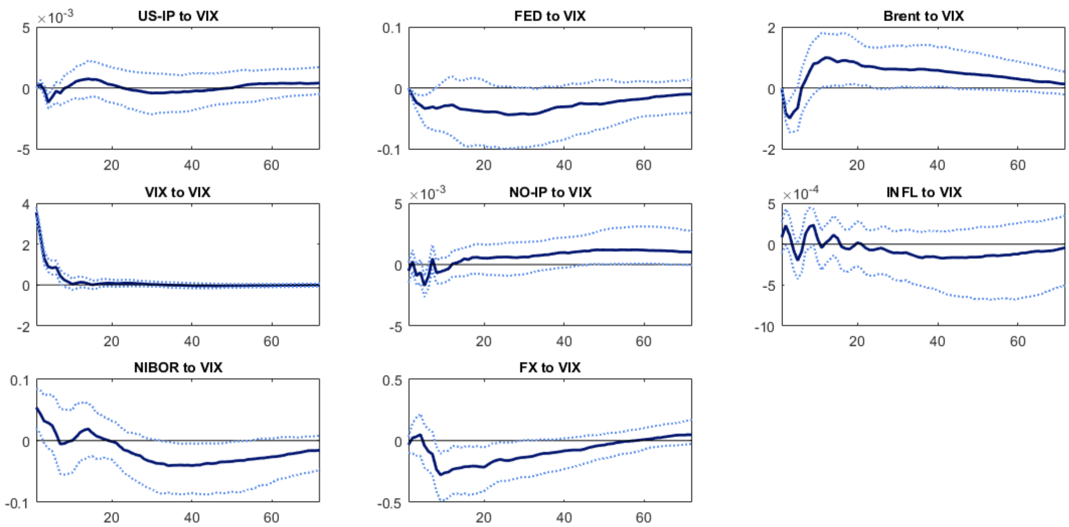

Figure 15. Monthly baseline VAR impulse response for a shock in the VIX index. The FX rate is determined such that higher values indicate a depreciated krone. The time horizon is 72 periods (6 years) ahead. Notation: US-IP is the U.S. industrial production, FED is the Federal funds rate (FFR), BRENT is the oil price, VIX is the VIX index, NO-IP is industrial production in Norway, INFL is inflation in Norway, NIBOR is the Norwegian money market rate and FX is the krone exchange rate.

To conclude with, the results on the impact of an uncertainty shock on the Norwegian economy are mixed. Basing a conclusion on the quarterly SVAR that supplies a more complete picture of economic activity than the monthly one with the IP index, the reactions are for the NIBOR's and GDP's part roughly as one might expect: financial disturbance abroad has a depressing but passing effect on the Norwegian economy. However, the predictions are very sensitive to model specification. Nothing conclusive can be said about inflation or the exchange rate; in general, quarterly SVARs predict a depreciation of krone while monthly SVARs predict appreciation (also the VARs in Appendix A and F). As it seems that control variables matter, I consider the baseline SVAR more reliable than the simple SVAR. The simple SVAR appears to exaggerate the reactions of Norwegian variables to the foreign financial shock: it is the most misleading regarding the Norwegian macrovariables: GDP or IP and inflation.

5.1.2. Impulse responses to an FFR shock

Figure 16 below displays the baseline SVAR impulse responses for a shock to the FFR (one standard deviation i.e. about 20 basis points). Again, I focus on the variables of interest: the last four ones. The Norwegian money market rate, NIBOR, is constructed as a foreign exchange swap rate against the USD LIBOR/the Kliem rate, as was shown in Equations (2) and (3) of section 2.2.2. Thus it is not surprising that the response of NIBOR is marked and statistically significant, although also lagging and hump-shaped. The maximum increase in NIBOR is approximately 20 basis points after about two years from the FFR shock[25]. The short-term response of NIBOR likely reflects the international credit channel and not domestic monetary policy actions since the short-term paths of Norwegian GDP and inflation do not give much support for monetary tightening.

[25] The Norwegian short-term interest rate rises substantially and significantly also as a response to a euro area monetary shock to Norway in Jannsen and Klein (2011). Moreover, they also find that the exchange rate (NOK per EUR) reaction to a euro area monetary shock is modest.

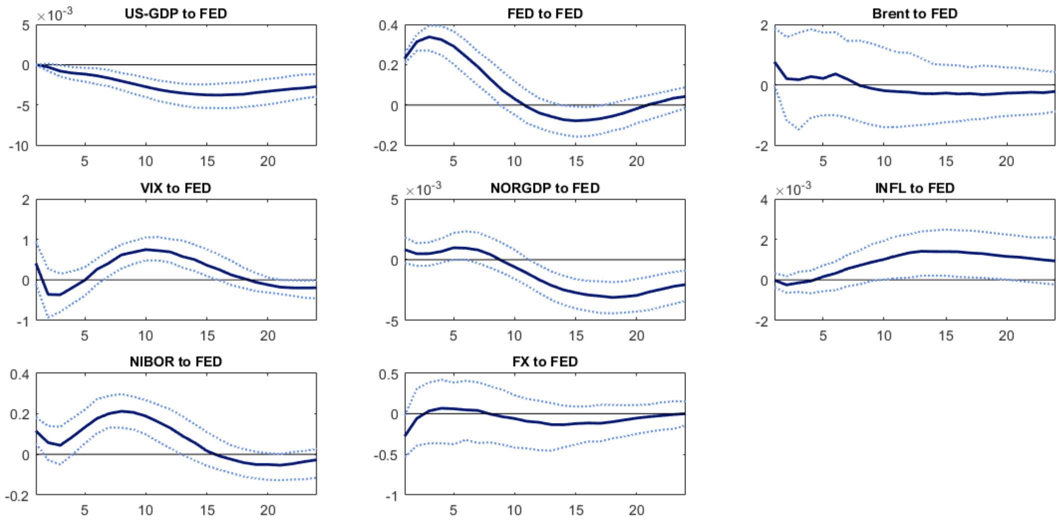

Figure 16. Quarterly baseline VAR impulse response for a shock in the Federal funds rate. The FX rate is determined such that higher values indicate a depreciated krone. The time horizon is 24 periods (6 years) ahead. Notation: USGDP is GDP in the U.S., FED is the Federal funds rate (FFR), BRENT is the oil price, VIX is the VIX index, NORGDP is GDP in Norway, INFL is inflation in Norway, NIBOR is the Norwegian money market rate and FX is the krone exchange rate.

The response of the FX rate is modest, fluctuating above and below the zero-impact line and not statistically significant. Keeping in mind that I am looking at krone's value against a basket of other currencies; the overall impact of U.S. interest rates on the aggregate value of the basket might simply be small. Switching the trade-weighted exchange rate in the baseline SVAR to the NOK/USD-rate yields naturally a larger impact, although not statistically significantly different from zero (see Fig. 17 below). The subdued impact of the FFR shock on the FX rate is rather surprising considering that theory often lifts the exchange rate channel forward as a central transmission channel of foreign shocks. However, the Norwegian interest rate level moves towards the same direction as in the U.S. which, in turn, as a center country may raise other foreign interest rates as well; international interest rates differentials may not have grown and so there is less pressure on the exchange rate to adjust by the uncovered interest parity.

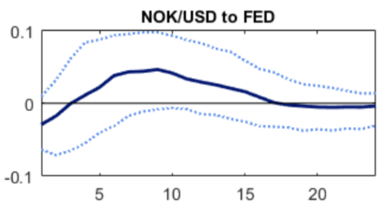

Figure 17. The impulse response of NOK/USD- exchange rate to a FFR shock. Higher values indicate a depreciated krone.

In Figure 16, a slight boost is observed in the Norwegian GDP in the short-run, although it is not quite statistically significant. As for the VIX shock, it is not clear why the GDP should react at all on impact and *rise* from its trend in the short-term, unless the response reflects an economic upturn abroad that stimulates Norwegian exports (strong foreign demand that the U.S. GDP was not sufficient to control for). The on-impact strong krone and high oil price point to that direction. In the medium-term (10-15 quarters ahead from the shock) the GDP does decline statistically significantly, which is consistent with a high NIBOR, as well as potentially weak foreign demand (U.S. GDP is below the normal level and uncertainty is above the normal).

Inflation in Norway appears to rise about five quarters from the FFR shock and is above the normal level until the end of the six-year horizon, at times even statistically significantly. Yet, the other Norwegian macroeconomic variables do not seem to back this up. One could speculate that there is inertia in inflation, such that the inflation generated by the short-lived boom continues to stay even after the GDP falls. Also, price puzzles are quite common in the empirical literature of monetary shocks in recursively identified VARs (Bjørnland and Thorsrud 2015, pp. 230). Variance decompositions displayed in Figure 39 (Appendix E) show that the FFR explains a (suspiciously) substantial share of the variation in the Norwegian GDP and NIBOR after ten quarters: 3-23% for the GDP and around 20% for the NIBOR. For the inflation and FX rate it is only a couple of percent.

Monthly

Figure 18 below shows monthly baseline results for the FFR shock. Beyond the more jagged movements that tend to be evened out in quarterly data, the results are much in keeping with the quarterly version above (Fig.16). Interestingly, the immediate responses of the NIBOR and the FX rate are near-zero, even though their contemporaneous responses vis-à-vis the FFR are *not* restricted. Being the prices of daily traded assets, these financial variables tend to be fast-moving in general. Running the SVAR again with the trade-weighted exchange rate replaced by the NOK/USD-rate reveals that there is still little response in the exchange rate during the first two years from the shock (Fig.19 below).

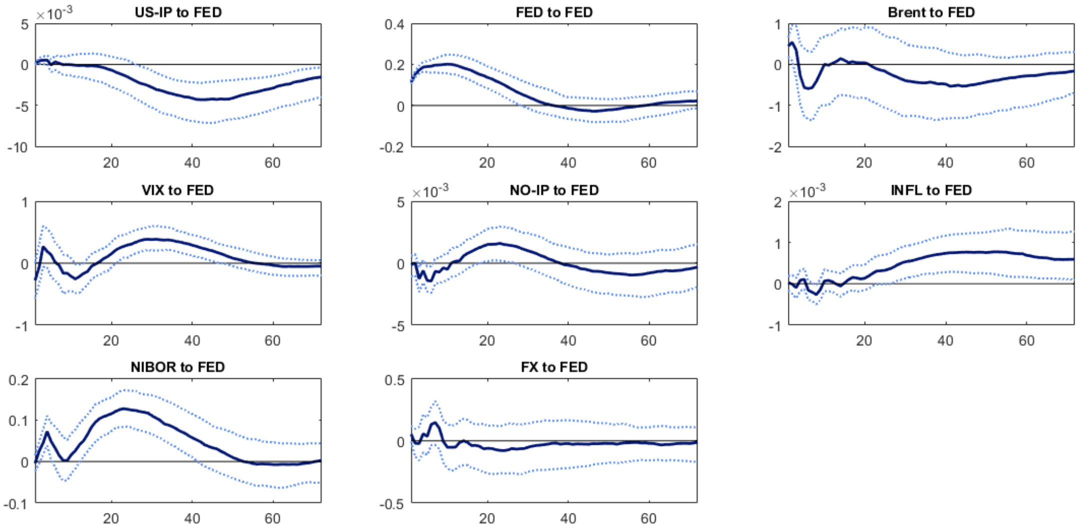

Figure 18. Monthly baseline VAR impulse response for a shock in the Federal funds rate. The FX rate is determined such that higher values indicate a depreciated krone. The time horizon is 72 periods (6 years) ahead. Notation: US-IP is the U.S. industrial production, FED is the Federal funds rate (FFR), BRENT is the oil price, VIX is the VIX index, NO-IP is industrial production in Norway, INFL is inflation in Norway, NIBOR is the Norwegian money market rate and FX is the krone exchange rate.

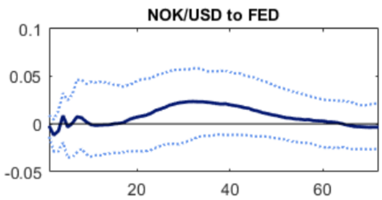

Figure 19. The impulse response of NOK/USD- exchange rate to a FFR shock.
Higher values indicate a depreciated krone.

Another exception (in Fig.18) from the quarterly results (Fig.16) is the Norwegian industrial production (NO-IP) which is now fluctuating more closely around the zero-impact line: the longer-term bust phase that was observable in the Norwegian GDP is substantially dampened in the IP. Still, the IP is not a perfect substitute for the GDP, thus the two series quite naturally differ in their reactions. One might have expected, however, that the FFR shock would spur greater reactions in the IP series which tends to be more volatile and arguably more susceptible to foreign shocks since it is largely comprised of tradable goods. The monthly variance decompositions are also similar to the quarterly ones, but for the IP series the FFR shock is much less relevant than for the GDP series.

To see whether the control variables in the baseline SVAR have achieved a difference, I compare its results to the simple SVAR (Appendix A) that contains only the main variables. Comparing impulse responses of the quarterly baseline SVAR in Fig.16 to the quarterly simple SVAR in Fig.26 (in Appendix A), adding controls does not have much impact on the path of NIBOR. Controls have achieved, however, that now the Norwegian GDP is largely depressed by the FFR shock rather than boosted. It is presumable that the boost in the simple SVAR was thus driven by other things like higher oil prices and lower uncertainty, not the FFR. Similarly, switching from the monthly simple SVAR (in Fig.28 in Appendix A) to the monthly baseline SVAR induces a general flattening in the responses. It is thus likely that endogeneity is a concern for the simple SVAR.

In sum, the impact of a U.S. monetary shock on the Norwegian economy is not unambiguously boosting or depressing economic activity in Norway. GDP/IP series do fluctuate, but the movements go in both ways. Inflation appears to be spurred for unobvious reasons. In all cases considered, reactions in the Norwegian interest rate are substantive, statistically significant and for the most part tracing the path of the FFR, which suggests that the international credit channel is influential. The response of the exchange rate is vague, inconclusive and perhaps even surprisingly small. Judging by the variance decompositions, a U.S. monetary shock exerts the greatest influence over the NIBOR and GDP among the Norwegian variables.

Again, the baseline SVAR results are much more indecisive and prudent in their predictions for the Norwegian economy than the simple SVAR. After the inclusion of control variables, a general flattening of the responses is observable. The simple SVAR is the most misleading for the GDP/IP and the FX rate, but also quite misleading for inflation.

5.1.3. Robustness of the Cholesky identified baseline SVAR

Robustness tests for the baseline SVAR are presented in Appendix F. In brief, the quarterly baseline results are not very robust to different lag lengths, most notably for the VIX shock. The ordering of variables did not prove to be a major issue in the recursive baseline SVAR.

Finally, I compare subsample (1993:M6-2007:M6) results to the complete sample for the FFR shock's part (see Fig.18 in comparison to Fig.52 in Appendix F). The impact of an FFR shock on the Norwegian variables seems to have changed over time, most notably for the financial variables NIBOR and the FX rate. In the complete sample, NIBOR's reaction is strikingly large and mostly statistically significant, unlike in the subsample. Therefore, U.S. interest rates have mattered more for Norwegian interest rates during the recent years. This likely reflects a deeper financial integration of the Norwegian financial markets, in particular the more extensive foreign operations in wholesale funding by the Norwegian financial intermediaries (see section 2.1.).

The exchange rate's reactions, too, have changed over time. In the subsample, one can observe a short-term depreciation of the krone, which is sizably diminished in the complete sample, even though a larger share of the time period in the subsample comprises of the period when Norges bank openly managed the exchange rate during the 1990s, which should bring the exchange rate reactions to the FFR shock *closer* to the zero-impact line in the subsample (note, the exchange rate is the trade-weighted index, not the NOK/USD-rate). One explanation could be that international interest rate differentials are reduced in the recent years if Norwegian interest rates follow more closely the foreign interest rates (international credit channel has become more important); interest rates adjust[26] such that there is less pressure on the exchange rate to do it.

5.2. Impulse responses for the HFI SVAR

The graphs below show impulse responses to a 5-basis-point increase in the shocked variable, the surprise in the federal funds futures rate (FF4), with 68% confidence bands. A 5-basis-point surprise in the Federal funds futures rate is a notable movement in the quarterly series but not exceptional (see Fig.4 in section 2.2.1.). Wild[27] bootstrapped confidence intervals are computed using 200 replications. Impulse responses for the FF4 and inflation are cumulated. Variance decompositions are presented in Appendix E.

The left panel of Figure 20 shows results for the **quarterly** HFI SVAR. It concludes that a U.S. monetary policy shock ideed has a short-term boosting impact and a longer-term depressing impact on the Norwegian economy. Moreover, there are elements in the impulse responses of the exchange rate channel and the international credit channel of monetary shocks and there are some statistical significance (at 68%) at least in the near-term responses.

[26] That is, interest rates co-vary with foreign rates, not necessarily through domestic policy actions (fear of floating or the like), but through the international credit channel.

[27] Wild bootstrap method is used to generate valid confidence bands under heteroscedasticity of error terms. The results were checked for the standard bootstrapped bands used in the other models, and the results were virtually identical.

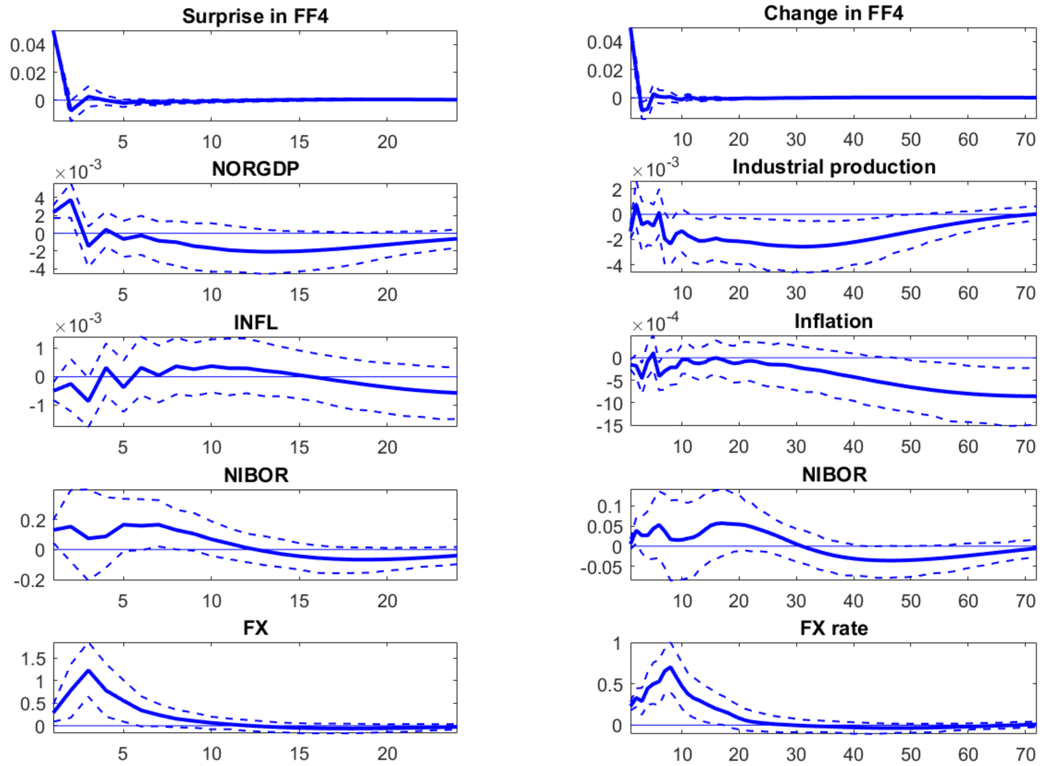

*Figure 20. Left panel: **Quarterly** HFI SVAR impulse responses for a shock to the surprise in Federal funds futures rate (FF4). The time horizon is 24 periods (6 years) ahead. The FX rate is determined such that higher values indicate a depreciated krone. Right panel: impulse responses for the **monthly** HFI SVAR. The time horizon is 72 periods (6 years) ahead.*

The exchange rate reacts on impact and it has a hump-shaped, statistically significant path of depreciation, which has disappeared after ten quarters of the shock. At highest the index value is more than one index units above the normal level. This is a considerable effect comparing to earlier results: The effect on the FX rate is strikingly different from the quarterly baseline SVAR that predicts an immediate *appreciation* of about 0.25 index units and barely any movement after that. The depreciated krone suggests that investment abroad offers a higher return, such that there are, after all, room for the expenditure-switching effects of the traditional exchange rate channel, unlike the baseline SVAR predicts.

Yet, the domestic rate of return rises as well, which mitigates the potential interest rate differential to the rest of the world: the NIBOR increases nearly 20 basis points within one period of the shock, which is a substantial effect but not far from the baseline results. This might reflect the international credit channel: funding costs in foreign currency have risen, pulling up the domestic level of funding costs. However, the increase in the domestic interest rate could as well reflect the response of domestic monetary policy actions that counter fluctuations in the domestic currency and the GDP. The NIBOR begins to fall rougly after eight quarters has passed and it goes slightly below normal level in the longer-run. In stark contrast to the previous VARs, not much of the response in NIBOR to a foreign monetary shock is statistically significantly different from zero.

The GDP is much in line with the baseline SVAR. The immediate and statistically significant upturn is puzzling but it is short-lived and turns later into a downturn. Like in the baseline SVAR, it is not clear why the Norwegian GDP should react *positively* and *on impact* to the U.S. monetary shock, especially now that the high-frequency identified monetary shock should not capture any other dynamics that simultaneously impact the Norwegian GDP, say, economic boom among Norway's trade partners. One might have expected the effect on Norwegian GDP to come delayed through the exchange rate and interest rate adjustments: The interest rate and exchange rate put opposite pressure on the GDP. It is likely that the influence of weak krone dominates, stimulating economic activity in the short-term (one can observe the expenditure-switching effects). Once the short-term depreciation of the currency has passed, the interest rate seems to influence the path of GDP and induce a downturn after about six months has elapsed. Unlike in the quarterly baseline SVAR, the downturn is barely statistically significant and the GDP reverts to normal level at the end of the six-year horizon.

Finally, inflation is slightly lower on impact, after which it is unclear and falling towards the end, but not statistically significantly different from zero. The drop in inflation is understandable in the light of a lower GDP path, although the GDP reverts to trend and inflation does not, which could indicate some inflation inertia.

Figure 21 below shows **baseline** SVAR results for a response of the Norwegian GDP and inflation to a **NIBOR shock**. It serves only as a rough guideline on how large a response a U.S. monetary shock can provoke in these two Norwegian variables compared to a domestic interest rate shock. The effects of the FF4 shock above in the HFI SVAR are at their largest close to the same magnitude as are the responses to a NIBOR shock (although the monetary shock in the HFI SVAR was more powerful than just a one-standard-deviation shock). Thus the effects of a U.S. monetary shock are certainly not trivial.

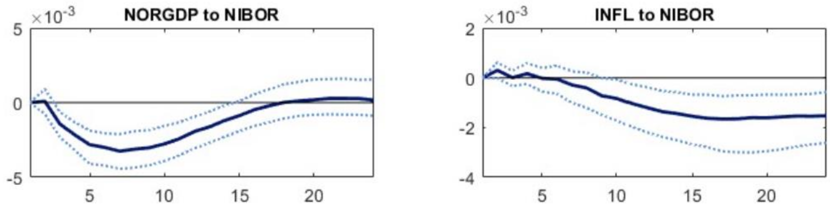

Figure 21. Impulse responses of the Norwegian GDP and inflation to a shock to the NIBOR. Estimated by the quarterly baseline SVAR.

The **monthly** HFI SVAR results in the right panel of Figure 20 are much in line with the quarterly HFI SVAR. Yet, some differences emerge. Now the immediate reaction of the NIBOR is near zero, as it was in the monthly baseline SVAR. At highest, the impact of the FF4 shock is only about 5 basis points' increase in NIBOR after two years from the shock and, all in all, hardly statistically significant. Moreover, the path of the IP is statistically significantly and almost unambiguously below the normal level; it appears that manufacturing bears much of the the brunt of U.S. monetary contraction that likely reduces foreign demand for Norwegian goods. The long-term fall in inflation is of the same magnitude as in the quarterly VAR but also statistically significant.

Variance decompositions (Figures 39 and 40 in Appendix E) reveal that a U.S. monetary shock is the most relevant for variation in the exchange rate: it explains up to 10% of variation in the quarterly HFI SVAR specification and 20% in the monthly. This a dramatic difference to the baseline SVAR. For Norwegian GDP and NIBOR, in turn, the relevance of U.S. monetary policy has clearly dropped from the baseline SVAR.

Appendix F provides robustness test results for the HFI SVAR: changing lag length yields qualitatively similar results, although magnitudes and timings are somewhat changed. Excluding the post-2007:M6 period does not bring any notable changes in the monthly HFI SVAR, but the reduction in volatility does improve slightly the accuracy of impulse responses for some variables by bringing the confidence bands closer to the median line.

In conclusion, the results vary considerably from model to model. I regard the HFI SVAR results in Figure 20 as the main results for a foreign monetary shock for the reason that I can be fairly confident that the HFI shock does not capture other events than monetary actions. Altough the ordering was not a major issue in the recursively identified VARs in this thesis, simultaneity is a concern and makes structural interpretation unreliable. One cannot be sure of what the recursively identified monetary shocks capture. For this reason, I plot the structural shock series of the baseline and the HFI SVARs to see how closely they match each other. Figure 22 below presents the structural shock series as computed by the baseline SVAR equation and the HFI SVAR equation (quarterly versions). As the figure makes apparent, the shocks trace each other but are not quite the same; the contemporaneous correlation between the series is 0.4941. Figure 23 further plots the cross-correlations between the two structural shock series for twenty leading and lagging values: correlation is the highest between contemporaneous values.

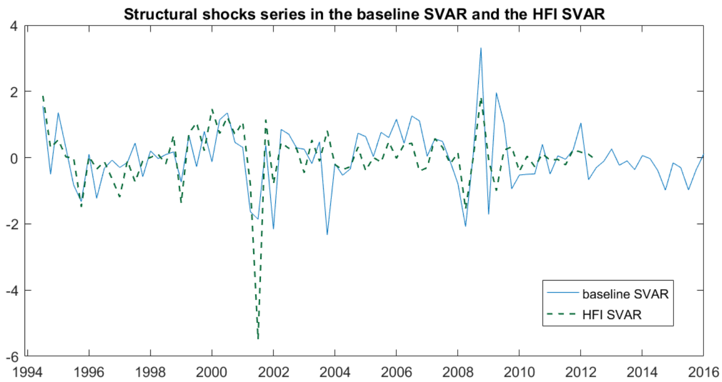

Figure 22. The structural shock series according to the quarterly baseline SVAR and the quarterly HFI SVAR.

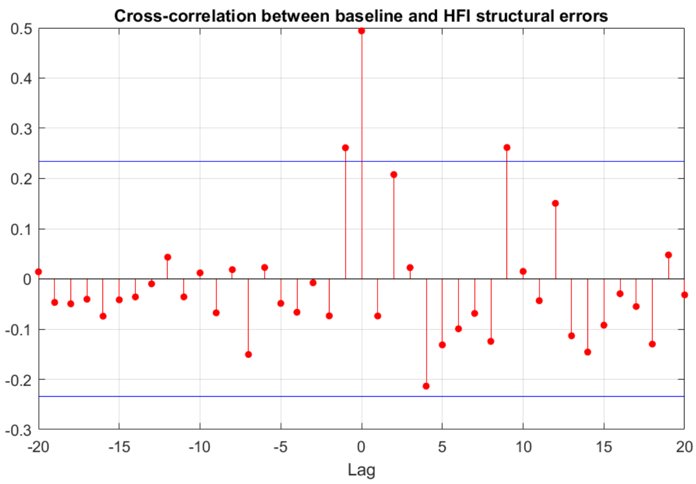

Figure 23. Cross-correlations of the structural shock series (baseline SVAR and HFI SVAR).

6. Implications – the Trilemma

One of the key implications of the Mundell-Fleming model is the 'impossible trinity' of attainable monetary policy objectives (also known as the 'Mundellian trilemma', among others). It states that a floating exchange rate should isolate an economy from foreign shocks, allowing the economy that lets its currency float to obtain both monetary independence and an open capital account. Rey (2015, 2016) puts into question the validity of the trilemma. In her view, the fact that international financial shocks can govern an economy's asset price- and credit cycles, despite a floating exchange rate regime, alludes to the break-down of the impossible trinity. She suggests that the trade-off of objectives is rather a dilemma: a floating currency is not sufficient to guarantee monetary independence in the context of free capital mobility, so an economy that aims for monetary autonomy should additionally introduce capital controls. She describes the trade-off between monetary independence and free capital movements as the 'irreconcilable duo'.

Many economists partly concur with Rey's criticism of the trilemma on the one hand admitting that complete insulation from foreign shocks is not achieved through a currency float, while on the other hand noting that the flexible exchange rate regime remains an important tool for allowing peripheral central banks to stabilize their economies when foreign shocks buffet the economy (Aizenman, Chinn & Ito 2015, Shambaugh & Klein 2013, Obstfeld, Shambaugh & Taylor 2005, Obstfeld 2015[28], to name only a few). Frankel (2016) asserts that only a model that assumes away financial integration may predict that a floating exchange rate *completely* insulates a country from foreign shocks: Trade surpluses and deficits are the traditional channel of international transmission of shocks. In the absence of private capital flows and official reserve transactions, the exchange rate adjusts as to keep the trade balance at zero, thus "absorbing" the shock.

Frankel (2016, pp.26) proposes that the relevant question to ask about monetary autonomy is not whether a monetary policymaker can remain passive after being hit by a foreign shock. It is whether the policymaker can "attain its policy objectives as well as before the shock, *after adjusting their policy settings in response to the shock"*. Ammer et al. (2016) also point out that there is "nothing in Rey's analysis that precludes a central bank with floating exchange rates from taking independent actions

[28] More specifically, Obstfeld 2015 finds that floating regime central banks have a substantive independent control over short-term rates, whereas the long-term rates are more correlated with the base country.

to offset the undesired effects on domestic financial conditions of foreign shocks". Therefore, assuming a world that is more financially evolved and integrated than the Mundell-Fleming world, it is quite natural to expect foreign shocks to evoke domestic monetary responses, with the important distinction that these responses need not imitate the movements of foreign central banks but instead follow the central banks' own domestic monetary objectives.

Obstfeld (2015) concludes that the trilemma remains valid although its trade-offs have worsened along with financial integration; besides macroeconomic stabilization (of inflation and output), the policymaker needs to account for financial stability to an increasing degree when foreign financial flows are substantial to the economy. Flexible exchange rates almost never provide full insulation against foreign shocks but they provide room for maneuver in adapting to them. Hence, flexible exchange rates have potential to provide monetary independence in the sense that the policymaker has ability to pursue a range of policy goals, albeit not reaching all of them in full all the time. Klein and Shambaugh (2013) also stress that countries can choose to pursue middle ground policies instead of the extreme solutions in the corners.

Therefore I ask: Has a floating krone provided Norwegian monetary policy room for maneuver when hit by a foreign shock – or does the policy rate imitate that of the Federal Reserve? Exactly how flexible has the flexible inflation targeting framework of Norges Bank been?[29] In the literature, the question of monetary autonomy has often been studied by regressing the domestic policy rate on the center country policy rate (Rey 2016). In a VAR setting I can regress the domestic policy rate against the foreign one, as well as a few other variables that the domestic policy rate might react to, and I can observe the dynamic responses within the system in the form of impulse responses.

Hence, to see how the Norwegian policy rate responds to a contractionary U.S. monetary shock, I run the HFI SVAR again (I believe it is the most reliable of all the models). I make two adjustments to it: I switch the NIBOR to the sight deposit rate which is Norges Bank's key policy rate, and I crop the sample to start from March 2001 which is when the primary policy objective officially became inflation targeting. Thus the time series span from 2001:M3 to 2012:M6 (136 observations in the monthly data). Further, this period coincides with increasing

[29] See section 2.1. for Norges Bank's policy objectives.

financial flows through the foreign operations of Norwegian financial intermediaries. Due to the shortness of the sample, I estimate only the monthly version of the VAR, although it means that I cannot use the GDP which I prefer over the IP.

The impulse responses are displayed in Figure 24 below. The response of the policy rate (sight deposit rate) to a contractionary U.S. monetary shock is a statistically significant drop of about 25 basis points one year after the shock, although the immediate response is zero (note, none of the Norwegian variables are restricted). This likely reflects the over one month frequency with which the policy rate is adjusted. The trajectory of the policy rate matches quite well the trajectories of inflation and industrial production. Moreover, the policy rate does not appear to try to manage the krone depreciation (it is not a case of fear-of-floating). With the exception of the inflation (that generally tends to have high persistence in the different models that has been estimated in this thesis), the Norwegian variables revert to their trend.

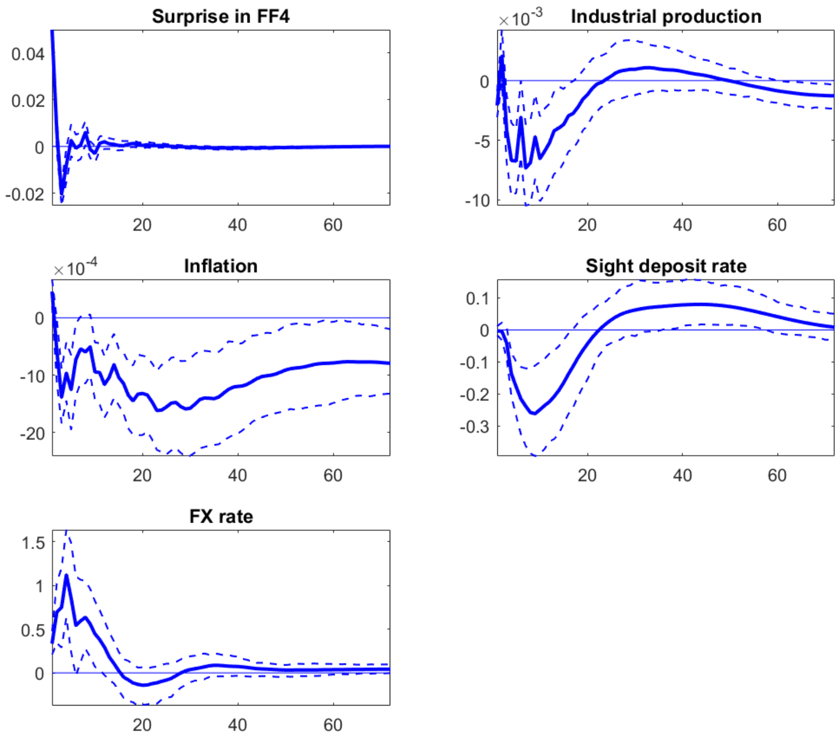

Figure 24. Impulse responses, with 68% confidence bands, for the HFI SVAR to study the Norwegian monetary policy response to a U.S. monetary shock. The FX rate is determined such that higher values indicate a depreciated krone. The time horizon is 72 periods (6 years) ahead.

This leads me to infer that Norwegian monetary policy responds to the U.S. monetary shock out of domestic commitments; the policy rate does respond to the foreign monetary shock but most likely as a reaction to the domestic macroeconomic variables that it is to influence within its mandate, not due to activist policy of managing the external value of the currency. A floating domestic currency endows monetary policy with liberty to focus on domestic macroeconomic needs. According to Frankel's (2016) interpretation of monetary independence, the results point to the direction that Norges Bank possesses capacity to "attain its policy objectives as well as before the shock (Norwegian variables mostly revert to their trend after the shock), *after adjusting their policy settings in response to the shock".* The inference here only applies to monetary independence vis-à-vis the U.S. Federal Reserve policies. Considering that krone previously was pegged to the ECU, results could differ vis-à-vis the European Central Bank actions.

7. Conclusion

This master thesis aimed to provide an answer to the question: To what extent can foreign financial shocks disturb macroeconomic conditions in Norway, and what does this suggest for monetary policy independence? To provide an answer to this question, several structural vector autoregressions were run. The results were mixed and sensitive to model specifications, indicating that simultaneity is difficult to exclude and results should thus be treated with caution. The results are as reliable as the identification scheme of the structural shocks, which pointed to different directions in many of the cases. Some specifications were, however, more credible than others.

A foreign financial uncertainty shock, as represented by a spike in the VIX index, has limited capacity to disturb the macroeconomic performance of the Norwegian economy: Most of the results are statistically insignificant and inconclusive, varying from one model specification to the other. The most substantial, statistically significant and robust reaction is in the NIBOR which shoots up on impact from the VIX shock (5-20 basis points, depending on model specification). The results provide a cautious affirmation of previous theoretical and empirical work on the impact of uncertainty on economic activity, which in this paper is shown to reach an international effect, that is, the domestic GDP drops and rebounds due to foreign financial turmoil, although a puzzling and statistically significant initial upturn is also observed. Moreover, not much of it were statistically different from zero.

A monetary shock in an influential economy to the world finance, the United States, has the potential to evoke more notable and statistically significant short-term responses in the Norwegian macroeconomy: The Norwegian short-term interest rate moves in parallel direction with the U.S. short-term rate. The channels of this impact are likely to have varied over the years as exchange rate targeting of Norwegian monetary policy has lost significance since the 1990s and integrated capital markets have made the domestic credit conditions more susceptible to foreign influences since the 2000s.

The external value of the krone falls as a response to the U.S. monetary shock, which empowers also the more traditional international monetary transmission channels to operate and induce expenditure-switching effects on Norwegian exports. By the variance decompositions, U.S. monetary actions are the most relevant for the variation in the exchange rate among the Norwegian variables, explaining over 10% of it in the medium- and long term.

A pattern emerges for Norwegian economic activity: There is a surprising, statistically significant and a robust initial expansion in the Norwegian GDP as a response to the U.S. monetary shock which later on turns into a less robust and statistically significant downturn. Moreover, the short-term boost to GDP is observable in **all** of the quarterly SVAR specifications (simple SVAR, baseline SVAR, HFI SVAR and the IV SVAR), including in the different robustness tests.

Thereby, the analysis comes to the conclusion that foreign financial shocks matter for Norway to a nontrivial extent, yet generally their influence is passing and the Norwegian variables under study, the GDP/industrial production, inflation, interest rate and exchange rate, tend to revert to their trends. Foreign monetary shocks appear to matter more for the Norwegian business cycle than foreign uncertainty shocks. The scope of this thesis is limited but it does suggest that Norwegian business cycles are partly driven by the global financial cycle, given the interpretation that the cycle is driven by the United States. While the FFSs are influential for the Norwegian economy, the domestic central bank seems pursue a policy determined by internal macroeconomic conditions, as allowed by the flexible exchange rate regime.

Further research could benefit from verifying whether the results are similar to shocks from other center economies that are likely to exert influence over the

Norwegian economy, such as the euro area[30]. A larger-scale VAR could be more successful in revealing and disentangling the different channels of impact at play and relax the over-fitting problem that leads to many insignificant estimates. The theoretical setting of a center economy and a periphery economy suggests that a block-exogenous VAR, a "SVAR-X", could be appropriate as well. Financial variables are likely to play an increasingly important role for the transmission of these shocks to macroeconomic outcomes, although research that incorporates them is restricted by the publically available data.

[30] Although, the subject is not undiscovered in the empirical research: Jannsen and Klein (2011) study the impact of euro area monetary shocks to Norway. Beyond monetary shocks, European financial uncertainty shocks could be studied; e.g. the European VSTOXX index (EURO STOXX 50 Volatility) could easily replace the VIX index.

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Appendix

Appendix A. The simple SVAR.

Two sets of structural VARs are estimated, labeled as 'the simple SVAR'. The recursive structure in its moving average form is as in Equation (10).

$$(10) \qquad \begin{pmatrix} EXO(t) \\ NORGDP(t) \\ INFL(t) \\ NIBOR(t) \\ FX(t) \end{pmatrix} = \begin{pmatrix} \theta_{11,0} & 0 & 0 & 0 & 0 \\ \theta_{21,0} & \theta_{22,0} & 0 & 0 & 0 \\ \theta_{31,0} & \theta_{32,0} & \theta_{33,0} & 0 & 0 \\ \theta_{41,0} & \theta_{42,0} & \theta_{43,0} & \theta_{44,0} & 0 \\ \theta_{51,0} & \theta_{52,0} & \theta_{53,0} & \theta_{54,0} & \theta_{55,0} \end{pmatrix} \begin{pmatrix} \varepsilon(EXO,\ t) \\ \varepsilon(NORGDP,t) \\ \varepsilon(INFL,t) \\ \varepsilon(NIBOR,t) \\ \varepsilon(FX,t) \end{pmatrix} + \sum_{i=1}^{\infty} \Theta_i \varepsilon_{t-i}$$

where EXO is the foreign variable of interest (either the VIX index or the Federal funds rate), GDP is Norwegian GDP, INFL is Norwegian inflation, NIBOR is the Norwegian money market rate and FX is the krone exchange rate. For a closer description, see section Data.

Two lags are chosen to be included in the quarterly simple VAR for comparability. Also, two is a number that can be justified considering the lag length criteria, see Table X in Appendix A. For comparability, 6 lags are chosen for the monthly simple SVAR.

Empirical results for the simple SVAR

The graphs below show impulse responses to a one standard deviation change in the shocked variable, with 68% confidence bands. Bootstrapped confidence intervals are computed using 200 replications. The CPI series is log-differenced and the impulse responses for the resulting inflation series are cumulated. In section 4.2.2.2. I switch the Norwegian GDP series to the Norwegian Industrial Production Index to attain monthly series on all variables. Variance decompositions are graphed in Appendix E.

Quarterly results

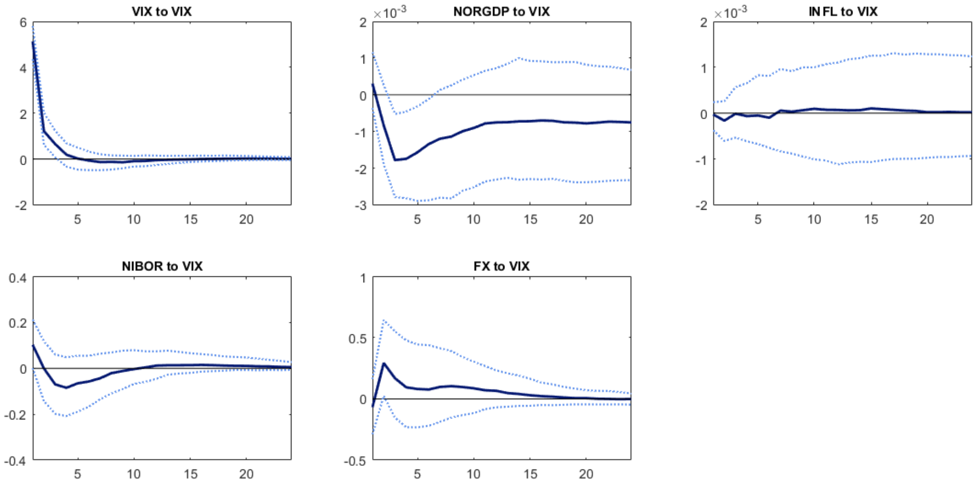

Figure 25. Simple SVAR impulse response for a shock to the VIX index. Notation: VIX is the VIX index, NORGDP is the Norwegian GDP, INFL is Norwegian inflation, NIBOR is the Norwegian money market rate and FX is the krone exchange rate. The time horizon is 24 periods (6 years) ahead.

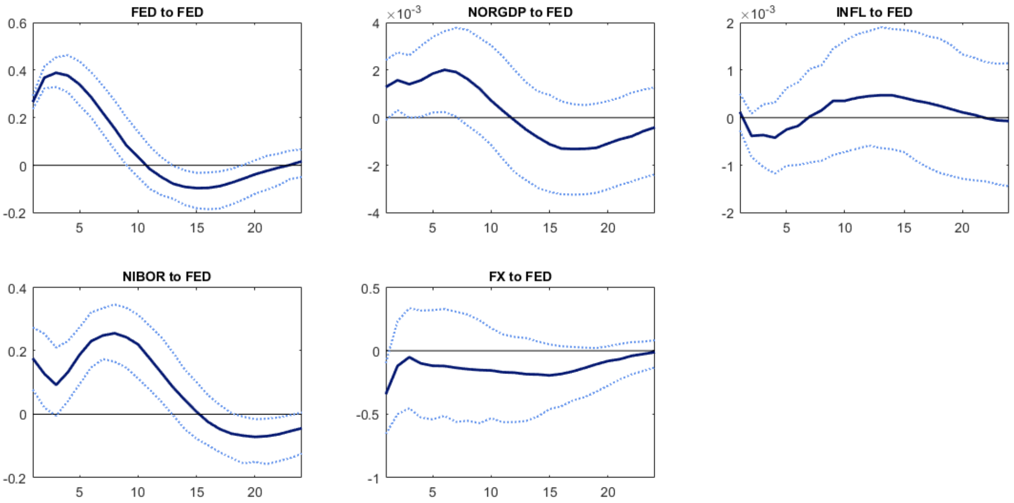

Figure 26. Simple SVAR impulse response for a shock to the Federal funds rate. Notation: FED is the Federal funds rate, NORGDP is the Norwegian GDP, INFL is Norwegian inflation, NIBOR is the Norwegian money market rate and FX is the krone exchange rate. The time horizon is 24 periods (6 years) ahead.

Monthly results

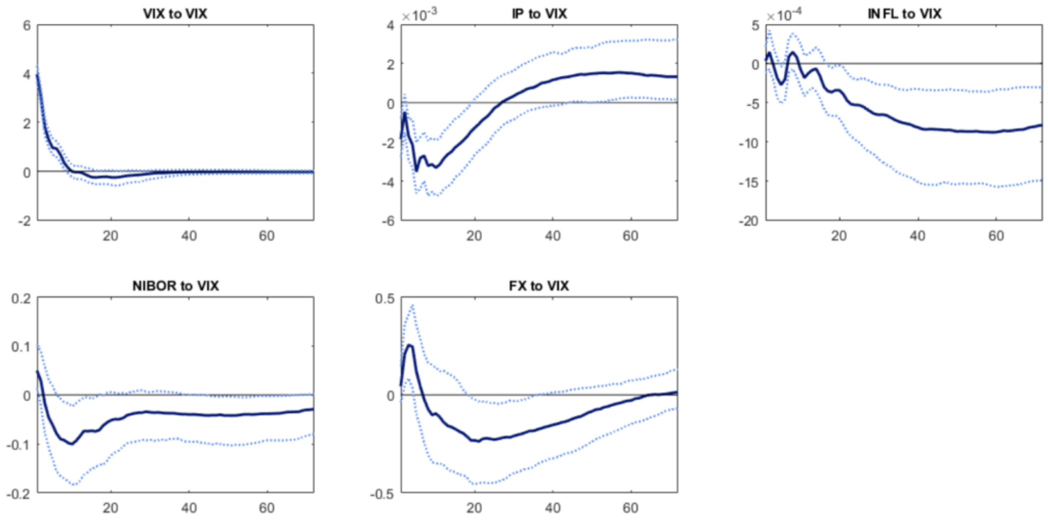

Figure 27. Simple SVAR impulse response for a shock to the VIX index. Notation: VIX is the VIX index, IP is the Norwegian Industrial Production Index, CPI is Norwegian CPI-ATE series, NIBOR is the Norwegian money market rate and FX is the krone exchange rate. Natural logarithms are taken of the IP and CPI series. The time horizon is 72 periods (6 years) ahead.

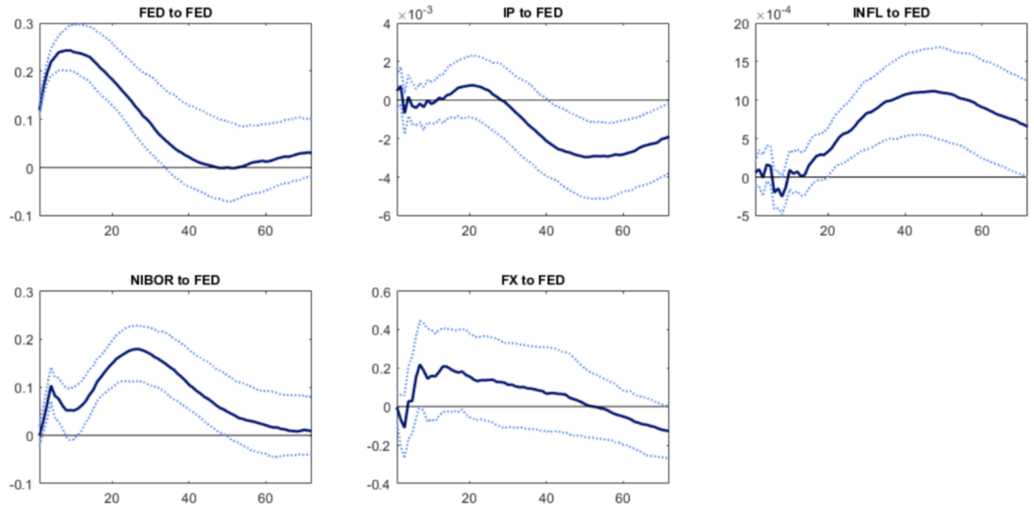

Figure 28. Simple SVAR impulse response for a shock to the Federal funds rate. Notation: FED is the Federal funds rate, IP is the Norwegian Industrial Production Index, CPI is Norwegian CPI-ATE series, NIBOR is the Norwegian money market rate and FX is the krone exchange rate. Natural logarithms are taken of the IP and CPI series. The time horizon is 72 periods (6 years) ahead.

Appendix B. Additional data information.

Control variable data

U.S. GDP: Seasonally adjusted, in billions of chained 2009 dollars (USD). Quarterly data 1990:Q1-2015:Q4. Source: U.S. Bureau of Economic Analysis.

U.S. IP: U.S. industrial production index. Seasonally adjusted, only manufacturing series as classified by the NAICS. Base year: 2012, Monthly data 1990:M1-2016:M3. Source: Federal Reserve bank of St. Louis.

Oil price: Global price of Brent crude oil in dollars. Quarterly data 1990:Q1-2016:Q1. Source: International Monetary Fund through Federal Reserve bank of St. Louis.

Data transformations

Since I only have quarterly data on the GDP series until 2015:Q4, I must transform the other series to quarterly and omit the latest values that do not add up to a full quarter yet (all values within 2016) to obtain the same number of observations for all of the time series (104 observations). Krone has been a de facto floating currency since Norges Bank let go of the peg to ECU late 1992 and took on other monetary policy objectives aside exchange rate targeting, whilst it committed to inflation targeting in year 2001. To obtain a somewhat consistent monetary regime throughout the sample used in the VAR, I crop the sample to start from the third quarter of 1993, which leaves me with 90 observations in the quarterly VARs. I take natural logarithm of Norwegian and U.S. GDP and log-difference CPI-ATE so that I obtain an inflation rate (I could also use the log-CPI-ATE in levels, but this often leads to an unstable VAR). Differencing the logged CPI-ATE series means that the first observation is lost, thus the number of observations is 89 before taking lags and the quarterly series start at 1993:Q4. For the monthly VARs I have 270 observations from 1993:M7 to 2015:M12 and differencing the CPI series leaves me with 269 before taking lags, which of course means losing more observations.

Data for the monthly HFI SVAR spans from 1993:M7 to 2012:M6 because the surprise in the Federal funds futures rate is available only until 2012:M6. Hence, for the monthly HFI VAR I have 227 observations after differencing the CPI-ATE series and before taking lags. For the quarterly HFI VAR this means 75 observations after differencing, before lags.

Appendix C. A technical summary of a vector autoregression

Structural VAR and reduced from VAR

The structural form of the VAR is given by:

$$(11) \qquad \boldsymbol{A}\boldsymbol{Y}_t = \boldsymbol{c} + \sum_{j=1}^{p} \boldsymbol{C}_j \boldsymbol{Y}_{t-j} + \boldsymbol{\varepsilon}_t$$

*where Y_t is a vector of independent variables, A and C_j are coefficient matrices, **c** is a vector of constants and ε_t is a vector of structural white noise shocks.*

It is the unknown structural form that I wish to estimate. However, the parameters in Equation (3) are not identifiable as such, so I need to work with the reduced form VAR first. Multiplying both sides of Equation (3) by $\mathbf{A}^{-1}$ yields the reduced form of the VAR:

$$(12) \qquad \boldsymbol{Y}_t = \boldsymbol{v} + \sum_{j=1}^{p} \boldsymbol{B}_j \boldsymbol{Y}_{t-j} + \boldsymbol{u}_t$$

with the corresponding variance-covariance matrix:

$$(13) \qquad E[\mathbf{u}_t\mathbf{u}_t`] = E[\mathbf{u}_t\mathbf{u}_t`] = E[\mathbf{A}^{-1}(\mathbf{A}^{-1})`] = \boldsymbol{\Sigma_u}$$ which is unlikely to be an identity matrix.

where $B_j = \boldsymbol{A}^{-1}\boldsymbol{C}_j$, $\boldsymbol{v}$ is a vector of constants and $\boldsymbol{u}_t$ is a vector of reduced form errors, that is, a linear combination of the structural errors $\boldsymbol{u}_t = \boldsymbol{A}^{-1}\varepsilon_t$.

The reduced form VAR is a system of equations that one can estimate by simply running an ordinary least squares (OLS) regression, equation by equation, which will give estimates for $\mathbf{v}$, $\mathbf{u}_t$ and the parameters in $\mathbf{B}_j$. Yet, to identify the structural errors within $\mathbf{u}_t$, one has to impose restrictions on the inverse matrix $\mathbf{A}^{-1}$. In this master thesis, two identification strategies are used. They are explained in sections 4.2. and 4.3.

After imposing restrictions on the $\mathbf{A}^{-1}$, I have identified the structural errors $\boldsymbol{\varepsilon}_t$. Hence, I have a structural VAR (SVAR). SVARs can be used to make causal inference of the impact of a shock on some variables. To see the impact of a structural shock, I need to compute the SVAR's impulse responses and variance decompositions. For this purpose, I need the structural moving average (MA) form of the VAR. I arrive at the MA form after first ensuring that the VAR in Equation (4) is stable. This is the case, if the eigenvalues of matrix $\mathbf{B}$ are less than one in absolute value.

Stationarity and stability of the VARs

A stable VAR is covariance-stationary: any given shock will eventually die out. Fortunately, stability of the VAR does not require that all the individual time series are stationary. Due to cointegrating relationships, a stationary VAR can be achieved from nonstationary individual time series. Hamilton (1994, pp. 579-582) explains that the cointegrating relationships between variables that are integrated of order one and cointegrated will be implicitly determined in the unrestricted VAR where each endogenous variable is regressed on the lags of itself and of all the other variables (Bjørnland and Thorsrud 2015, pp. 273). These variables can be estimated in levels using the OLS. This is a desirable feature in VARs that prevents one from making data transformations (differencing, filtering etc.) that result in losing information.

None of my time series seem stationary by visual inspection, except perhaps for the krone exchange rate (see section Data). Some of the series appear to be trending deterministically up (GDP series/IP series and CPI-ATE) or down (interest rates). The VIX and NIBOR seem to have transitory breaks, whereas the Federal funds rate and Brent crude-oil series have breaks in level-shifts. This is, however, not an issue in the VARs since the break point in the NIBOR series is cut out when the series is cropped at mid-1993. Monthly and quarterly series are considerably less volatile, for example, as the VIX is converted to quarterly data by taking three-month averages, the spike in approximately 2009 is dampened (Fig. 29). The log-differenced CPI-ATE series appear to be stationary as well (Fig. 30).

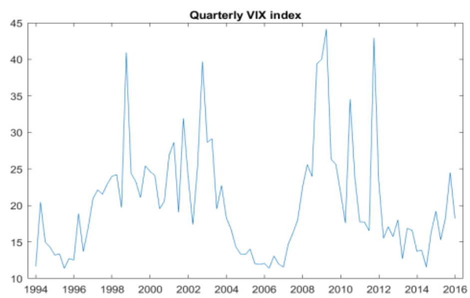

Figure 29. The Quarterly VIX index. 1993:Q4-2015:Q4.

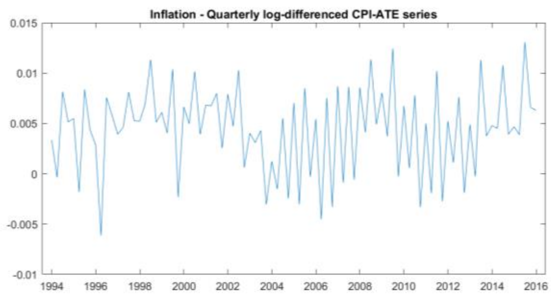

Figure 30. Inflation series. 1993:Q4-2015:Q4.

Despite the nonstationary series of variables, the reduced form VAR is stable for all the VARs that will be estimated. Accordingly, the largest eigenvalue of the reduced-form coefficient matrices are less than one[31]. Hence, they are invertible and the structural moving average (MA) representation of the VAR can be derived.

MA form, impulse responses and forecast error variance decompositions

The structural moving average form of the VAR is given by:

$$(14) \qquad Y_{t+s} = \boldsymbol{\omega} + \sum_{j=0}^{\infty} \boldsymbol{\Theta}_j \, \boldsymbol{\varepsilon}_{t+s-j}$$

Where ω is a vector of constants, Θ is a matrix of the structural MA coefficients for the structural shocks vector ε.

It is in their structural MA forms that I present the different SVARs that I estimate in later sections. The results from structural VARs are typically reported as impulse responses and forecast error variance decompositions. One can find the impulse responses from the coefficient matrix Θ_j. Using the simple SVAR of Equation 17 (Appendix A) as an example, the contemporaneous response of 'FX'-variable to a shock in 'EXO'-variable would be:

$$(15) \qquad \theta_{51,0} = \frac{\partial FX(t)}{\partial \varepsilon(EXO,t)}$$

Impulse responses, that one gets from simulating the structural MA equations, trace out the response of current and future values of each of the variables to a change in the current value of one of the structural errors, assuming that this error returns to zero in the periods ahead and that all other errors are equal to zero. The simulated impulse works through the SVAR system with the coefficients estimated from actual data. (Stock and Watson 2001.)

The *forecast error variance decomposition* (FEVD, 'variance decomposition' for short) is the percentage of the variance of the error made in forecasting a variable (mean square error, MSE) due to a specific shock (in variable m) at a given horizon (s steps ahead)":

[31] Maximum eigenvalues for the baseline SVAR: 0.9920 for the quarterly version and 0.9952 for the monthly. Maximum eigenvalues for the HFI SVAR: 0.9918 for the quarterly version and 0.9986 for the monthly.

$$(16) \qquad \text{FEVD} = \frac{Cumulated\ squared\ coefficients\ in\ \Theta\ for\ the\ m{-}th\ column,\ \ s\ steps\ ahead}{MSE}$$

In other words, the FEVD reports how much of the forecast error variance (MSE) is due to variability in the structural shock. Despite the name, variance decompositions are informative also when the VAR is used for other purposes than (out-of-sample) forecasting, considering that the impulse responses are in essence an in-sample forecast of the impact of a shock. Hence, the FEVD is akin to a partial R^2 for the forecast error, given a forecast horizon. (Stock and Watson 2001, pp. 106, Bjørnland and Thorsrud 2015, pp. 225-226.)

Appendix D. Lag selection criteria and residual autocorrelation test

Lag selection

Table 1 shows that Akaike information criterion (AIC) recommends six lags, while Schwarz (BIC) and Hannan-Quinn (HQC) information criteria recommend only one lag for the simple SVAR. Two lags is a good compromise since it is the second most recommended lag length for all the criteria. All in all, a lag length of two for the quarterly VAR and six for the monthly VAR is chosen, firstly, based on the information criteria; secondly, to avoid over-parameterization in the quarterly VAR (less than 90 observations were available); and thirdly, by the assumption that foreign monetary and uncertainty shocks should not have a very persistent direct impact. The VAR models should also be comparable, and a lag length equivalent to six months' time is justifiable across the models.

Baseline SVAR

	AIC	BIC	HQC
1	-2.5214	-0.4232	-1.6785
2	-2.8494	1.114	-1.2571
3	-2.7984	3.0301	-0.4568
4	-2.8315	4.8622	0.2594
5	-2.5049	7.0539	1.3353
6	-3.2015	8.2224	1.388

	AIC	BIC	HQC
1	-6.5343	-5.5054	-6.12
2	-7.1403	-5.1967	-6.3576
3	-7.2828	-4.4246	-6.1318
4	-7.3156	-3.5429	-5.7963
5	-7.202	-2.5146	-5.3144
6	-7.1007	-1.4987	-4.8447
7	-7.0925	-0.5758	-4.4682
8	-7.058	0.3733	-4.0654
9	-7.1039	1.2419	-3.743
10	-7.0935	2.167	-3.3643
11	-7.0898	3.0853	-2.9923
12	-7.2843	3.8054	-2.8184
13	-7.2672	4.7371	-2.4331

14	-7.2117	5.7072	-2.0093
15	-7.1089	6.7247	-1.5381
16	-7.2561	7.4921	-1.317
17	-7.0846	8.5782	-0.7772
18	-7.1833	9.3941	-0.5076
19	-7.3035	10.1885	-0.2595
20	-7.3382	11.0684	0.0741
21	-7.6021	11.7191	0.1785
22	-7.9496	12.2862	0.1994
23	-8.5679	12.5826	-0.0506
24	-9.3851	12.68	-0.4995

Table 1. Lag length selection criteria for the baseline SVAR. Left panel: the quarterly baseline SVAR. Right panel: the monthly baseline SVAR.

HFI SVAR

	AIC	BIC	HQC
1	-12.0732	-11.1019	-11.6879
2	-12.1716	-10.3907	-11.4651
3	-11.8011	-9.2108	-10.7734
4	-12.048	-8.6483	-10.6992
5	-11.8592	-7.6501	-10.1893
6	-11.4418	-6.4231	-9.4507

	AIC	BIC	HQC
1	-13.3051	-12.8155	-13.107
2	-13.6307	-12.7331	-13.2676
3	-13.6603	-12.3546	-13.1321
4	-13.7876	-12.0738	-13.0942
5	-13.6811	-11.5593	-12.8227
6	-13.6372	-11.1075	-12.6138
7	-13.5547	-10.6168	-12.3661
8	-13.5133	-10.1675	-12.1597
9	-13.4115	-9.6577	-11.8929
10	-13.3438	-9.1819	-11.66
11	-13.3677	-8.7977	-11.5189
12	-13.7574	-8.7795	-11.7436
13	-13.6847	-8.2987	-11.5058
14	-13.5512	-7.7572	-11.2072
15	-13.4165	-7.2145	-10.9074
16	-13.2961	-6.686	-10.6219
17	-13.2296	-6.2115	-10.3903
18	-13.1951	-5.769	-10.1908
19	-13.1491	-5.315	-9.9797
20	-13.2048	-4.9626	-9.8703
21	-13.1424	-4.4922	-9.6429
22	-13.1925	-4.1342	-9.5279
23	-13.1517	-3.6854	-9.3221
24	-13.0811	-3.2067	-9.0863

Table 2. Lag length selection criteria for the HFI SVAR. Left panel: the quarterly HFI SVAR. Right panel: the monthly HFI SVAR.

Residual autocorrelations

The figures below plot residual autocorrelations of the models. Bartlett two-standard-error bands for white noise are given by the blue lines.

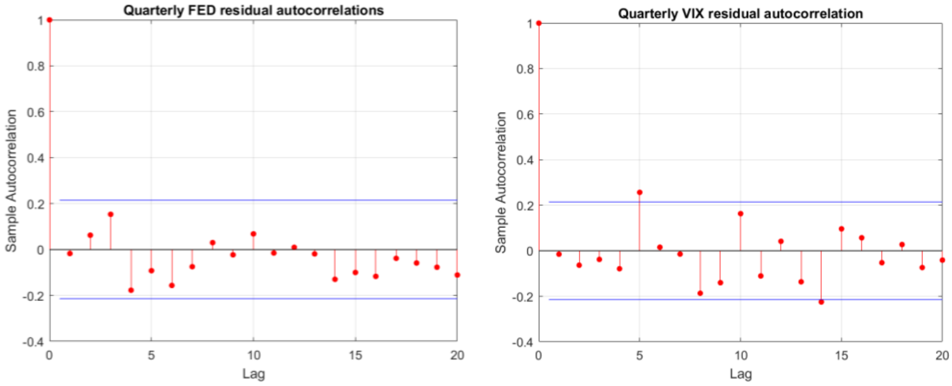

Figure 31. Residual autocorrelations for the quarterly baseline SVAR. Left panel: FFR shock, right panel: VIX shock.

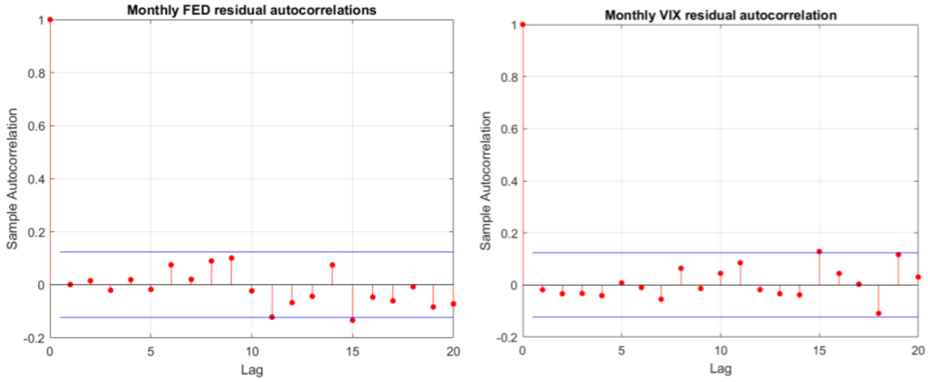

Figure 32. Residual autocorrelations for the monthly baseline SVAR. Left panel: FFR residuals, right panel: VIX residuals.

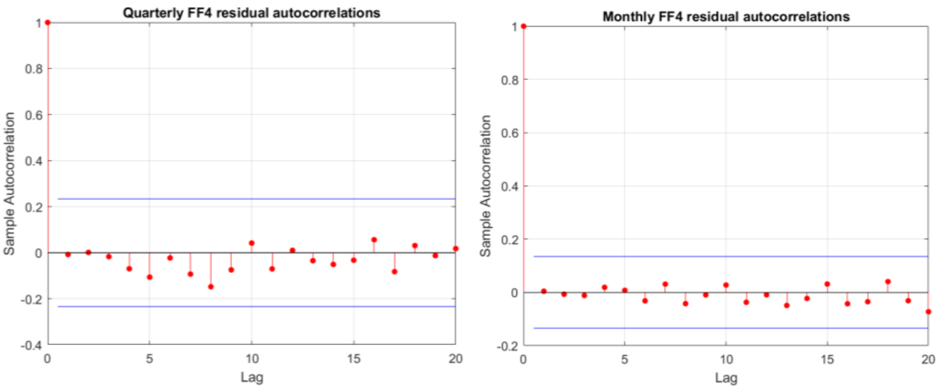

Figure 33. Residual autocorrelations for the HFI SVAR. Left panel: quarterly residuals, right panel: monthly residuals.

Appendix E. Variance decompositions

Variance decompositions (FEVD) for the simple SVARs

Quarterly

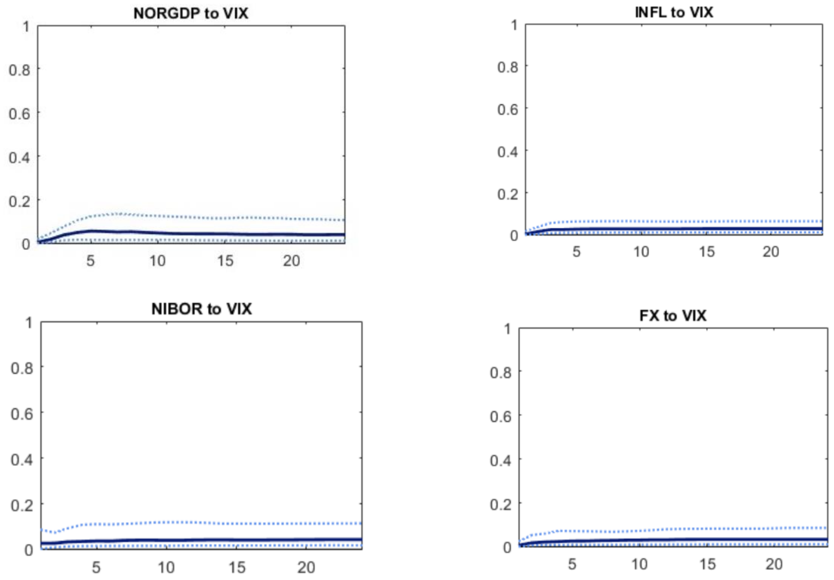

Figure 34. Variance decompositions for a shock to the VIX index. The quarterly simple SVAR.

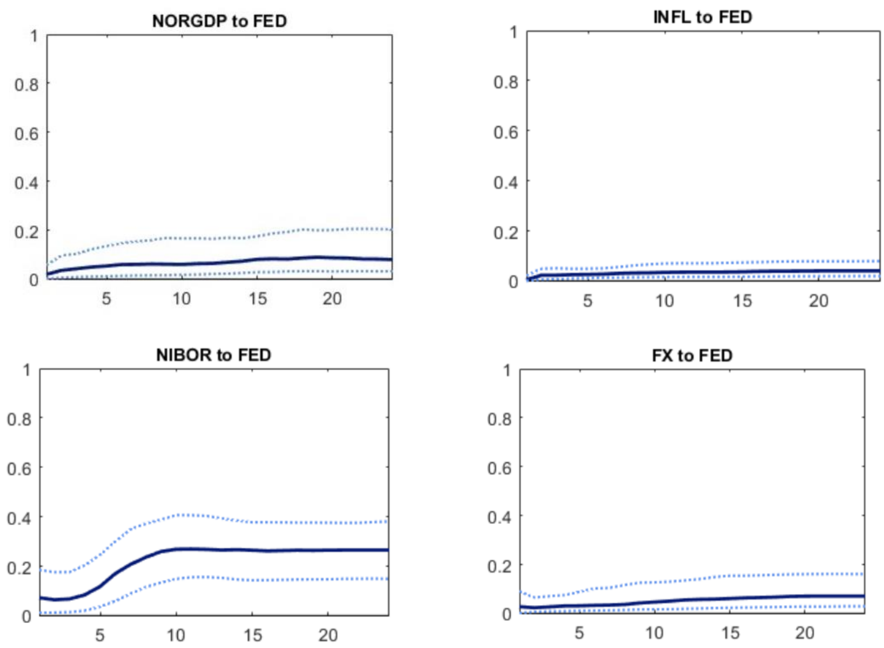

Figure 35. Variance decompositions for a shock to the Federal funds rate. The quarterly simple SVAR.

Monthly

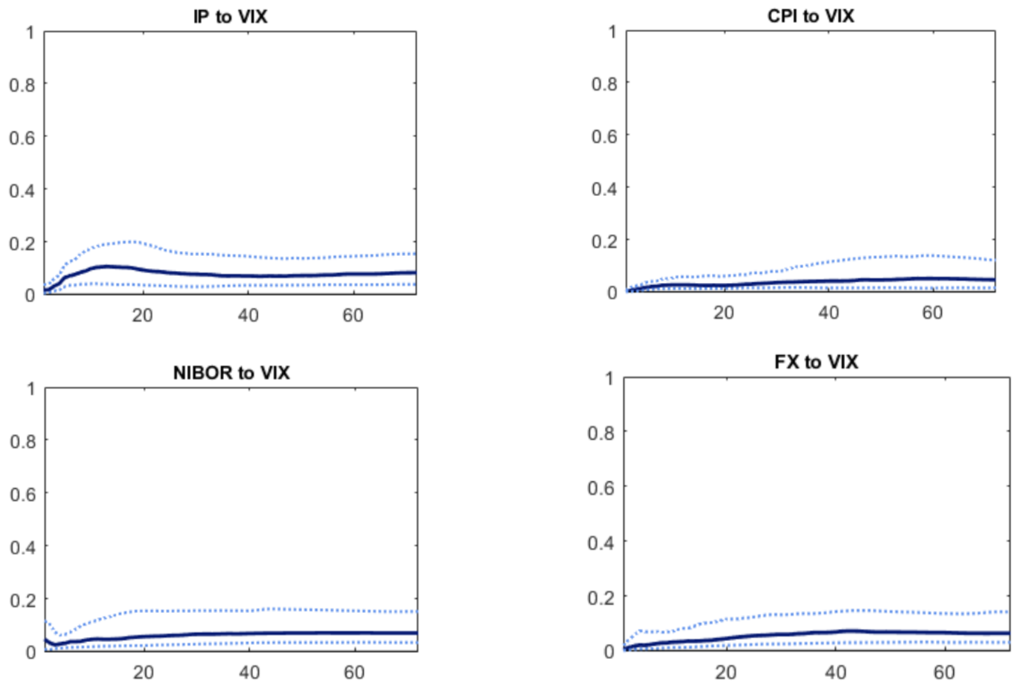

Figure 36. Variance decompositions for a shock to the VIX index. The monthly simple SVAR.

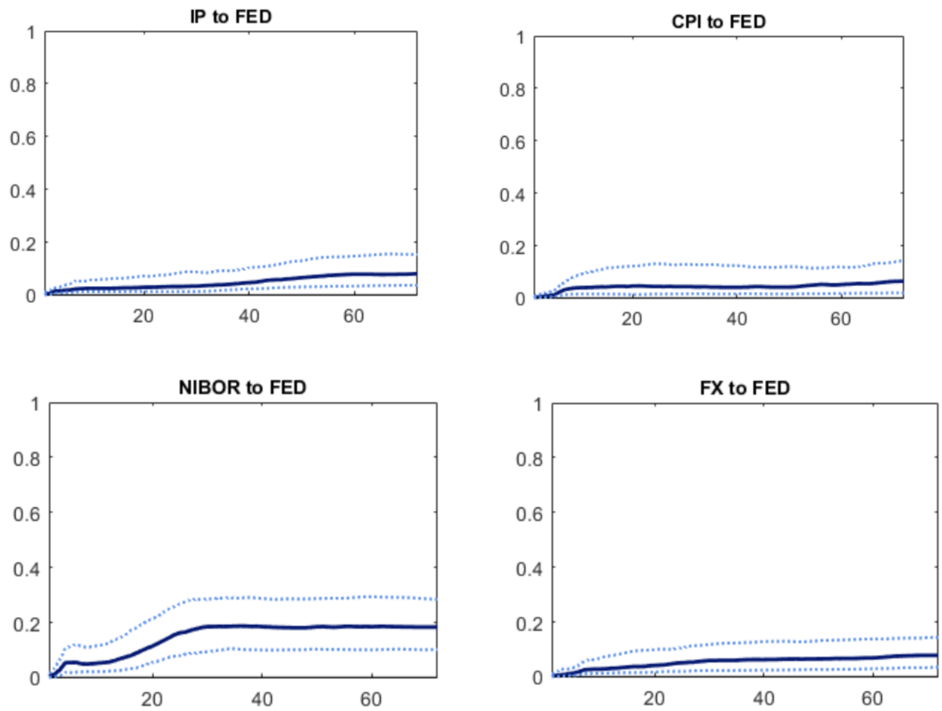

Figure 37. Variance decompositions for a shock to the Federal funds rate. The monthly simple SVAR.

Variance decompositions for the baseline SVAR

Quarterly

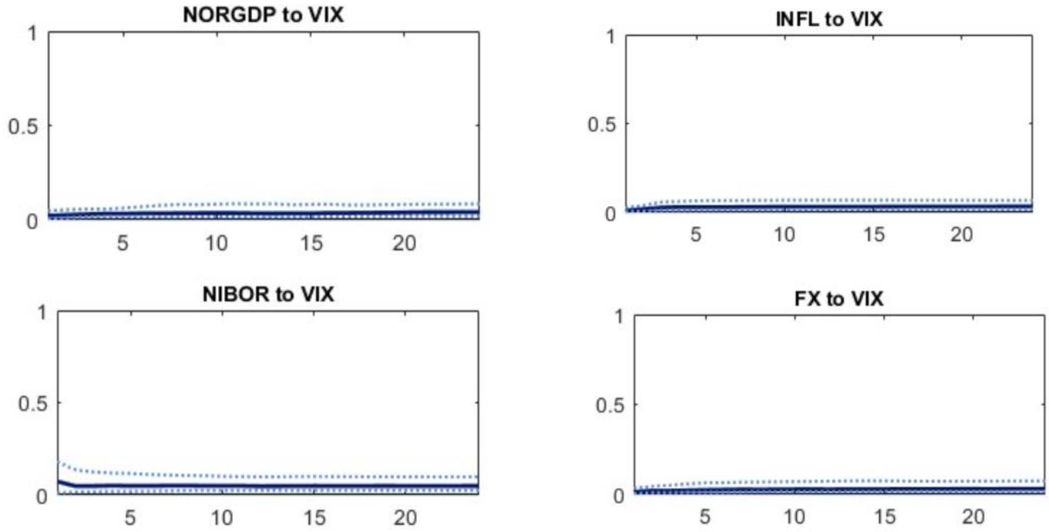

Figure 38. Variance decompositions for a shock to the VIX (only for selected variables). The quarterly baseline SVAR.

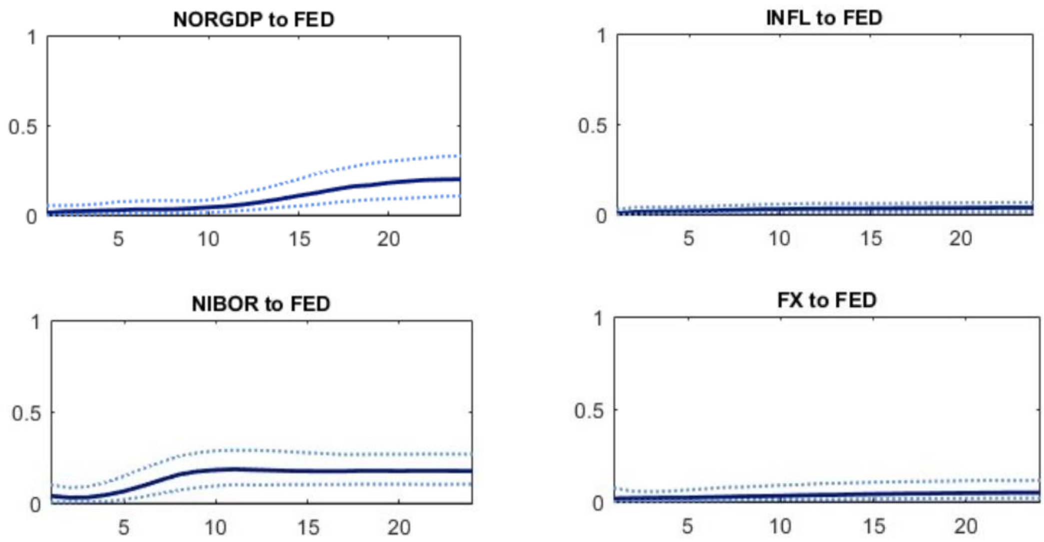

Figure 39. Variance decompositions for a shock to the Federal funds rate (only for selected variables). The quarterly baseline SVAR.

Monthly

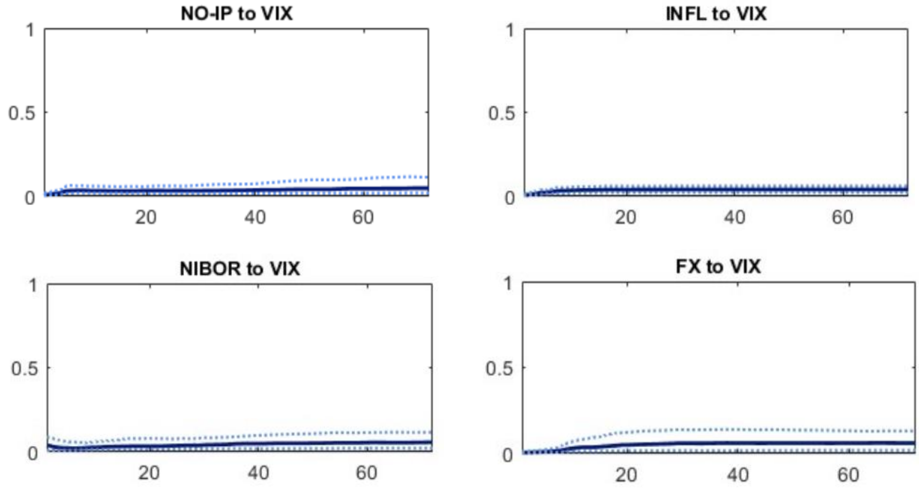

Figure 40. Variance decompositions for a shock to the VIX (only for selected variables). The monthly baseline SVAR.

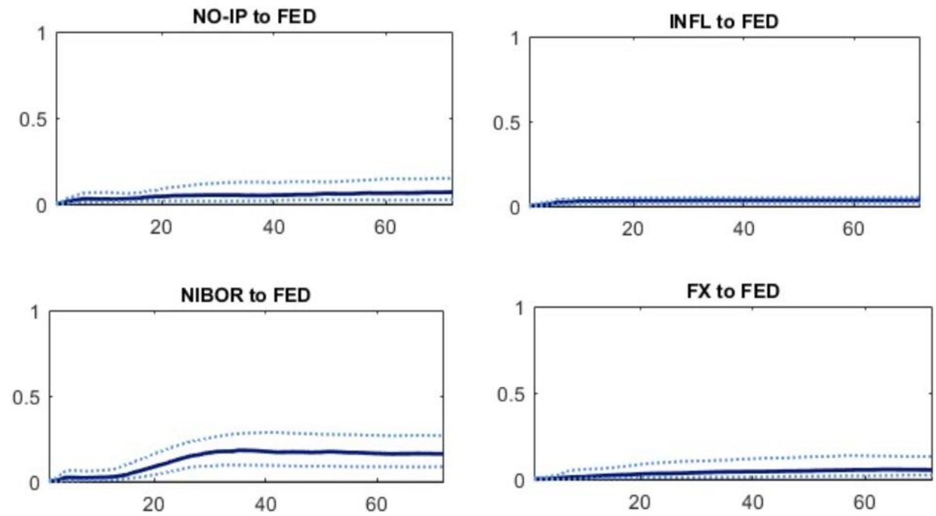

Figure 41. Variance decompositions for a shock to the Federal funds rate (only for selected variables). The monthly baseline SVAR.

Variance decompositions for the HFI VAR

Quarterly

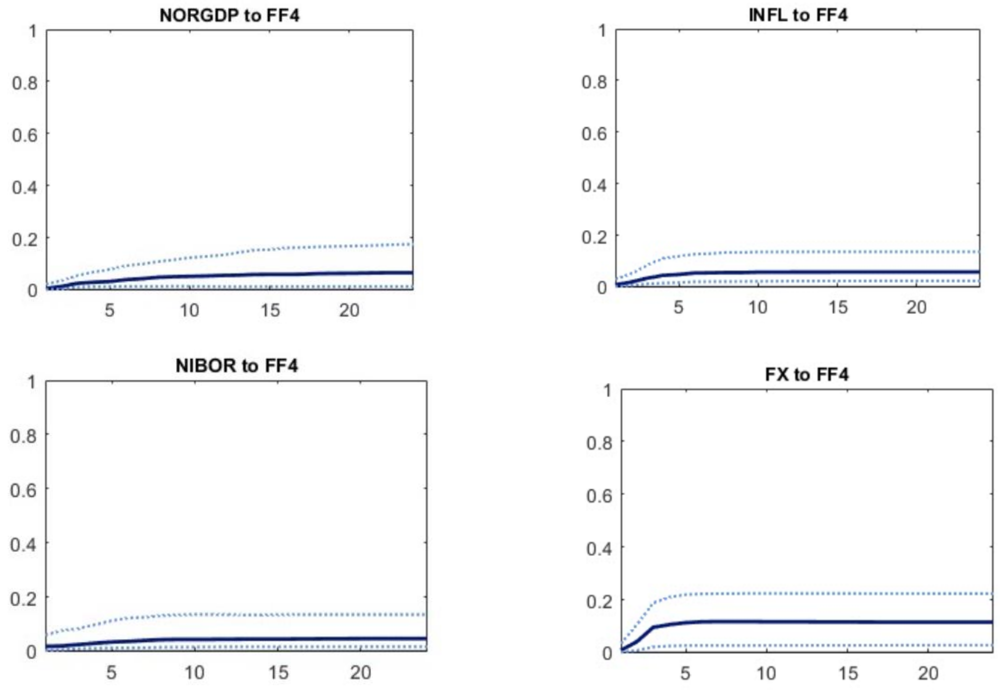

Figure 42. Variance decompositions for a shock to the Federal funds futures rate. The quarterly HFI SVAR.

Monthly

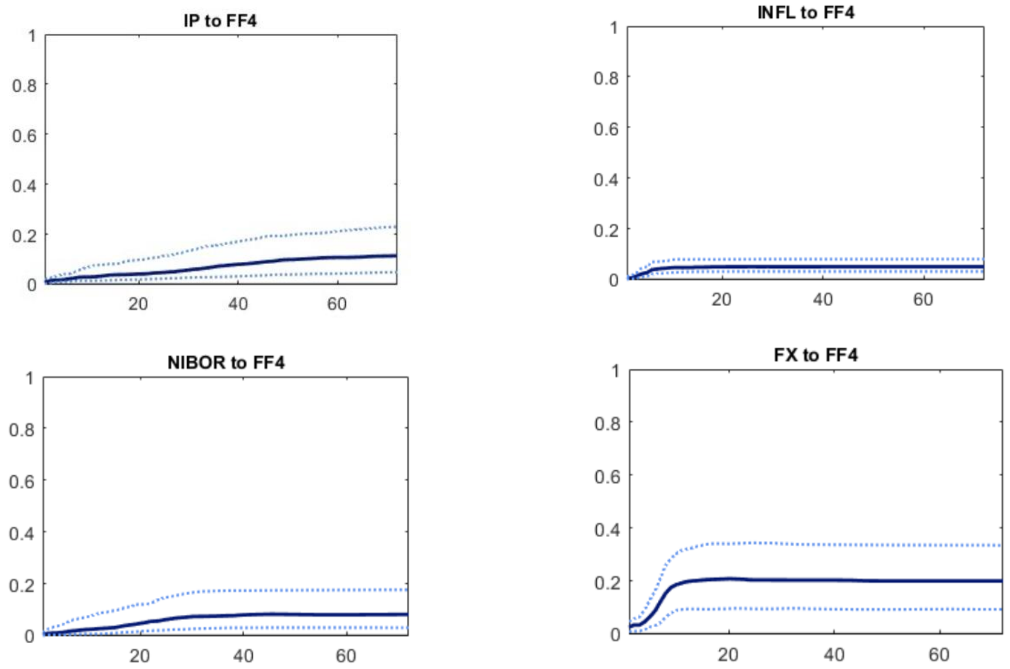

Figure 43. Variance decompositions for a shock to the Federal funds futures rate. The monthly HFI SVAR.

Appendix F. Robustness

I conduct two robustness checks on the monthly and quarterly baseline SVARs: I vary the lag length and the ordering of the variables. The monthly baseline SVAR that has more observations permits me to additionally test whether results are robust to subsamples. Thus I cut off the sample from 2007:M7 onwards, excluding the period of financial crisis. This can be meaningful when studying the FFR shock but less so for the VIX shock; an important period of variation in the VIX after mid-2007 is lost. After all, why study the effects of uncertainty in the financial market and at the same time cut off the period of uncertainty? Hence, I study the cropped-sample impulse responses only for the FFR shock.

Lag length of two for the quarterly VAR and six for the monthly VAR was chosen firstly, based on the information criteria (see Appendix D); secondly, to avoid over-parameterization in the quarterly VAR (less than 90 observations were available); and thirdly, by the assumption that foreign monetary and uncertainty shocks should not have a very persistent direct impact. Changing the lag length from two to four changes somewhat the quarterly baseline SVAR results for the **VIX shock** (see Fig.44): mostly for the Norwegian GDP, inflation and exchange rate. The quarterly baseline SVAR results of the **FFR shock** in turn (see Fig.45) are mostly the same with a higher lag length. Although, the response of inflation to an FFR shock is largely lost and the confidence bands are bloated (more parameters need to be estimated with the same amount of observations). The *monthly* baseline SVAR results, in turn, are quite robust to different lag lengths, for both the VIX and FFR shocks.

Changing the ordering of the bottom variables in the baseline SVAR is not meaningful since they are not restricted in their reactions to the top variables in the first place. The ordering of the top variables may change the results, however, because they are contemporaneously restricted with respect to the VIX. One can conclude that the baseline SVAR results with regard to the VIX shock are robust to changing the ordering of the top variables, such that oil price and FFR are *not* prohibited from reacting on impact to the **VIX shock** (see section 4.2.1.). This has some slight implications to the NIBOR and the FX rate. This is not surprising given the probable contemporaneous interaction between the financial variables. Yet, even the results for the financial Norwegian variables are qualitatively much the same irrespective of the ordering. The results with regard to the **FFR shock** are virtually the same irrespective of the ordering of the top variables. In sum, the ordering of variables was not a major issue in the recursive baseline SVAR.

Finally, I study the responses to an FFR shock based on the monthly subsample 1993:M6-2007:M6 (see Fig.18 in comparison to Fig.52), the results of which are analyzed in section 5.1.3. and 5.2.

Different lag lengths

The quarterly baseline SVAR, 4 lags

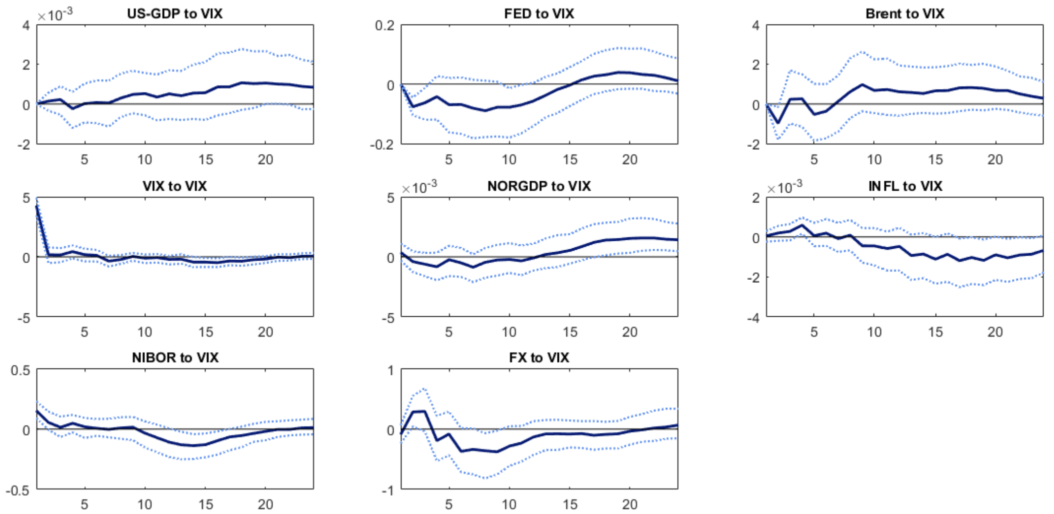

Figure 44. Impulse responses to a shock to the VIX with a lag length of 4. Quarterly baseline SVAR.

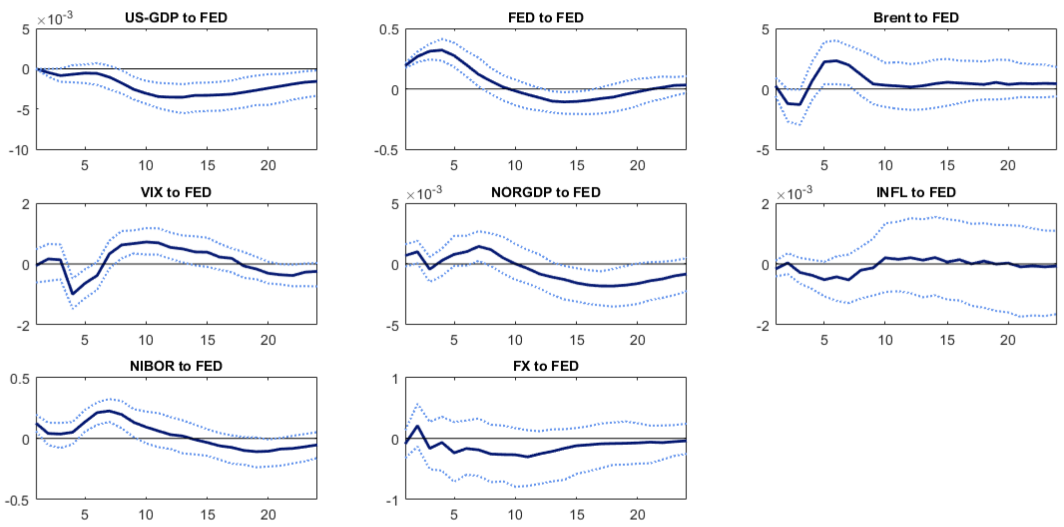

Figure 45. Impulse responses to a shock to the FFR with a lag length of 4. Quarterly baseline SVAR.

The monthly baseline SVAR, 12 lags

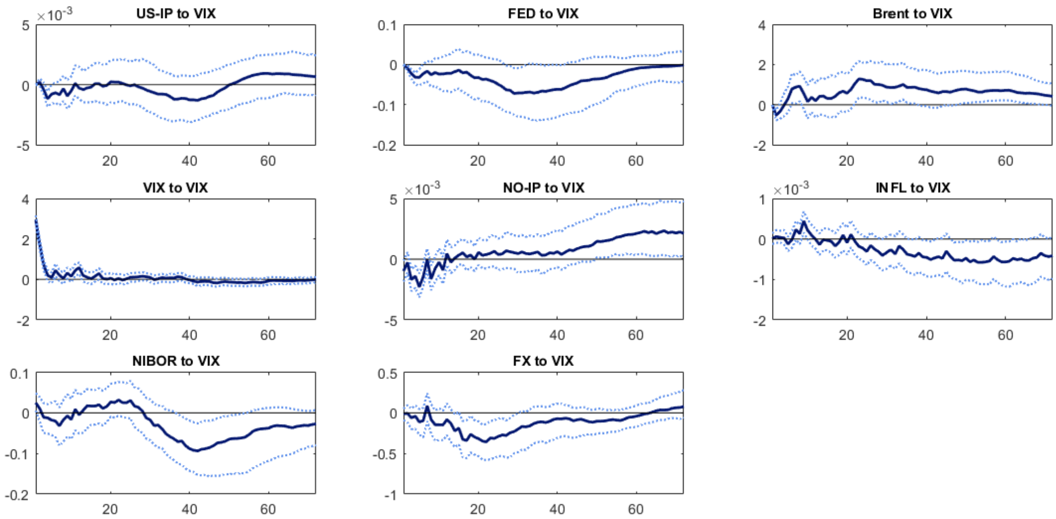

Figure 46. Impulse responses to a shock to the VIX index with a lag length of 12. Monthly baseline SVAR.

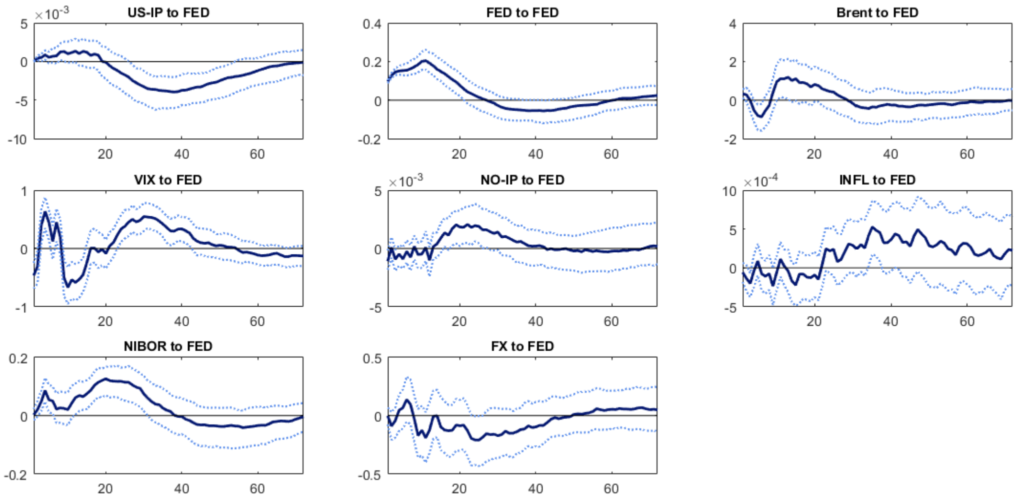

Figure 47. Impulse responses to a shock to the FFR with a lag length of 12. Monthly baseline SVAR.

The quarterly HFI SVAR

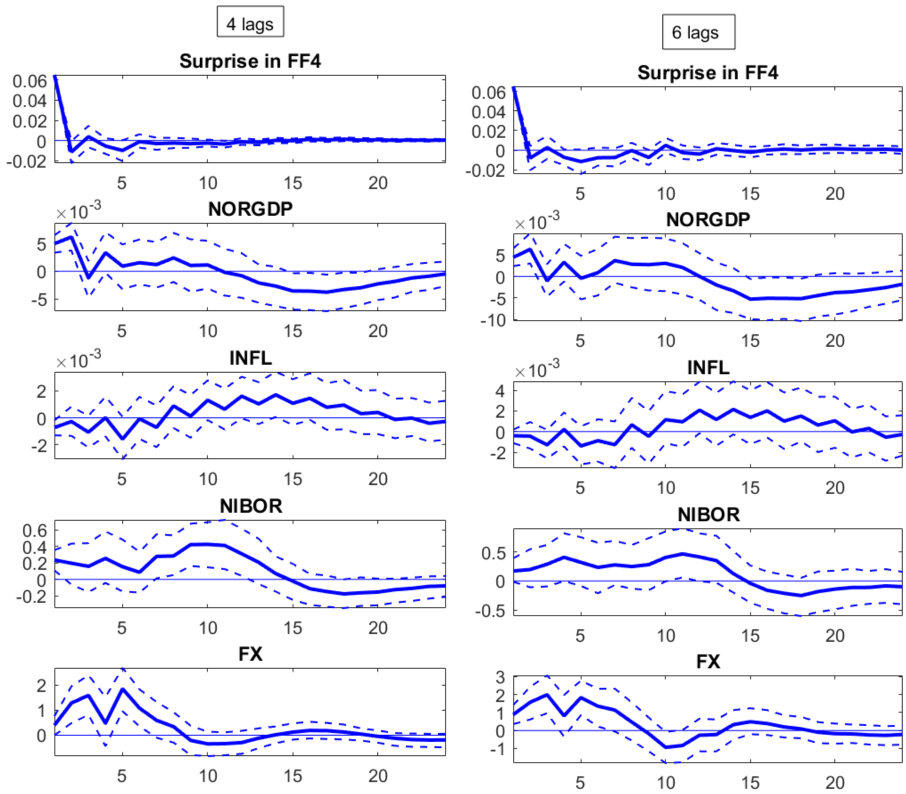

Figure 48. Impulse responses with different lag lengths. Quarterly HFI SVAR.

The monthly HFI SVAR

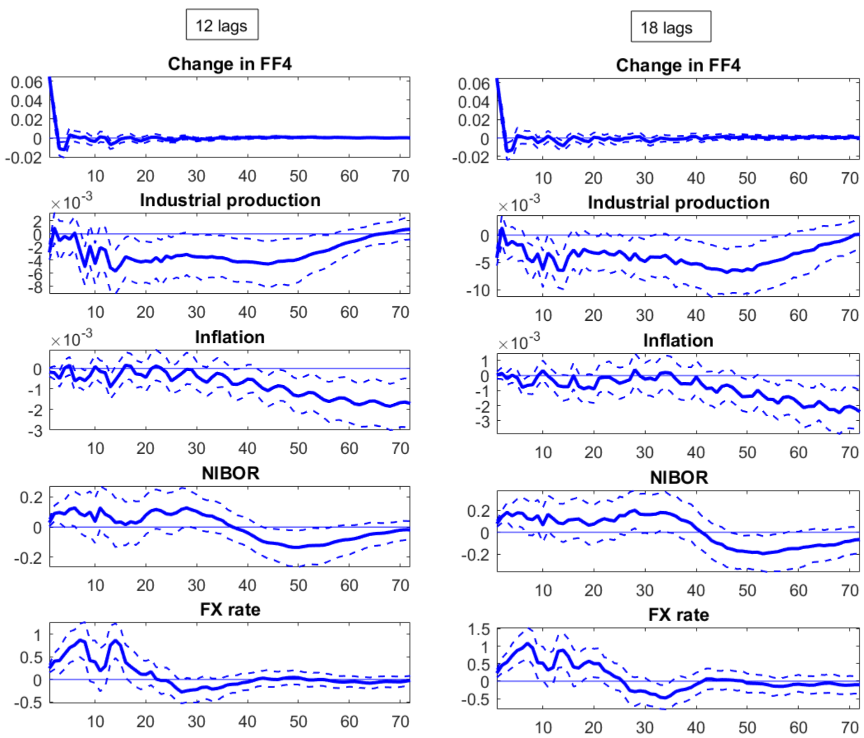

Figure 49. Impulse responses with different lag lengths. Monthly HFI SVAR.

Baseline SVAR – different orderings

Quarterly baseline SVAR results for the ordering: US-GDP, VIX, Brent, FED, NORGDP, CPI, NIBOR, FX

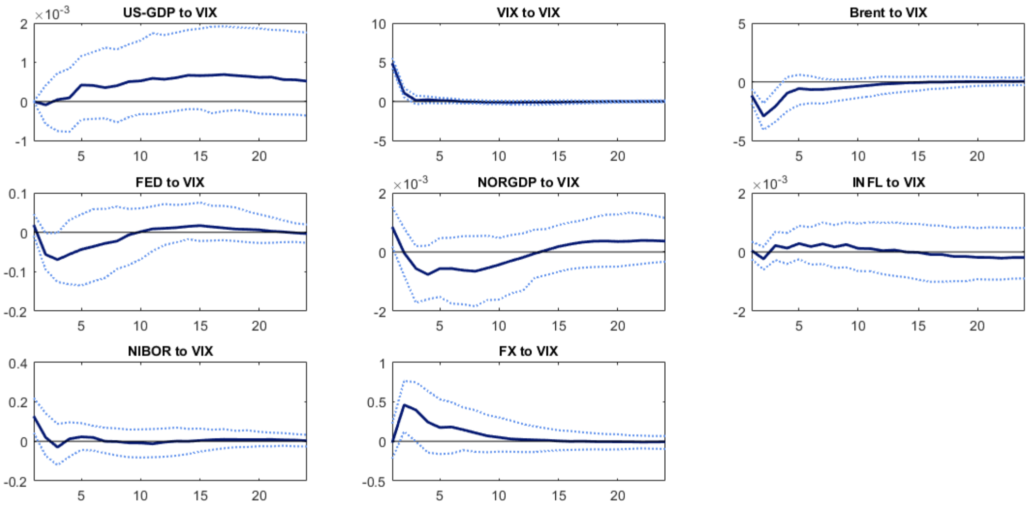

Figure 50. Baseline SVAR results for the ordering: US-GDP, VIX, Brent, FED, NORGDP, CPI, NIBOR, FX.

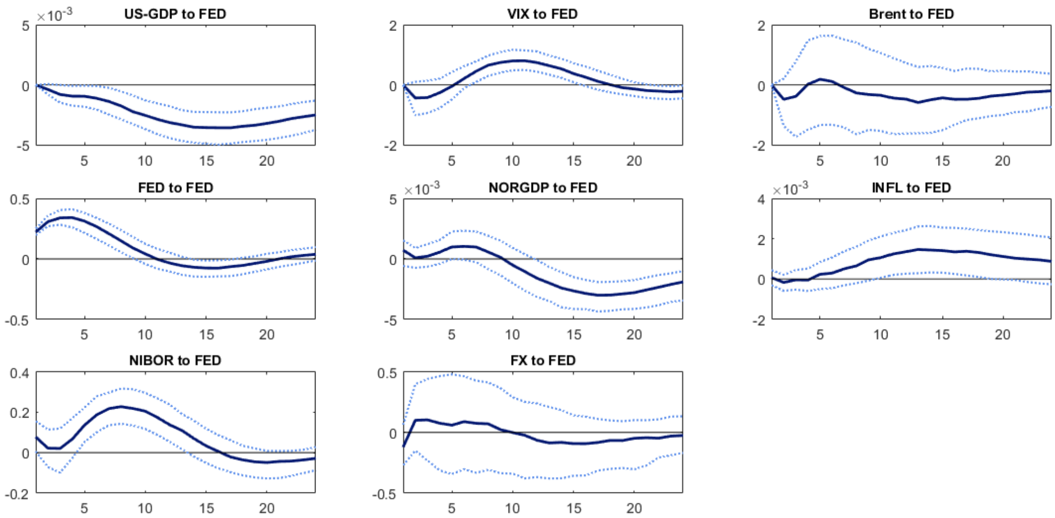

Figure 51. Baseline SVAR results for the ordering: US-GDP, VIX, Brent, FED, NORGDP, CPI, NIBOR, FX.

Exclusion of the financial crisis

Holding all other SVAR characteristics unchanged, I crop the sample for the monthly baseline SVAR and HFI SVAR: the estimation period is only 1993:M7-2007:M6.

Baseline SVAR

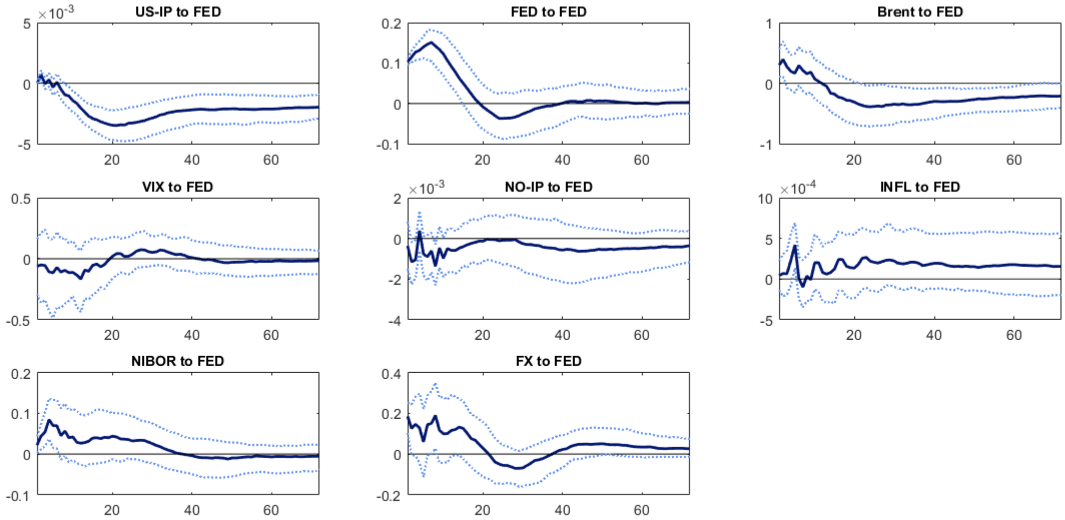

Figure 52. Monthly baseline SVAR results for a U.S. monetary shock. Subsample 1993:M7-2007:M6.

HFI SVAR

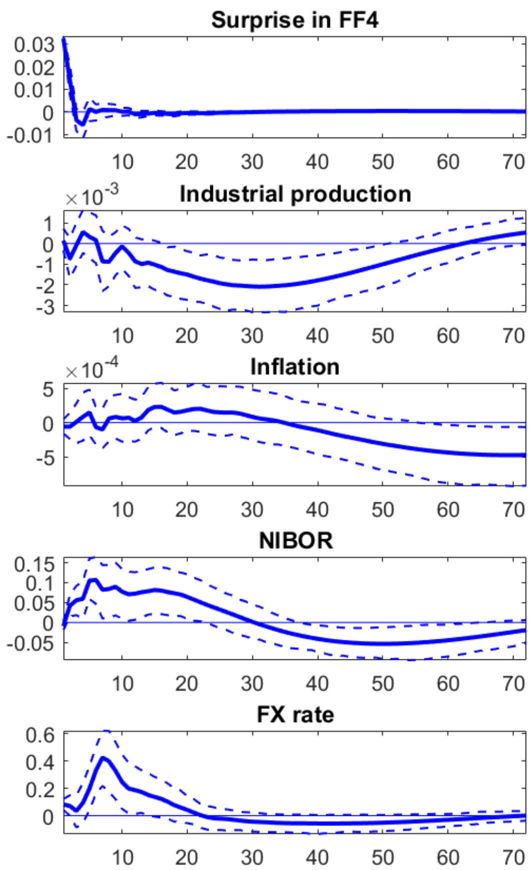

Figure 53. Monthly HFI SVAR results for a U.S. monetary shock. Subsample 1993:M7-2007:M6.

Appendix G. The IV SVAR

For the SVAR in this section, labeled the IV SVAR, I adopt Gertler and Karadi's (2015, hereafter GK) methodology to construct a structural VAR that also belongs to the group of high-frequency identified monetary shocks. GK make use of external instruments to identify monetary shocks in their structural VAR. Firstly, they distinguish between a monetary policy indicator and a monetary policy instrument, unlike most monetary shock VAR studies where the two variables are one and the same (typically a current short-term Federal funds rate). They use a one-year government bond rate with a somewhat longer maturity than the current Federal funds rate as a policy indicator in their VAR. They do this in order to include shocks to forward guidance in their measure of monetary policy innovation. This is useful because forward guidance about the path of future target rates became a significant instrument for the Federal Reserve to influence markets after the short-term rate reached the zero lower bound in late 2008. It is thus assumed that a nontrivial portion of the true monetary policy shock represents forward guidance. Accordingly, the longer-term rate is chosen as the policy indicator to capture revision of beliefs about the future path of short-term rates, induced by the 'forward guidance part' in the monetary shock.

Monetary policy indicator that accounts also for forward guidance provides me potentially with a more powerful influence of monetary shocks on economic activity since the shock's impact depends on the degree of news from forward guidance embedded in the shock (GK, pp. 69). This is an enhancement to my model but it is not ultimately why I resort to GK's approach. This can be done in the standard recursive framework as well. The greatest advantage comes, as for the HFI SVAR, from the exogeneity assumption of the monetary shock in this SVAR.

Where GK slightly differ from typical HFI VAR papers is in using an external instruments approach in the identification process. More specifically, they use the futures rate surprises only as an instrument in the first stage of two-stage least squares (TSLS, see Equation 21). An external instrument is a variable used only for identification, without including the instrument itself in a structural VAR (Stock and Watson 2012, pp.16). In the first stage (Equation 21), they have identified a structural component of the monetary policy shock that they can regress in the second stage on which ever variable of interest (see Equation 15, GK pp. 55-57).

In general, let f_{t+j} be the settlement price on the FOMC announcement date in month t for Federal funds futures expiring in month t+j, and let $f_{t+j,-1}$ be the corresponding settlement price on the day prior to the FOMC announcement.[32] Furthermore, let $(E_t i_{t+j})^u$ be the unexpected movement in the target funds rate anticipated for month t+j, with $(E_t i_t)^u = i_t^u$ being the surprise in the current target rate. Subsequently, we can express surprise in the futures rate as follows:

(17) $(E_t i_{t+j})^u = f_{t+j} - f_{t+j,-1}$

For $j \geq 1$, the surprise in the expected target rate can be thought of being equivalent to a shock to forward guidance, for j=0 a surprise in the current target rate. GK's preferred external instrument is the change in the monthly three-month ahead fed funds futures rate (FF4) that occurs during the FOMC announcement:

(18) $\Delta FF4_t = f_{t+3} - f_{t+3,-1}$

They opt for $\Delta FF4_t$ because they find it a strong instrument for the monthly VAR residuals (as I do for the quarterly reduced form VAR residual of the interest rate). The surprise in the three-months ahead Federal funds futures rate is assumed to be orthogonal to the structural shocks of the other variables, $\boldsymbol{\varepsilon}_t^q$, but correlated with the structural monetary policy shock, ε_t^p:

(19) $E[\Delta FF4_t \, \boldsymbol{\varepsilon}_t^q] = 0$ where ε_t^q is a vector of error terms for variables $q \neq p$

(20) $E[\Delta FF4_t \, \varepsilon_t^p] \neq 0$

That is, there is no reason why an unexpected policy announcement should generally coincide with innovations in the other VAR variables (Equation 19), but it is most probable that the shift in the Federal funds futures rate in the 30-minute window around an FOMC announcement reflects an innovation in monetary policy (Equation 20).

The TSLS procedure is as follows. Run an OLS regression on the reduced form VAR to obtain estimates of the reduced form residuals $\mathbf{u}_t$. Denote u_t^p as the reduced form residual for the policy indicator and denote $\mathbf{u}_t^q$ as a vector of the reduced form

[32] The following expressions and notation borrow from Gertler and Karadi (2015).

residual for variables $q \neq p$. The first-stage regression isolates the unproblematic, exogenous variation in u_t^p and leaves the problematic variation in the error term:

(21) $u_t^p = \alpha + \gamma \Delta FF4_t + e_t$ where $\hat{u}_t^p = \hat{\alpha} + \hat{\gamma} \Delta FF4_t$

The second-stage takes the fitted value of the first stage, $\hat{u}_t^p$, which is an estimate of the structural monetary policy shock (subject to measurement error) and regresses the other reduced form residuals on it:

(22) $u_t^q = \beta_0 + \beta_1 \hat{u}_t^p + \xi_t$

where $\hat{u}_t^p$ is orthogonal to the error term under the assumption of Equation (19). The second stage allows to back out the structural parameters needed for a structural VAR (for a more detailed technical description, refer to GK 2015, pp. 50-52).

Hence, for the IV SVAR, the following VAR in its moving average is estimated:

$$(23) \quad \begin{pmatrix} 1yr(t) \\ NORGDP(t) \\ CPI(t) \\ NIBOR(t) \\ FX(t) \end{pmatrix} = \begin{pmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \\ \mu_5 \end{pmatrix} + \begin{pmatrix} \theta_{11,0} & \theta_{12,0} & \theta_{13,0} & \theta_{14,0} & \theta_{15,0} \\ \theta_{21,0} & \theta_{22,0} & \theta_{23,0} & \theta_{24,0} & \theta_{25,0} \\ \theta_{31,0} & \theta_{32,0} & \theta_{33,0} & \theta_{34,0} & \theta_{35,0} \\ \theta_{41,0} & \theta_{42,0} & \theta_{43,0} & \theta_{44,0} & \theta_{45,0} \\ \theta_{51,0} & \theta_{52,0} & \theta_{53,0} & \theta_{54,0} & \theta_{55,0} \end{pmatrix} \begin{pmatrix} \varepsilon(1yr,\ t) \\ \varepsilon(GDP, t) \\ \varepsilon(CPI, t) \\ \varepsilon(NIBOR, t) \\ \varepsilon(FX, t) \end{pmatrix} + \sum_{i=1}^{L} \Theta_i \varepsilon_{t-i}$$

where 1yr is the one-year government bond rate, NORGDP is Norwegian GDP, CPI is Norwegian inflation, NIBOR is the Norwegian money market rate and FX is the krone exchange rate.

Accordingly, in Equation (23) only the coefficients in the first column are identified using the TSLS. The ordering of variables is arbitrary in this setting.

Impulse responses for the IV SVAR

Figure below shows impulse responses to a 20 basis points increase in the one-year U.S. government bond rate which is used as the monetary policy indicator. The left panel in the figure shows results for the IV identified monetary policy shock. As a comparison, the right panel shows results for the Cholesky identified monetary policy shock for the same period. Both VAR specifications use two lags. Wild bootstrapped confidence intervals of 68% are computed using 200 replications. In this specification, the CPI series is only logged, not log-differenced like in other VARs.

Quarterly

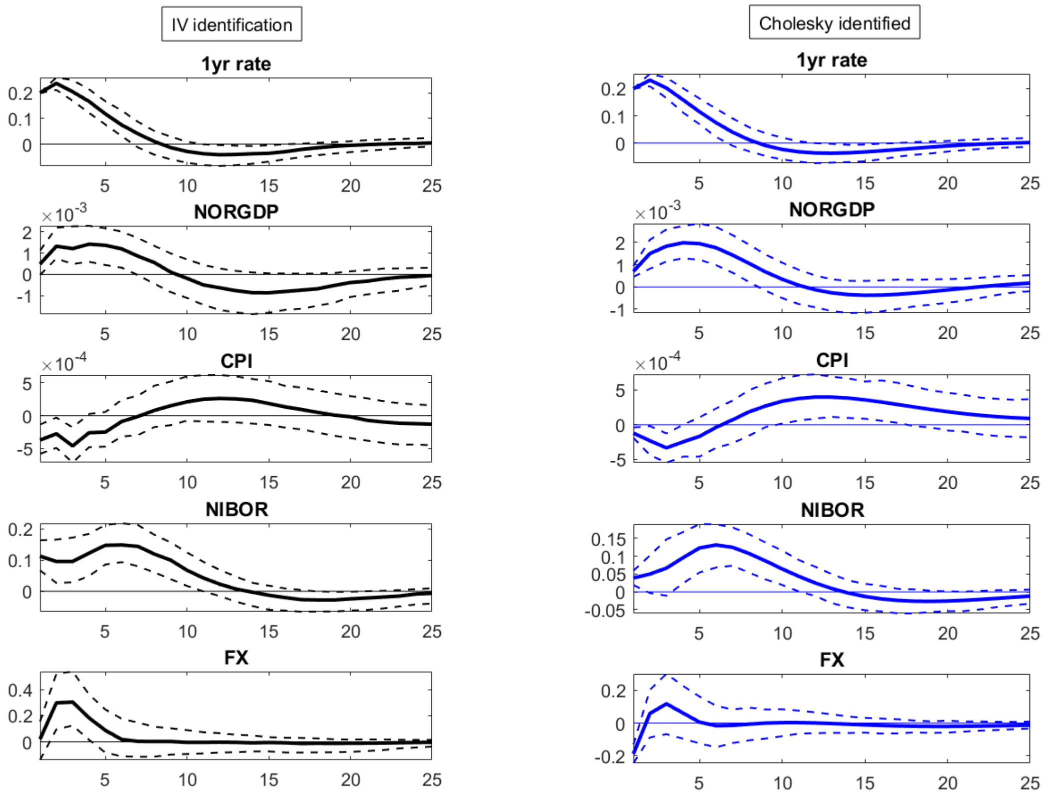

Figure 54. 25 periods (6.25 years) ahead impulse responses to a shock in the one-year government bond rate. The quarterly data span from 1993:Q3 to 2012:Q2, comprising 76 observations.

The trajectories of Norwegian variables for the quarterly **HFI SVAR** (Fig. 20, left panel) and for the **IV SVAR** (Fig. 54, left panel) are in keeping with each other for the most part, although the magnitudes are dampened in the IV SVAR from those of the HFI SVAR (that supplies a greater magnitude foreign monetary shock). As one can observe from the chart in the upper left corners, the shocks differ much from each other: the HFI shock dies off quickly, not exerting direct influence over the other variables much longer than a year, either contemporaneously or with a lag (lag length is equivalent to six months' time). The IV shock, in turn, is much more persistent, which is likely reflected in the impulse responses. Most notable difference is between the impulse responses of the Norwegian GDP: while the response is of lower magnitude, the short-term upturn is much more persistent in the IV SVAR compared to the HFI SVAR. However, when comparing the IV SVAR to the quarterly HFI SVARs with higher lag lengths (in Appendix F), the persistence of the short-term expansion in GDP matches the HFI SVAR more closely.

In the right panel of Figure 54, I plot a SVAR that was derived from the same reduced form VAR as was the IV SVAR, but now identified recursively with Cholesky; the only difference between the panels is the identification scheme. The trajectories of Norwegian variables between the left and the right panel are surprisingly similar but not quite the same. The initial responses of the CPI, NIBOR and the FX rate differ. Also, the medium- to longer-term slump in the GDP is more obvious in the instrumental variables identified SVAR. Nonetheless, the results are overall very much alike, which raises suspicions that there has occurred an error in either programming the code[33] or some type of measurement error in the two-staged least squares (although instrument strength was checked and weak instruments is not an issue). After all, comparison of HFI SVAR to the baseline SVAR and the simple SVAR revealed that control variables and identification scheme matter immensely for results, and so simultaneity is a concern unless exogeneity of variables is assured in some reliable way. Therefore, I still consider the more transparent HFI SVAR results in Figure 20 as the main results for the foreign monetary shock. These results were, for the most part, confirmed by the IV SVAR.

[33]The Matlab code was originally created to reproduce the results in Gertler and Karadi (2015, pp.61). Any flaw in the code must have been due to my error in adjusting the Matlab code to the Norwegian setting of my VARs. I am thankful to Ambrogio Cesa-Bianchi for sharing his code at his website.

Appendix H. Preliminary master thesis report.

BI Norwegian Business School

NORWAY AND THE GLOBAL FINANCIAL CYCLE

Hand-in date: 15.01.2016

Student's name and ID number:

Laura Johanna Kuitunen, 0945474

Campus:

BI Oslo

Examination code and name:

GRA19003 – Preliminary Master Thesis Report

Supervisor:

Gisle J. Natvik

Programme:

Master of Science in Business

Major in Economics

Table of contents

Introduction

The objective of this master thesis is to study how international financial shocks could affect financial stability and macroeconomic conditions in Norway and if the Norwegian economy follows the Global Financial Cycle. Rey and Miranda-Agrippino (2015) define the Global Financial Cycle as “the interaction between U.S. monetary policy, real activity and global financial variables such as credit spreads, cross-border credit flows, bank leverage and the global factor in asset prices”, however the U.S. economy does not have to be the only driver of the Global Financial Cycle. Motivation for studying this, is that the Global Financial Cycle is likely not aligned with countries’ specific macroeconomic conditions. This can lead to excess credit growth, or alternatively too tight monetary conditions, exacerbating boom-bust cycles (Rey 2015).

The related objective of the master thesis is also to see whether the ‘impossible trinity’ is appropriate description of the attainable monetary policy goals for Norway or are the options better described by the ‘irreconcilable duo’, a concept proposed by Rey (2015). It states that a country really faces a trade-off only between independent monetary policy and free movement of capital, which cannot be completely eliminated by a floating exchange rate regime. With focus on the Norwegian economy, I aim to answer questions of the type:

- Do fluctuations in asset prices (stock prices, house prices) follow the global financial cycle? Why are leverage and credit growth synchronized across countries?

- What are the consequences of financial globalization for the workings of national financial systems?

- Could the Norwegian krone be characterized as a safe haven currency and are unpredictable capital in- and outflows a concern?

- What is the effect of the Global Financial Cycle on banks’ refinancing costs of in dollars?

During the last decades and especially after the ‘Great Recession’ of the late 2000s, the view that financial factors play an important cyclical role has gained traction, and so modelling business cycles without consideration of financial aspects may be incomplete (Jordà et al. 2011). Also Borio and Lowe (2002) call for research that accounts for the interaction between financial and real factors as determinants of business fluctuations.

Firstly, there is no consensus of what precisely constitutes the definition of financial stability or instability. Bårdsen et al. (2006, 6-8) provide an extensive review of the definitions and concepts associated with financial stability. Most definitions highlight the efficient functioning of the markets for allocating savings to investment, which often entails availability of information about risks and profitability. They cite Mishkin who covers most of these aspects with his definition: "Financial instability occurs when shocks to the financial system interfere with information flows so that the financial system can no longer do its job of channeling funds to those with productive investment opportunities". On a related note, some see financial instability as departure from the economy's equilibrium and draw special attention to bubbles that can destabilize the system. It should be noted, however, that most of these aspects just mentioned are disputed or disregarded in other definitions, and so ambiguity remains about views of financial stability.

For the purposes of this master thesis, financial instability is seen as conditions where disruptions that banks (and other financial intermediaries) face have the ability to disable or limit their normal functioning due to, for example, reduction in the banks' profitability or capitalization. In other words, the financial markets are not robust to absorb the shocks that hit them. In general, these shocks can develop either endogenously in the financial system, or they can have developed in the macroeconomy and be exogenous shocks to the financial system.

Based on a study on historical incidents of recessions and financial crisis, Borio and Lowe (2002) assert that economic imbalances in the form of bloated asset prices (predominantly in property prices or equities), excessive credit extension and, in some occasions, high levels of investment tend to coincide with financial turmoil. They emphasize that it is insufficient to conclude merely from the elevated level in one variable, for instance in private credit, that the economy stands at risk for financial instability. Similarly, identifying a bubble in some asset class, while intrinsically interesting, reveals only some of the overall conditions that prevail in the system and risks that it is exposed to. For the economy's robustness, the combined effect of imbalances in the financial and real sectors is more important than determining whether or not a bubble exists.

According to Minsky's (1977) financial fragility hypothesis, economies undergo endogenous financial cycles. Dahl et al. (2011, 2) summarize the hypothesis: "When times are good, asset prices and credit tend to rise, stretching private balance sheets and contributing to the build-up of financial imbalances. Such imbalances usually unwind in a disruptive manner when a shock occurs and threatens financial stability." Procyclical reaction of asset prices thus tends to reinforce the initial adverse shock.

The financial accelerator is a self-reinforcing feedback mechanism between credit, asset prices and real economic activity (Hammersland R. & Bolstad Træe 2012). An important determinant with regard to financial stability in the event of an external shock is thus the indebtedness of households and house price developments preceding the shock. Credit driven boom in the housing market is quickly reversed when the economy is hit by an adverse shock. In Norway, both house prices and private credit have been at high levels in the recent years. The IMF (2015) reports that household debt to disposable income in Norway, at 220 percent, was among the highest of OECD countries at end-2014. They additionally report that the housing market is estimated to be overvalued by 25-60 percent.

Channels of Impact

Norway is a small open economy that has floating exchange rates – monetary policy goals are principally inflation targeting and upholding the real economic activity with consideration for financial stability. The economy has very open financial markets; the large banks finance themselves to a large extent in the U.S. money markets using foreign exchange swaps (FX swaps). This means that they borrow U.S. dollars short term, swap the dollars for Norwegian krone and swap the krone back to dollars when the swap matures and it is time to roll over the U.S. money market debts. The wholesale funding in foreign currency has made the Norwegian banks less dependent on retail funding (deposits) and has allowed them to expand their balance sheets more than they could have if depending their financing solely on domestic funds. At the same time, it has exposed them to maturity mismatch and, to a lesser degree, to currency mismatch (against which they hedge with the FX swap arrangement).

Being exposed to the maturity mismatch means that the bank's assets are of longer term than its liabilities. Thus, in order to stay liquid the bank must refinance its debts regularly before the payoff of the assets is realized. Operating in the U.S. money markets naturally means that the Norwegian banks partly adopt the credit conditions prevailing in the U.S. that are governed by policies of the Federal Reserve. Although the smaller banks in Norway do not engage in the FX swaps, they do borrow and lend with the larger banks in the Norwegian interbank market, and so are impacted by the liquidity of the larger banks. Therefore, the financing of Norwegian banking system is a natural channel for the international financial shocks to hit the Norwegian economy.

Safe haven or not?

'Hot money' flows into emerging economies in good times and flees in bad times (Financial Times, Jan 10 2016). It has been suggested that Norway is a safe haven for investors due to the country's stable economic growth and sound external balances. If this is the case, the flows of hot money are the opposite than those for the emerging economies; flight to quality causes money to flow in in times of global economic turmoil, whereas in better times the money is drained out.

This is not always the case however, as Lund (2011) points out. The EUR/NOK market is relatively small and illiquid as measured in terms of the bid-ask spread. The bid-ask spread, the difference between the market's lowest ask-price and highest bid-price, represents transaction costs of trading currencies and thus serves as a proxy for liquidity. Investors seem to consider Norway as one of the "periphery countries" of Europe whose financial markets are both illiquid and exposed to the European financial conditions despite their periphery status[34]. The combination of

[34] Despite being outside the Eurozone, the Scandinavian markets were not shielded from the euro-crisis, which caused investors to withdraw their investments in favor of more liquid markets, weakening the Scandinavian currencies.

illiquidity and exposure to the European markets is an unfavorable one, because the illiquidity induces large swings in the exchange rates when the investors unwind their krone-holdings after hearing adverse news from Europe. Among the few currency pairs compared, the EUR/NOK had the largest (positive) correlation between the bid-ask spread and NOK depreciation, suggesting that the lack of liquidity indeed makes the NOK volatile and thus a poor safe haven currency. Rather, the krone is more of a second-order safe haven currency, which means that investors utilize it only after more liquid safe haven currencies, such as the Swiss franc, have appreciated sufficiently.

Consequently, the flows of funds in and out of Norway as a response to global financial cycles is less clear-cut than for emerging economies on the one end of the scale and the major industrialized countries on the other. Be that as it may, sudden and uncontrollable flows of funds have a destabilizing effect on the financial markets, disturbing the banks' credit extension, which makes the safe-haven question a 'real economy problem'.

Is the 'impossible trinity' invalidated?

The 'impossible trinity' (also referred to as the 'Mundellian trilemma' or 'monetary trilemma') states that any given country cannot simultaneously obtain a flexible exchange rate regime, independent monetary policy and free movement of capital across borders. Rey (2015) challenges this well-established result in international macroeconomics which Mundell proposed in 1963 (Mundell 1963). In Rey's view, the fact that international financial shocks can govern an economy's asset price- and credit cycles, despite a floating exchange rate regime, alludes to the break-down of the impossible trinity. In theory, a floating exchange rate should function as a shock absorber, such that the economy's monetary policy remains independent. Nonetheless, floating exchange rates have not prevented economic disturbances from spreading across national borders despite that they have become more common since the 1990s. Aizenman et al. (2015) on the other hand find that the type of exchange rate regime is an important factor in determining whether the peripheries are sensitive to changes in financial conditions in the center economies (in the U.S., the Euro area, Japan, and China).

Data

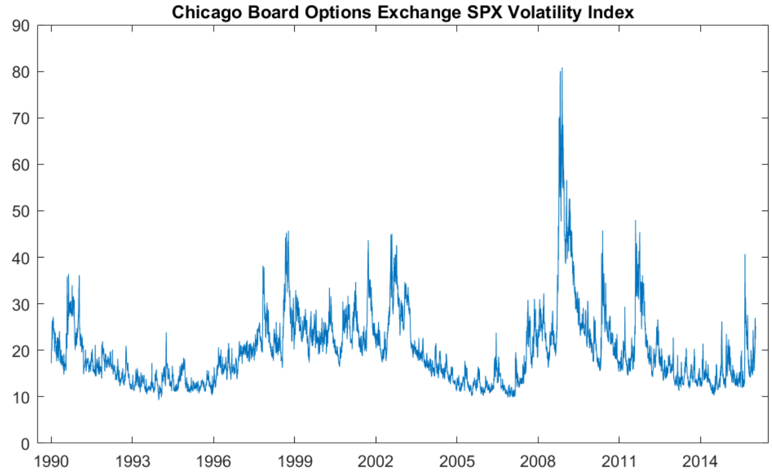

Figure 55. The VIX Index. Daily data 1990-2016. Source: Bloomberg.

The VIX index reveals markets' expectations of the next 30-day volatility in the S&P 500 Index (SPX), calculated from put- and call options that are written on the S&P 500. It serves as a proxy for uncertainty and risk aversion among investors. An index value of 30 is often regarded as the threshold for high volatility expectations.

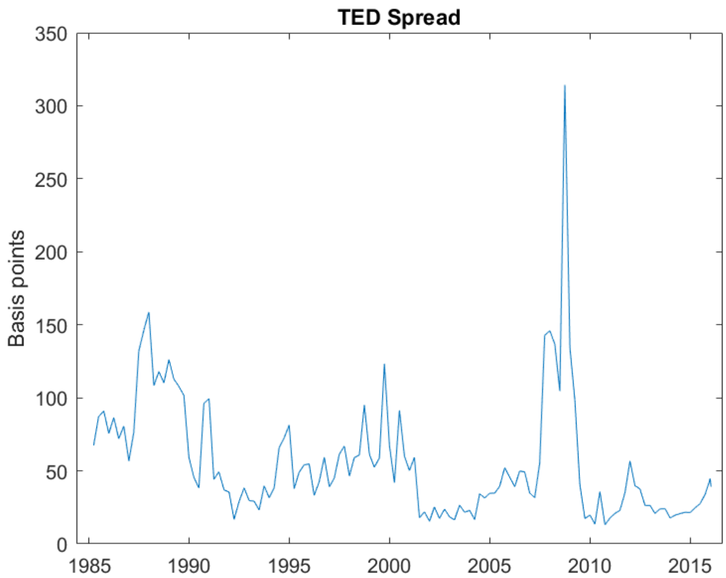

Figure 56. The 3-month TED Spread. Quarterly data 1985-2016. Source: Bloomberg

TED Spread is the difference between the 3-month Eurodollar Deposit Rate in London and the 3-month U.S. Treasury Bill yield and captures the risk premium for credit risk.

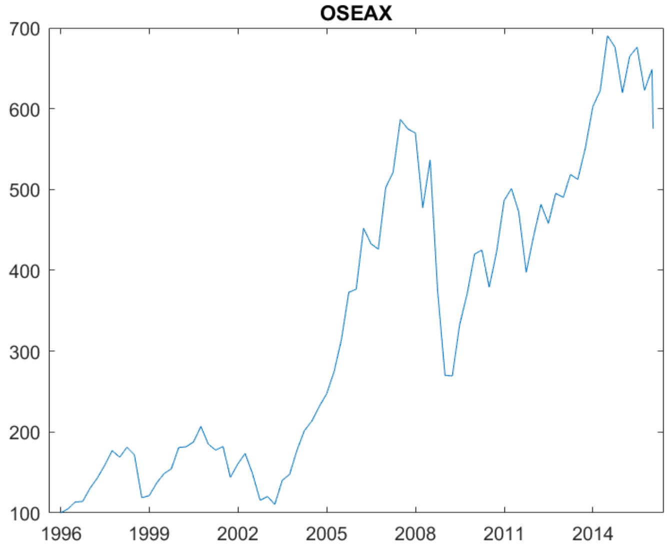

Figure 57. The OSEAX index – The stock return index of all shares at the Oslo Stock Exchange adjusted for dividend payouts. Quarterly data 1996-2016. Source: Bloomberg.

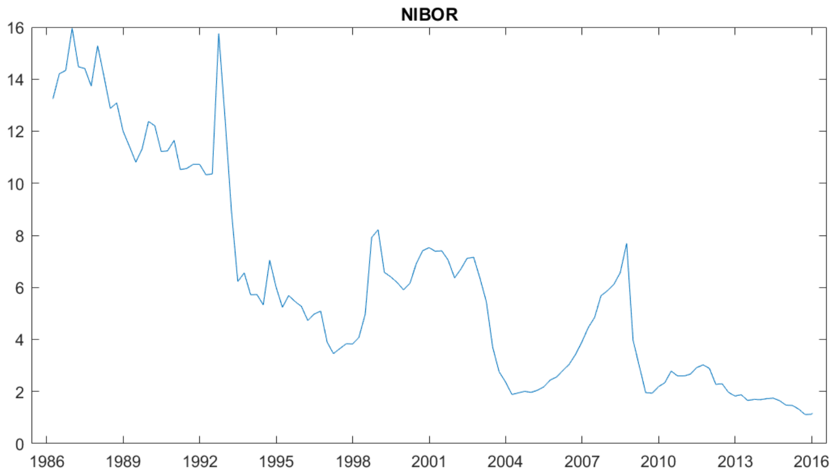

Figure 58. The 3-month NIBOR rate – the Norwegian interbank offer-rate (ask-rate). Quarterly data 1986-2016. Source: Bloomberg.

Methodology

To study the effects of the international financial shocks on the Norwegian macroeconomic variables, I will employ a structural vector autoregressive model (SVAR). Univariate autoregressive models (AR) regress the dependent variable against its own lagged values using the OLS. Vector autoregressive models (VARs) in turn are multivariate systems where a dependent variable's own lagged values, as well as other variables' (contemporaneous and lagged) values are included in the reduced form regressions, making the variables endogenous and the system unsuitable for OLS estimation. (Bjørnland and Thorsrud 2015.)

The identification problem refers to the inability to identify the structural parameters since the parameters might reflect other influences than what they are thought to represent. To put it less abstractly in the case of the 'standard VAR' (the VAR in its reduced form), the problem is that the reduced form errors may be correlated. This means that the shocks in different variables will likely not occur independently – movement in one covariate is accompanied by movement in another covariate in the system, and so the parameter for the first covariate actually represents the joint effect of both of these covariates. The OLS estimation suffers of simultaneity (simultaneous causality) and the resulting estimates will be biased. To distill a covariate's independent impact on the dependent variable, one has to impose restrictions on the coefficients in the multivariate system, so that only that specific covariate is affecting the explanatory variable at a time.

Causal relationships can be studied through SVARs. One way to impose restrictions is to assume a recursive structure for the VAR system, which is the procedure in this master thesis. If the reduced form VAR is stable, it is invertible and the reduced form can be transformed into a moving average (MA) form. The MA form can then be manipulated into the product of structural coefficient- and error matrices using the Cholesky decomposition. As a result, the lagged values of the variables ordered lower in the system cannot have a contemporaneous impact on the variables that are ordered higher.

Restricting the system like this entails that the recursive structure is supported by economic theory. That is, it needs to be plausible that (i) the response of some variables in the system comes with a delay (most macroeconomic variables, such as the GDP, tend to react to shocks more slowly than e.g. financial variables) or (ii) some variables in the system do not have an impact on the others in any case (for example, macroeconomic variables of a small open economy cannot move variables that are driven by global factors). The preliminary specification of the SVAR to be used in this thesis is:

$$\begin{pmatrix} VIX(t) \\ GDP(t) \\ CPI(t) \\ NIBOR(t) \\ FX(t) \end{pmatrix} = \begin{pmatrix} \theta_{11,0} & 0 & 0 & 0 & 0 \\ \theta_{21,0} & \theta_{22,0} & 0 & 0 & 0 \\ \theta_{31,0} & \theta_{32,0} & \theta_{33,0} & 0 & 0 \\ \theta_{41,0} & \theta_{42,0} & \theta_{43,0} & \theta_{44,0} & 0 \\ \theta_{51,0} & \theta_{52,0} & \theta_{53,0} & \theta_{54,0} & \theta_{55,0} \end{pmatrix} \begin{pmatrix} \varepsilon(VIX,\, t) \\ \varepsilon(GDP, t) \\ \varepsilon(CPI, t) \\ \varepsilon(NIBOR, t) \\ \varepsilon(FX, t) \end{pmatrix} + \sum_{i=1}^{\infty} \Theta_i \varepsilon_{t-i}$$

where VIX = VIX index, GDP = Gross Domestic Product, CPI = CPI-ATE which is CPI adjusted for taxes on goods and cleared of energy prices (KPI-JAE), NIBOR = 3-month money market rate in Norway, FX = trade-weighted NOK Exchange Rate

The ordering of variables is not always obvious from theory or experience, and thus the robustness of results may be verified by alternating the order of variables in the recursive structure. At times, the ordering of variables that are not of special interest is less important and only partial identification suffices (see e.g. Rey 2015, 304). Once the model appears to be correctly specified, the effect of different shocks can be interpreted by each variable's impulse responses and the overall variance decomposition. Given the length and frequency of the data available, it is possible that the VAR will be overly parameterized; there are too few observations to estimate the large number of parameters, especially if also the lag number is large.

Instead of building the SVAR with the short-run restrictions as shown above, the model used in the thesis could rather be a SVAR with block-exogeneity. It assumes separate systems (blocks) where some blocks are independent of the others, while the dependent blocks take the output of independent blocks as an input. Implicitly, we did this with the short-run restrictions above by ordering the global variables (VIX and TED) on the top. Using blocks means that the independent blocks are independent also with a delay, hence they do not respond at all to the dependent block, with lags or without. Short-run restrictions on the other hand allow response after the first period has lapsed. The benefit of block-exogenous SVARs is that a larger number of variables can be included.

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