ERASMUS UNIVERSITY ROTTERDAM

Erasmus School of Economics

Master Thesis Financial Economics

The Side-Effects of Unconventional Monetary Policy: Has the ECB Driven Up the European Private Equity Sector?

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The views stated in this thesis are those of the author and not necessarily those of the supervisor, second assessor, Erasmus School of Economics or Erasmus University Rotterdam.

Abstract

This paper investigates the effect of unconventional monetary policy by the ECB on private equity fundraising and valuations in the years after the global financial crisis. We further enrich current academic literature by incorporating the aforementioned interpolated private equity variables in standard techniques used to research the effect of unconventional monetary policy in the euro area. We deploy a Bayesian structural vector autoregression model in the period 2015m1-2022m12. We use both the Choleski decomposition and sign restrictions as identification methods and we follow prominent existing literature by including the variables GDP, prices, central bank's assets and the VIX index in our research. We find an insignificant persistent positive effect of unconventional monetary policy on fund NAV indorporating both identification techniques. Additionally, we find an initial positive effect on the fundraising variable, which turns negative and converges to zero. In the research, we generate impulse response functions, we forecast and show the model's coefficients.

Keywords Unconventional monetary policy · Bayesian structural vector autoregression · Structural vector autoregression · Impulse response function · European Central Bank · Zero lower bound · Transmission mechanism

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Acronyms

ABSPP	Asset-Backed Securities Purchase Programme
AIC	Akaike's information criterium
APP	Asset Purchase Programmes
AR	Autoregressive
ATSM	Affine term structure model
AUM	Assets under management
BLS	Bank Lending Survey
BoE	Bank of England
BoJ	Bank of Japan
BVAR	Bayesian vector autoregression
CBPP3	Third Covered Bond Purchase Programme
CSPP	Corporate Sector Purchase Programmes
DAX	Deutscher Aktien Index
DD	Due Diligence
DF	Dickey-Fuller
DFR	Deposit Facility Rate
DSGE	Dynamic stochastic general equilibrium
ECB	European Central Bank
EU	European Union
FCI	Financial conditions index
FED	Federal Reserve
FD	Forward Guidance
FOMC	Federal Open Market Committee
FPE	Final prediction error
GDP	Gross domestic product
GFC	Global Financial Crisis
HCIP	Harmonized index of consumer prices

IRC	Interest rate channel
IRF	Impulse response function
LP	Limited partner
LSAP	Large scale asset purchase
MA	Moving average
MCMC	Markov chain Monte Carlo
MRO	Main refinancing operations
MSM	Markov Switching Model
NAV	Net asset value
NCB	National Central Banks
NIRP	Negative Interest Rate Policy
OLS	Ordinary least squares
OMT	Outright Monetary Transactions
PE	Private Equity
PEF	Private equity funds
PEPP	Pandemic Emergency Purchase Programme
PSPP	Public Sector Purchase Programme
QE	Quantitative easing
SMP	Securities Market Programme
SRTSM	Shadow Rate Term Structure Model
SVAR	Structural vector autoregression
SVEC	Structural vector error correction
TLTRO	Targeted Long-Term Refinancing Operations
UMP	Unconventional monetary policy
VAR	Vector autoregression
VIX	Volatility Index
WHO	World Health Organization
ZLB	Zero lower bound

1 Introduction

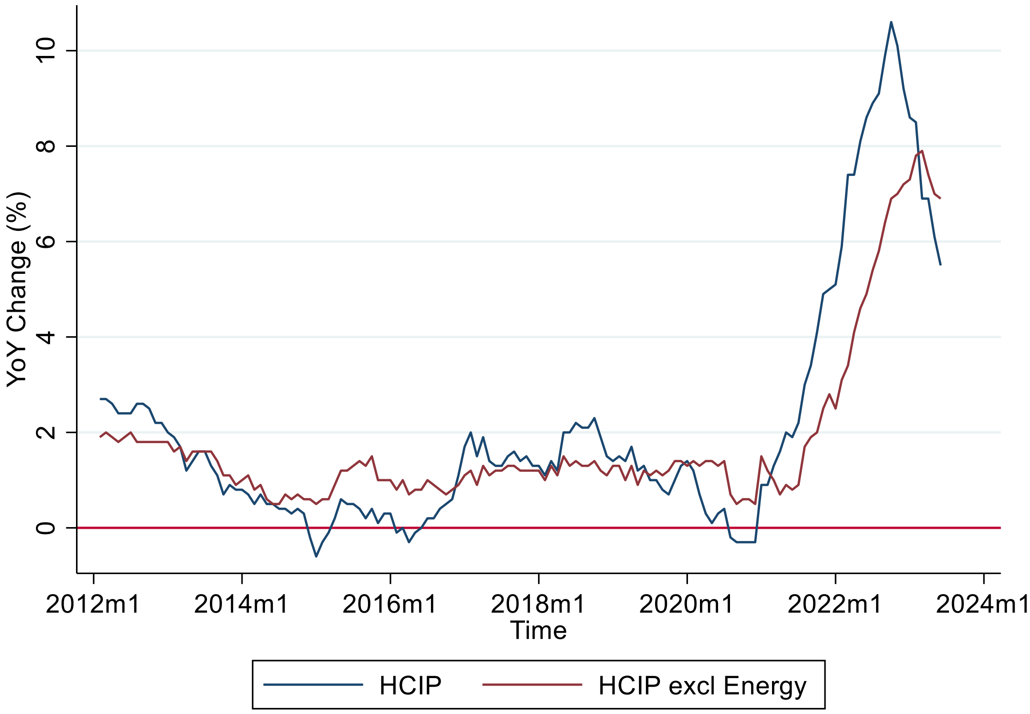
1.1 Context

After the *Global Financial Crisis* (GFC), the *European Central Bank* (ECB), similar to other central banks, tried to keep domestic price developments under control by moving its policy interest rates. The controlling of the Euro area price level is the main task of the ECB. However, during 2014, the ECB introduced a negative interest rate, which meant it became constrained by the *Zero Lower Bound* (ZLB) on this interest rate, which on its turn meant that the conventional way of affecting price levels by the central banks, which is steering the interest rate was deemed an ineffective way to keep prices at a desired level. Now that this conventional way of monetary policy was became ineffective, the ECB increasingly made use unconventional monetary policy measures, which are instruments by central banks that do not depend on operating the nominal interest rate. An example of unconventional monetary policy is *quantitative easing* (QE), a term that quickly popularised post-GFC and is a big topic of debate. The variety of implemented unconventional monetary policies resulted in a large increase of the balance sheet of the ECB.

Monetary policy is a set of tools used by central banks to influence the economy in its respective monetary area by controlling the inter-bank interest rate and it's monetary area's money supply. These monetary policy tools can either be deemed conventional or unconventional. Monetary policy tools generally are aimed to ensure price stability, which is often a central bank's most important task. Monetary policy can either be deemed expansionary or contractionary. Expansionary monetary policy aims to stimulate the economy and is often instigated in times of slow economic growth, while contractionary policy tries to decrease the money supply growth and aims to keep inflation at reasonable levels in times of high economic growth. A conventional expansionary policy is decreasing the interest rate, while a conventional contractionary policy is increasing the interest rate. An example of an unconventional expansionary policy is buying open market securities and an example of unconventional contractionary policy is selling these securities. The difference in effectiveness of both types of monetary policy is a debated topic on itself, Sheedy (2016) finds that unconventional instruments are a poor substitute for the conventional nominal interest rate.

For a long period of time post GFC, the ECB did successfully keep price development in the Euro area relatively in check. There have been some periods of continuous months of deflation and generally, the annual rate of change of the price level in the Euro area was below its target level of two percent, which shows the rationale for the expansionary policies that the ECB implemented over the last decade. However, since roughly the end of 2021 we have seen the flipside of the effect these expansionary policies. We saw a sharp rise of the Euro area interest rate starting in the beginning of 2021. The annual rate of change of the price level started to exceed the ECB's target inflation rate in the middle of 2021 before reaching its local maximum of more than ten percent at the end of 2022. The annual rate of change of Euro area price level has been decreasing since, however is still exceeding the ECB's inflation target of two percent by a significant margin[1]. Figure 1.1.1[2] shows a visual representation of the development of the Euro area price level, post GFC.

Figure 1.1.1 – Visual representation of the development of the Euro area price level (until mid-2023).



The core mechanism through which monetary policy affects the economy and thus, the way in which the ECB tries to keep the Euro area price level under control is called the "*Transmission Mechanism*" (ECB, 2023b). The ECB has set its price stability target at a 2% inflation rate. The mechanism through which the economy is affected by monetary policy contains a set of channels through which can be explained how monetary policy measures can have an effect on the economy. Mishkin (1995) lays out these different channels. The "*Interest*

[1] As of June 2023.

[2] Figure 1.1.1 shows both the HCIP and the HCIP excluding energy. Energy is excluded due to its volatility, specifically during the displayed time period.

Rate Channel" (IRC) is the central transmission mechanism that outlays how monetary contraction transmits to the real economy. Joyce *et al.* (2011) name three main channels through which specifically unconventional monetary policy affects prices of various assets. First of all, the authors note the "*policy signalling effect"*. This channel includes information market participants learn about the future path of monetary policy though QE. For example, because of new QE rounds by a central bank, market participants may form an opinion about the potential continuing of a low policy interest rate. The next channel is the "*portfolio balance effects"*. QE pushes up the prices of the bought assets as well as prices of other assets. If a market participant sells its asset to the central bank it will substitute this asset for another financial asset from another market participant, to rebalance its portfolio, unless if money is a perfect substitute for the bought up asset. This will drive up the price of the newly bought asset and this will go on and on. The last mentioned channel is the "*liquidity premia effect"*. Central banks can improve market functioning of dysfunctional markets by increasing liquidity through actively trading. These three aforementioned channel suggest there should be some effect of unconventional monetary policy by the ECB on the European *private equity* (PE) sector.

1.2 Societal Relevance

Wealth inequality as a result of policy has always been an important and debated topic. After the GFC and during the implementation of worldwide unconventional monetary policy, we saw questions around the distributional effect of unconventional monetary policy appear (Cohan, 2014). While early in its deployment of unconventional monetary policy programmes, we saw the ECB's president Draghi focus on strength of the Euro area, a good example for this is his famous "Whatever it takes" speech from 2012. Later, while concerns for wealth inequality had risen this became an increasingly important topic in Draghi's interactions with press addressing the ECB's monetary policy, like his lecture on May 14th 2015. Worries about the implication on wealth inequality due to unconventional monetary policy were not unsubstantiated. Domanski *et al*. (2016), for example, find an increase in wealth inequality as a result of unconventional monetary policy across a sample of European countries, as well as the United States. Additionally, the authors argue that rising equity prices have a substantial role to play in this effect. Domanski and his co-authors consider equity to be stocks, mutual funds and real estate, which invites the question whether or not the effect will be similar looking at PE. Kozicki *et al.* (2011) name increased financial market distortion, decreased credibility of a central bank and unwanted consequences on macro-economic conditions as three QE risks, again pointing towards a potential interesting side effect of unconventional monetary policy and QE on, for example, the PE sector.

To be able conduct monetary policy successfully and know what effects these policies will have on, for example, financial markets, monetary authorities need the right assessment of the effects of their instigated monetary policies. Research plays a key part in informing and advising policy makers about the mechanism through which their measures are going to affect the economy, directly and indirectly. Policy makers need to be able to learn from potential mistakes to make better informed decisions in the future. This paper aims to assist policy makers by providing more knowledge about the intersection of unconventional monetary policy and private financial investment markets.

1.3 Academic Relevance

Predominantly, academic literature on the effect of unconventional monetary policy has focussed on its effect on factors that dictate size of the economy and its well-being, like GDP and prices[3] most notably. Research on the Euro area, taking into account different time periods, countries or even programmes, has typically shown an increase in both after the implementation an unconventional monetary policy by the ECB, post GFC. Among others, leading papers that show these effects include Darraq-Paries & De Santis (2015) and Mouabbi & Sahuc (2019). In addition, with the advancement and increasing progression of economic and specifically macro-economic modelling, researchers have applied a variety of econometric tests to assess the effectiveness of unconventional monetary policy and find these aforementioned effects. Examples of types of models that are prominent in academic papers are, for example, DSGE and variations of VAR models.

Over time researchers have started to look at the effect of unconventional monetary policy on a broader set of variables. Previously we mentioned the importance of cautiously taking into account various side effects policy measures can have. As mentioned, one set variables these policies can effect are financial markets. Haitsma, *et al.* (2016) show that shocks of both conventional and unconventional monetary policy affect the EURO STOXX 50 index,

[3] Price level initially was included in the empirical section of this paper, due to it being an important part of previous research on the effect of unconventional monetary policy, however due to apparent integration between variables in the model, the variable prices were excluded in the models. A more detailed explanation will follow in the Data & Methodology section of this paper.

with the latter providing stronger effects. Additionally Rogers *et al.* (2014) show a similar result for the "*Deutscher Aktien Index"* (DAX) index.

There are various reasons why there is a larger focus on the public markets in academic research on the effect of monetary policy on financial markets. First of all, publicly listed companies are investable by a larger amount of the public. Entry barriers to investing on the stock market are small, while entry barriers to invest in private companies are extremely high. You generally speaking, need a lot of capital to be able to invest in private companies with your own capital. Secondly, and probably the main reason is the lack of available data. Private investment companies are not required to publicly disclose their (financial) data and results. In practice you see data being collected through *limited partners* (LP)s of investment funds, like pension funds or other types of asset managers, or through the act of self-reporting. Self-reported data on performance however, can be subject to biases due to investment managers not reporting their performance when they deem it not good enough. Additionally, investment firms with underperforming funds might cease to exists due to not being able to raise a consecutive fund. We do not use performance data from sources that incorporate self-reported data and thus believe this research not to be subject to these biases.

1.4 Research Question

In this paper we are looking at the ECB's unconventional monetary policy and its effect specifically on European private investment markets, to establish more information for policy makers about what side effects unconventional monetary policy can have in the Euro area. With this additional research policy makers can make better informed decisions during comparable future macro-economic times. The effect of unconventional monetary policy on the aforementioned European PE markets is our main area of interest and thus, the main research question of this thesis is formulated as follows;

Research Question : *What is the effect of the ECB's unconventional monetary policy on the European private equity sector?*

The variables of interest that we look to weigh this effect on the European PE sector are the European aggregate fundraising level and Euro area fund value. Additionally, we look at the difference of the generated impulse response functions incorporating two different identification techniques, the Choleski decomposition and Uhlig's (2005) sign restrictions. We compare the results of the IRFs of the other included variables with existing literature, which predominantly looks at earlier time periods. We look at the relation between fundraising and fund value in the VAR context, we apply forecasting methods to predict the future direction of the incorporated variables. Lastly, we replace the ECB balance sheet variable by the monetary base variable for robustness purposes.

This thesis is constructed in the following manner. Section two will include the important economic relevant principles and will give a thorough description of all unconventional monetary policy measures deployed by the ECB since the GFC. Following, we will explain all relevant empirical methods to consider when examining the working of unconventional monetary policy. The third section continues with the data description and model specification before laying out the results of this research in section four. Section five concludes the paper along with a discussion of the paper’s limitations and will accordingly provide recommendations for future research.

2. Literature Review

2.1 History of Unconventional Monetary Policy by the ECB

Table 2.1.1 lays out a short description of the ECB's unconventional monetary policy tools we have seen implemented since the GFC. The paragraphs afterwards give extended explanations and add more reasoning to why the ECB has implemented these various unconventional monetary policy tools and lastly those paragraphs include some review of literature written specifically about the discussed monetary policy programmes.

Table 2.2.1 – Monetary policy tools instigated by the ECB since the GFC

Programme	Duration	Definition
Securities Market Programme (SMP)	May 2010 - September 2012	The purchasing of various debt securities in order to ensure depth and liquidity in failing parts of the European debt securities markets (ECB, 2010).
Outright Monetary Transactions (OMT)	September 2012	Commitment by the ECB to purchase risky sovereign debt in Euro area stressed sovereign debt markets (ECB, 2012).
Forward Guidance (FD)	July 2013 –	Signalling of information by the ECB on its future intentions about its own monetary policy (ECB, 2013).
Targeted long-term refinancing operations (TLTRO)	June 2014 - June 2022	Threefold programme that allows the ECB to offer long-term banking loans at favourable conditions which allows said banks to lend to businesses and consumers in the Euro area (2021, ECB).
Negative interest rate policy (NIRP)	June 2014 – July 2022	Negative deposit facility rate introduced by the ECB to incentivise lending from banks into the real economy to achieve its price stability objective (ECB, 2014).
Asset Purchase Programmes (APP)	October 2014 – July 2022[4]	The acquiring, by the ECB, of private and public sector assets at a large scale with the intend to increase lending into the economy (ECB, 2016).

[4] July 2022 marks the end of net purchases, the ECB will continue reinvesting the principal payments from maturing securities purchased under the APP (ECB, 2023).

Pandemic Emergency Purchase Programme (PEPP)	March 2020 – March 2022[5]	Temporary asset purchase programme of private and public sector securities, as a reaction on the COVID-19 crisis (ECB, 2020)

The explanation of the interest rate channel of the monetary transmission mechanism during the introduction showed that central bank use interest rates to approach its desired target inflation rate. However, this channel only works when interest rates are above the ZLB. The ECB reached this ZLB for its short term interest rates in 2014, a more detailed explanation will follow later in this literature review. Because of reaching the ZLB the ECB could not use the aforementioned interest rate channel as a monetary transmission policy tool anymore, as future interest rate cuts were not possible anymore. Afterwards, as long as the ECB's interest rates were negative, conventional monetary policy as transmission mechanism tool got substituted by unconventional monetary policy tools.

Even before reaching the ZLB, but increasingly since, the ECB has been deploying various unconventional monetary policy tools. The "*Securities Markets Programme*" (SMP), which was announced by the ECB's Governing Council in May 2010, was intended to ensure depth and liquidity in failing parts of the European debt securities markets. The tensions in these failing market segments had been hampering the appropriate operating of the monetary policy transmission mechanism and thus the SMP's goal was to restore the working of the transmission mechanism (ECB 2010). The SMP ran from in announcement day of May 10th 2010 to September 6th 2012. On that day the ECB's governing Council decided to terminate the SMP. Existing securities were to be held until maturity.

Resulting in the termination of the SMP, the ECB's Governing Council decided to take on *"Outright Monetary Transactions"* (OMT). This tool, announced in September 2012, was a commitment by the ECB to purchase risky sovereign debt in Euro area stressed sovereign debt markets. Again, the goal of the programme was to preserve the appropriate monetary policy transmission mechanism. (ECB, 2012). The programme followed the ECB's president Mario Draghi's *"Whatever it takes"* speech. For OMT to be activated in Euro area member states a set of four conditions needed to be met. While the instrument was never actually issued

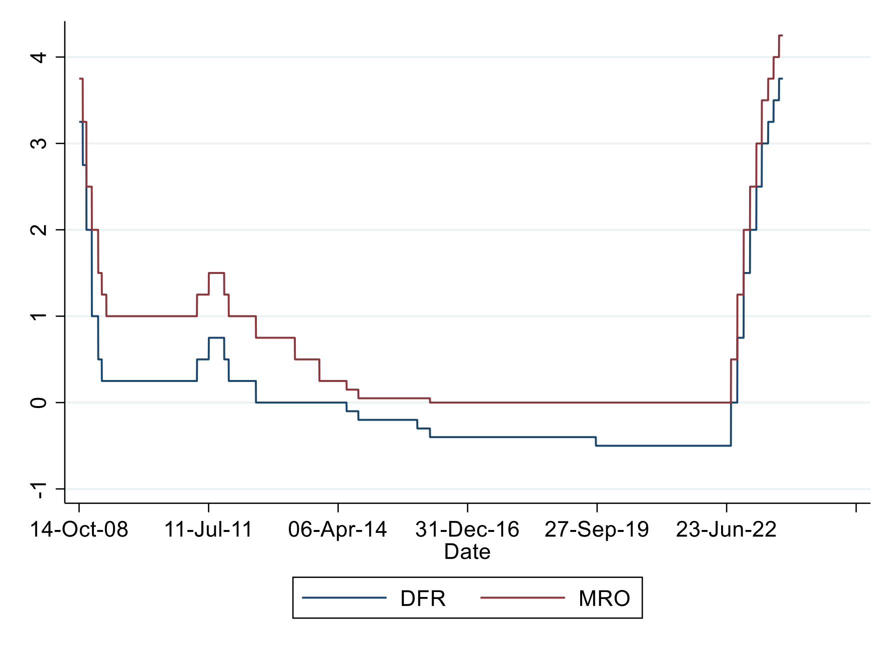
[5] March 2022 marks the end of net asset purchases, the ECB plans to reinvest principal payments from maturing asset purchased under the PEPP until at least the end of 2024 (Böninghausen, Fernández, McCabe, & Schumacher, 2022).

researchers did find that following the announcement of the ECB about the start of OMT, bond spread within the Euro area decreased significantly, making just the announcement of OMT effective (De Grauwe & Ji, 2013).

The third discussed form of unconventional monetary policy, called "*forward guidance*" (FG), has no direct effect on the balance sheet of the ECB. Forward guidance is, the signalling of information by the ECB on its future intentions about its own monetary policy, based on the ECB's assessment of the Euro areas outlook for price stability. The ECB began using this unconventional tool in July 2013, when the Governing Council of the ECB announced it expected interest rates to remain low for a longer period of time. Afterwards, the ECB has used the tool numerous times. The intended mechanism works through the adoption of the interest rates by commercial banks following the guidance by the ECB. Hereafter, businesses and consumers can get cheaper loans, which encourages investment and spending, stimulating economic growth (ECB, 2017). The ECB altered its monetary policy stance by forward guidance at the end of 2021, this was before the first interest rate hikes mid-2022.

In June 2014, the ECB introduced a negative Deposit Facility Rate (DFR), the DFR is the interest rate at which Euro area banks can make overnight deposits with the ECB. Additionally, the ECB set its Main Refinancing operations (MRO) at 0.05 in September 2014. At the time other central banks had already set their MRO close to zero for some years. Figure 2.1.1 shows how the DFR and MRO have developed over time since the GFC. At the time, lowering the DFR into negative territory was a fairly unprecedented move, but not new. Central banks in Switzerland, Denmark and Sweden had applied negative interest rate with relative success before the ECB applied the policy. The timing of the MRO and DFR rates set by the ECB meant that the ECB had not been constrained by the Zero Lower Bound (ZLB) up until the second halve of 2014. Later, other central banks of the larger scale monetary areas, like the FED, followed entering their DFR into negative territories, with their own *Negative Interest Rate Policy* (NIRP). Negative bank lending rates had the goal to incentivise lending from banks into the real economy to achieve its price stability objective (ECB, 2014). Since 2014 the ECB has cut the DFR into negative territory 5 times since 2014. The last time that happened was in 2019 (Boucinha & Burlon, 2020). Following the rampant inflation we saw in the beginning of 2022, ECB raised its DFR with 50 basis points out of negative territory in July 2022 marking the end, for now, of NIRP. Afterwards, we have seen multiple ECB interest rate hikes following each other. In chronological order, the ECB raised its DFR by 75 basis points in September 2022, another 75 basis points in November 2022. Following the November 2022 hike we saw three 50 basis point hikes in respectively, December 2022, February 2023 and March 2023. Lastly, the ECB raised the DFR with 25 basis points in May 2023[6] (ECB, 2023).

Figure 2.2.1 – DFR and MRO since the GFC.



We have seen that the ECB started using unconventional monetary policy measures extensively after its DFR decreased below, and its MRO approached the ZLB. Important to notice is that thus, up until the second halve of 2014, unconventional monetary policy merely was a supplement, to conventional monetary policy, instead of a necessity (Cour-Thimann & Winkler, 2012). Traditional standard economic theory tells us negative interest rates mean there is an infinite demand for money. Historically, the Keynesian school of thought has argued the ineffectiveness of negative interest rates as a monetary policy tool, using the liquidity trap. The liquidity trap can be defined as a circumstance in which conventional monetary policy measures are unsuccessful, because interest rates are at or near zero and deposits and bonds are seen as substitutes by consumers. Increasing the money supply has no desired effect in this situation. Figure 2.3.1 visually shows the liquidity trap. When interest rates are equal to zero, the demand for money becomes horizontal and further increases in the supply of money do not affect the interest rate level (Blanchard, *et al.,* 2010).

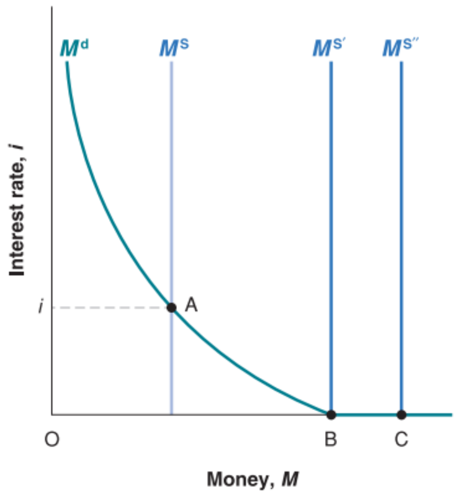
Keynes himself argued about the ineffectiveness of monetary policy in his crown jewel *The General Theory of Employment, Interest Rates and Money* (1936). In his work Keynes argued, quote;

[6] As of June 2023.

"There is the possibility...that, after the rate of interest has fallen to a certain level, liquidity-preference may become virtually absolute in the sense that almost everyone prefers cash to holding a debt which yields so low a rate of interest. In this event the monetary authority would have lost effective control over the rate of interest. But whilst this limiting case might become practically important in future, I know of no example of it hitherto".

Keynes's thoughts were extended by John Hicks (1937), who argued that if the cost of holding money is to be neglected, it is always superior to hold this money instead of lending it out, when the interest rate is zero. Therefore the interest rate must be always positive. Krugman (1998) concludes that once an economy is in an liquidity trap conventional macroeconomic wisdoms stop to apply, resulting in some unconventional conclusions. Krugman shows that once a cash-in-advance constrained no longer holds, interest rates go to zero, however do not decrease further as consumers prefer to hold money instead of borrowing at a lower rate.

Figure 2.3.1 – The liquidity trap[7]



Together with its NIRP policy, the ECB introduced Targeted Long-Term Refinancing Operations (TLTRO)s in June 2014. Through TLTRO, which has been launched threefold; namely, TLTRO I in 2014, TLTRO II in 2016 and TLTRO III in 2019, the ECB could offer long term banking loans at favourable conditions which allows said banks to lend to businesses and consumers in the Euro area (2021, ECB). In November 2022, the ECB recalibrated its TLTRO III operations by indexing the interest rate on all remaining TLTRO III operations to the average

[7] Source: Blanchard, Amighini and Giavazzi (2010)

key ECB interest rates. The goal of this recalibration was, again, to ensure price stability in the Euro area and to return inflation to the ECB's 2% minimum target (ECB,2022).

Darracq-Paries & De Santis (2015) apply a panel VAR methodology to research the effect of TLTRO on GDP and prices. Singling out a specific prrogramme requires more advanced identification techniques than for example is applied in this research, as it is hard to distinguish the shock of a specific policy. The autohors identify a monetary policy shock through the *Bank Lending Survey* (BLS), by applying sign restrictions on the BLS demand and supply factor as well as all other variables in the model. With their research the authors extend on exisitng literature by looking at the effect of the programme beyond its effect on credit supply and demand. Following research that show similar effects of TLTRO inlcude Balfoussia and Heather (2016), who apply a VAR framework, without structural identification restrictions, proxying GDP by industrial production, among others. Proxying GDP by indstrial production is common in the literature and is also done in this research. The authors build on Angelopoulou, Balfoussia, and Gibson (2014) by constructing a *Financial conditions index* (FCI). The methodology assumes that the full amount of liquidity allocated to euro area banks is funneled to loans in the private sector. This methodolog therefore does not require to impose identifying restritions to distinguish shocks and therefore differs significantly from the SVAR approach applied in this research.

In October 2014, the ECB started with its large scale Asset Purchase Programmes (APP). Within these programmes the ECB acquired private and public sector assets at a large scale with the intend to increase lending into the economy (ECB, 2016). The working of the policy is twofold, firstly, directly by buying assets from financial institutions like banks and pension funds, who facilitate credit into the economy and secondly through banks lending part of their increased deposits from investors, who on their turn have sold assets to the ECB, to businesses (Finnegan & Kapoor, 2023). APP consists of four different programmes; *Corporate Sector Purchase Programme* (CSPP), *Public Sector Purchase Programme* (PSPP), *Asset-Backed Securities Purchase Programme* (ABSPP) and the *Third Covered Bond Purchase Programme* (CBPP3). Of these, the PSPP accounted for the largest increases of the ECB's balance sheet, totalling more than 2500 billion euros, with the total stock of APP standing at 3403 billion Euros by the end of April 2023.

On March 18th 2020, just 5 days after the *World Health Organization* (WHO) declared Europe as the epicentre of the COVID-19 pandemic, the ECB's Governing Council announced the start of a the *Pandemic Emergency Purchase Programme* (PEPP), which goal was to counter the risk to the monetary policy transmission mechanism COVID-19 outbreak would impose in the Euro area (ECB, 2023). Initially, the ECB announced a purchase package of €750 billion, the duration of the plan was set until the end of 2020, however the announcement did include the notion that the Governing Council will terminate the net asset purchases under PEPP when it judges that the COVID-19 crisis is over, but in any case not before the end of the year (ECB, 2020). The PEPP includes all asset categories that were already eligible under the ECB's existing APP.

The macro-economic effects of all these programmes have been studied extensively in recent years. Empirical research has constantly shown a positive effect of unconventional monetary policy by the ECB on the key variables GDP and prices. A core research methodology and the methodology applied in this research, used to empirically investigate the effect of these policies is called SVAR.

2.2 SVAR Methodology

In order to analyse the effect of monetary policy, researches use *Structural Vector Autoregressive* (SVAR) models. SVAR models were first popularized by Christopher Sims (1972 & 1980). In basis SVAR models are statistical models used in academic research in order to capture the effect of multiple endogenous variables over time. In these SVAR models, the included variables are treated as endogenous (Canova & Ciccarelli, 2013). SVAR models are an extension over standard *Vector Autoregressive* (VAR) models. The key attribute of a SVAR models, and where these are an enhancement over standard VAR models, is that these SVAR models impose key restrictions and set conditions as to how certain variables would behave and would react to each other, which is important when trying to capture the exogenous shock of an implemented monetary policy tool, something we are going to have to deal with later. More about this will follow in the paragraphs about identification.

Although the application SVAR methodology is fairly young, it has seen extensive development and a significant amount of use cases in recent decades. After the aforementioned introduction of the methodology by Sims, the SVAR methodology started getting used as a tool for analysing specific macroeconomic disturbances like the 1990 – 1991 US recession (Blanchard, 1993) and (Walsh, 1993) or the behaviour of US business cycles more generally, referring to articles published before 1990 (Blanchard & Watson, 1986), (Shapiro & Watson, 1988) and (Blanchard & Quah, 1988). Soon after the methodology got extended to other monetary areas like Japan (Hutchison & Carl, 1992) and Australia (Moreno, 1992). Lee &

Pesaran (1993) extended the literature not by considering information from multiple macro-eceonomic variables within an economy, like the all the previous referred to articles, but rather considering multiple sectors within an economy. Following, Koop, Pesaran & Potter (1996) proposed to combine both this multivariate and multi sector approaches within the literature. Generally papers in this time deal with the challenge of identifying a shock by putting zero restrictions on the A matrix. The researchers limit the potential of certain variables to have a contemporaneous effect on other variables in the model. In this research we follow this early methodology by applying the Choleski decomposition as an identification technique. A more detailed explanation of the working of the Choleksi decomposition will follow later in this literature review as well as in the methodology section of this paper.

While early macroeconomic research, like all the aforementioned papers, applying VAR methodology focussed on intra-country effects, the research developed when researches started looking at intercountry effects. Presumably the earliest significant example of this is Gerlach and Smets (1995a) (Dominguez-Torres & Hierro, 2019). Gerlach and Smets research the effectiveness of monetary policy in the G-7 countries using three variables; output, prices and short-term interest rate. Contrary to our research, Gerlach and Smets do not include the VIX index yet in their research, the VIX index would later be introduced in academic literature on monetary policy in order to assist in identifying monetary policy shocks. Additionally, while we do not look at cross-country effects in this research we do recognise the potential for further research on the cross-country effects of unconventional monetary policy shocks. Additionally Gerlach and Smets (1995b) research the contagion effects of speculative effects on fixed exchange rate regimes in Finland and Sweden during the foreign exchange rate crisis between August 1992 and August 1993. With this research the authors follow the theoretical model proposed by Flood and Garber (1984). Flood and Garber's leading work showed two situations which can lead to the collapse of a fixed exchange rate regime. In one, an unpredictable and cataclysmic event leads to the fall and in the second a series smaller disturbances leads to the collapse of the fixed exchange rate regime.

The paper by Gerlach and Smets (1995a), as well as many other released papers in the mid-nineties follow a series of very influential papers on understanding monetary policy stances. These papers include Bernanke and Blinder (1990) and Christiano, Eichenbaum and Evans (1994), which both are early contributions to research to understand monetary policy stances. Bernanke and Blinder were leaders in the research by acknowledging the explanatory functionality of the federal funds rate to understand the application of monetary policy by policy makers. During this time, economists increasingly tried to better understand monetary policy. An example of a research movement with the indication of understanding monetary policy stance during this time is the narrative approach presented by Romer and Romer (1989). In their nonparametric paper, which is fittingly called; "*Does Monetary Policy Matter? A New Test in the Spirit of Friedman and Schwartz"*, the authors follow the narrative approach theory introduced by Friedman and Schwartz (1963). Romer and Romer identify the instances monetary policy makers shift their monetary policy stance by looking at the minutes released by the *Federal Open Market Committee* (FOMC). While the methodology has advantages due to its simplicity, it is limited by its subjectiveness and its difficulty in distinguishing between exogeneous and endogenous components of monetary policy (Bernanke & Mihov, 1995). While the approach of Romer and Romer (1989) is non-parametric, during this time extensive progress is made in paratmetric research on understanding monteary stances. We acknowledge that the work by Bernanke and Blinder (1990) and Christiano, Eichenbaum and Evans (1994) has become extremely influencial in the way researchers understand montary policy stances by policy makers is. Additionally it serves as a building block for the follwing research on the effect of conventional monetary policy and therefore also unconventional monetary policy.

One of the leading papers that has followed the movement of understanding monetary policy stances by looking at the central bank's interest rate is the aforereferred to article by Bernanke & Mihov, 1995). Bernanke and Mihov find that innovations to the federal funds rate are good means of policy innovations in the periods 1965-1979 and 1988-1994. Additionally, the authors find that these monetary policy shocks lead to reasonably and precisely estimated responses to variables like GDP. Academics started using the paper by Bernanke and Mihov, as well as other leading papers durign this time, as a benchmark for further research. During this time and basically throughout the literature on monetary policy applyign SVAR methodology, the identification problem was of significant importance. Bernanke and Mohov are credited due to their ability to reconclile a number of leading researches at the time like Christiano, Eichenbaum and Evans (1994) and Strongin (1992) and develop a unifying framework which would serve as a benchmark for further research on the topic. Bernanke and Mihov discuss the shortcoming of not discussing thoroughly on non-policy equations of the forementioned papers. Bernanke and Mihov provide economic interpretations for the banking sector equations. Through these interpretations restrictions can be placed in the model (Leeper, Sims, Zha, & Hall, 1996). Additionally, Leeper, Sims, Zha and Hall makes signifcant contribution to the literature by delving deeper into the identification probelem. The authors incorporate three sorts of identifying restrictions. First of all, the authors set certain elements of the *A-matrix* to zero. Secondly, Leeper *et al.* use a probabilistic assertions about elements of A. Lastly the authors impose informal restrictions on the reasonableness of the impusle response functions. With this last condition Leeper *et al.* bound themselves to existing common theory about monetary contractions and its effect on the federal funds rate, output, prices. This line of thinking would later by disputed by Uhlig (2005)

During this time, the research on monetary policy was evolved to the extent that the literature had reached a "healthy" state as described by Uhlig (2005). The research methodology which was introduced by Sims (1972, 1980) and evolved rapidly in just a few decades . Uhlig (2005), while recognising the value of the existing literature, raises caution about the circularity around conclusions in the literature. Uhlig states that common theory in undergraduate textbooks runs the following; a monetary contraction should raise the federal funds rate, lower prices and reduce real output. If the identification scheme does not satisfy this, than the responses are deemed a puzzle, while it is deemed a success when the scheme does follow the theory. Uhlig warns about blindly following this reasoning. Uhlig proposes a new "agnostic" identification method by imposing sign restrictions on the variables included in the model. Uhlig's work would lay a basis for future research on the effect of monetary policy, including this paper. Another significant paper, which builds on the work of Uhlig, on the effect on monetary policy is the paper by Gambacorta *et al.* (2012). We largely follow Gambacorta *et al.* (2012) with the methods we impose, however we do add additional PE variables to the models. Additionally Gambacorta *et al.* (2012) apply a panel VAR, while we specifically look at the Euro area. The methodology section we will further elaborate on the way we follow Gambacorta *et al.* (2012).

During section 2.1 we elaborated on the need for unconventional monetary policy at the ZLB. Now that we have noted on significant literature analysing the effect of monetary policy, we will look at some of the math associated with SVAR methodology.

To illustrate further the working of a (S)VAR model, consider the following basic VAR(1) model with three endogeneous macro-economic variables, y_{1t}, y_{2t} & y_{3t} (Note: these are theoretical variables they do not represent real life macro-economic variables). We assume a lag order of p = 1. As we are first looking at VAR models we assume for now that these endogeneous variables do not have the abbility to have a contemporaneous effect on eachother. The system for this VAR model is the following;

$$y_{1t} = a_1 + b_{11}y_{1t-1} + \ b_{12}y_{2t-1} + b_{13}y_{3t-1} + \varepsilon_{1t} \qquad (1)$$

$$y_{2t} = a_2 \ + b_{21}y_{1t-1} + \ b_{22}y_{2t-1} + b_{23}y_{3t-1} + \varepsilon_{2t} \qquad (2)$$

$$y_{3t} = a_3 \ + b_{31}y_{1t-1} + \ b_{32}y_{2t-1} + \ b_{33}y_{3t-1} + \varepsilon_{3t} \qquad (3)$$

We assume the error terms are uncorolated and thus we can see in this system is that the endogenerous variables y_{1t}, y_{2t} & y_{3t} do not affect eachother, except in with their lagged values. Additionally we can see that that the error terms only effect the endogeneous variables in their own equation. We can write the above system in the following compact matrix notation;

$$Y_t = \ A + BZ_{t-1} + E \qquad (4)$$

Where vector Y consists of two variable x and y, and is notated by $Y_t = \begin{bmatrix} y_{1t} \\ y_{2t} \\ y_{3t} \end{bmatrix}$, A, a vector of intercepts with three parameters and BZ_{t-1}, a matrix of $k \times p^2$ or $1 \times 3^2 = 9$ parameters in front of a vector of lags, lastly, E is a vector of error terms, with the assumption $\varepsilon_i \ = N(0, \Omega)$ with $p(p+1) \ / \ 2$ or $3(3+1) \ / \ 2 = 6$ parameters in the covariance matrix, **Ω**. We can unfold this matrix notation and write the VAR model the following;

$$\begin{bmatrix} y_{1t} \\ y_{2t} \\ y_{3t} \end{bmatrix} = \begin{bmatrix} a_1 \\ a_2 \\ a_3 \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} \begin{bmatrix} y_{1t-1} \\ y_{2t-1} \\ y_{3t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{bmatrix} \qquad (5)$$

With, $\Omega \ = \begin{bmatrix} \Omega_{11} & \Omega_{12} & \Omega_{13} \\ \Omega_{12} & \Omega_{22} & \Omega_{23} \\ \Omega_{13} & \Omega_{23} & \Omega_{33} \end{bmatrix}$, which captures all the contemporaneous effects of the model and are given by correlations between the residuals in the model. These are all set at zero in the currently described situation. The additional parameters totals the amount to 18. The parameters are given by;

$$\theta = \{a_{1,}a_2, a_3, b_{11}, b_{12}, b_{13}, b_{21}, b_{22}, b_{23}, b_{31}, b_{32}, b_{33}, \Omega_{11}, \Omega_{12}, \Omega_{13}, \Omega_{22}, \Omega_{23,} \ \Omega_{33}\} \qquad (6)$$

These 18 parameters are difficult to interpret, however we can interpret the coefficients by looking at what happens to the variables in Y_t when there is a shock to the error term in time t. This action is called an impulse response analysis. If we allow a variable to have a contemporaneous effect on another variable we would see an instant response as well as dynamic response over time. To show these effects mathematically we consider thr VAR model in the following MA form.

$$Y_t = \varepsilon_t + C_1\varepsilon_{t-1} + C_2\varepsilon_{t-2} + \cdots + C_{t-1}\varepsilon_t + C_0 \quad (7)$$

We differentiate with respect to the error term to see what happens to a specific variables when there is a shock to this error term and find that;

$$\frac{dY_t}{d\varepsilon'_t} = I_p, \quad \frac{dY_{t+1}}{d\varepsilon'_t} = C_1, \ldots$$

where I_p is an identity matrix containing ones in the diagonal and zeros elsewhere if we assume no contemporaneous effect. C_t shows what happens to the variables in $\mathrm{Y_t}$ at time t. The derivatives we find when differentiating can be represented in the aforementioned *impulse response function* (IRF) graphs.

Evidently, no contemporaneous effect in a real world is improbable as error terms are often correlated, which is captured by the aforenoted omega matrix. To be able to capture the contemporaneous effect[8], we can write the model as the following structural form, where the errors in vector U are uncorrelated.

$$\begin{bmatrix} 1 & -\omega_{12} & -\omega_{13} \\ -\omega_{21} & 1 & -\omega_{23} \\ -\omega_{31} & -\omega_{32} & 1 \end{bmatrix} \begin{bmatrix} y_{1t} \\ y_{2t} \\ y_{3t} \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} \begin{bmatrix} y_{1t-1} \\ y_{2t-1} \\ y_{3t-1} \end{bmatrix} + \begin{bmatrix} u_{1t} \\ u_{2t} \\ u_{3t} \end{bmatrix} \quad (8)$$

Additionally, researchers have applied the Bayesian approach to VAR models. The BVAR methodology was first introduced by Doan, Litterman and Sims (1984) and Litterman (1986). Some leading papers using the Bayesian approach and making the method considerable for application in this research are Schenkelberg & Watzka (2011) and Weale & Wieladek (2016), both of which provide guidance in order to better understand of the workings of SVAR/ BVAR and identification. The Bayes Theorem, which describes the probability of an event based on previous knowledge about the conditions surrounding this event, lays at the basis of Bayesian statistics. The Bayesian view opposes the frequentist view, in which this prior knowledge about the event is disregarded. The stationarity tests that follow in this thesis are examples of tests following frequentist methods. In regards to VAR modelling, the Bayesian approach aims to deal with the standard problem of overparameterization of VAR models. The approach does this by the entering of a prior. The prior introduced by Litterman, also called the Minnesota prior or the Litterman prior, carries information about the long run properties of the data, which are independent from the short run observed data. Introducing the prior assists with improving the precision forecast of VAR Models (Litterman, 1986). The Minnesota prior is

[8] We will show why these contemporaneous effects are relevant in the following Identification section.

centred around the idea that variables follow a random walk process. The Bayesian approach helps to deal with non-stationarity problems within a model. Zapata & Garcia (1990), analysing the prediction power of models looking at U.S. cattle prices, find a better performance of BVAR models over standard VAR models when there is a presence of unit root stochastic processes, which is often the case when dealing with macro-economic variables. The prior, which parameters, Lambda and Theta, are chosen by the researcher, together with the actual data form the posterior distribution of the model. Another example of a prior implemented in the Literature is the Normal inverted-Wishart prior.

A common sampling method applied when dealing with Bayesian methods is the use of *Monte Carlo Markov Chain* (MCMC). Monte Carlo is the practice of estimating the properties of a distribution by examining random samples from the distribution (Van Ravenzwaaij *et al.,* 2018). A Monte Carlo simulation is drawing a large sample from a distribution and calculating the averages from those samples and thus, gathering your best guess to the average of the distribution. The Markov Chain of the Monte Carlo is the idea that random samples are generated by a sequential process, each sample is used as a stepping stone to the next random sample. These new samples only depend on the last drawn sample not those before the last drawn sample.

We have mentioned the problem of identification throughout the literature review. But how does one actually identify monetary policy shocks? We will now denote the two identification methods that we use in this paper.

Without capturing this exogeneous shock you cannot make claims about the effect a policy has had on certain macroeconomic variables. The process of capturing this exogeneous shock is called identification. Two common ways that appear in academic literature on monetary policy. Namely, the Choleski decomposition method and sign restrictions as proposed by Uhlig (2005). Identification requires some a priori theoretical thinking about the variables included in the model. No tests provide you with the correct answer about in what ways the variables included in the model effect each other, instead the author must be able to reason their decision making based on existing economic theory and a priori thinking

The historically standard applied method of identification, the Choleski decomposition method, which was introduced in the aforementioned Christopher Sims paper from 1980 and further popularized by leading macro-economic papers like the aforementioned Christiano *et al.* (1998) paper, lays zero restrictions on the contemporaneous estimates of the variance –

covariance matrix by ordering the endogenous variables in the model. The ordering of the variables is crucial, as it decides which endogenous variables can effect each other in the current period.

To illustrate we reintroduce our theoretical SVAR model with three endogenous variable, namely y_{1t}, y_{2t} & y_{3t}. A denotation of $\{y_{1t},\ y_{2t},\ y_{3t}\}$ illustrates that endogenous variable y_1 has a contemporaneous effect on variables y_2 and y_3. Additionally, variable y_2 has a contemporaneous effect on y_3. Lastly, variable y_3 does not have a contemporaneous effect on the other endogenous variables in the model. To show the working of the Choleski decomposition visually let us look back at our example model and specifically equation 8. If we apply the Choleski decomposition we can write our example model as;

$$\begin{bmatrix} 1 & 0 & 0 \\ -\omega_{21} & 1 & 0 \\ -\omega_{31} & -\omega_{32} & 1 \end{bmatrix} \begin{bmatrix} y_{1t} \\ y_{2t} \\ y_{3t} \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} \begin{bmatrix} y_{1t-1} \\ y_{2t-1} \\ y_{3t-1} \end{bmatrix} + \begin{bmatrix} u_{1t} \\ u_{2t} \\ u_{3t} \end{bmatrix} \qquad (9)$$

In the early days of academic research on the effect of monetary policy, the Choleski decomposition method was the standard identification technique. However the research progressed and new, more sophisticated, identification techniques got introduced. The next identification method we look at is Uhlig's (2005) sign restrictions approach. Uhlig's approach to identification involves putting sign restrictions on impulse responses of the monetary policy variable. Again, theoretical reasoning is needed to come up with the way variables react to a monetary policy shock. There is no check for the correctness of the sign restrictions. The correctness is evaluated by the reasonability of the impulse responses they produce. The researcher preferably needs to make these restrictions according to conventional wisdoms (Uhlig, 2005). Consider again three variables A, B and C. If, according to standard economic theory a contraction in monetary policy variable A, raises variable B and decreases variable C, the chosen identification scheme by the researcher should reflect these relationships. Equation 10 represents a model with randomly chosen sing and zero restrictions.

$$\begin{bmatrix} 1 & -\omega_{21} & 0 \\ \omega_{21} & 1 & 0 \\ -\omega_{31} & 0 & 1 \end{bmatrix} \begin{bmatrix} y_{1t} \\ y_{2t} \\ y_{3t} \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} \begin{bmatrix} y_{1t-1} \\ y_{2t-1} \\ y_{3t-1} \end{bmatrix} + \begin{bmatrix} u_{1t} \\ u_{2t} \\ u_{3t} \end{bmatrix} \qquad (10)$$

Recently, the effectiveness or even rightfulness of the sign restriction method has also been subject to judgement and criticism. Elbourne & Ji (2019) show that the identification scheme applied in the aforementioned papers does not rightfully recover unconventional monetary policy shocks by replacing numbers on the balance sheet and switching sign restrictions. The authors put forward an alternate identification scheme incorporating future rates resulting in credibly identified shocks. Applying this identification scheme, the authors do not find evidence that unconventional monetary policy has successfully been affecting the real economy, contrary to what earlier research has suggested. In Boeckx *et al*. (2019), the authors respond to Elbourne & Ji and show that, both for switching the directions of the restrictions and replacing balance sheet with random numbers, gathering similar results is not surprising. Additionally the authors argue that the low correlation with obtained shocks using high frequency data can be explained by both shocks capturing monetary policy to a different extent. Namely, the one captures balance sheet policy, the other forward guidance

2.3 Alternative Economic Models Applied

Now that we have looked at SVAR methodology we will introduce other methodologies, as researchers have applied various other econometric models in order to analyse the effect and efficiency of implemented unconventional monetary policy tools. In this research we have focussed on a certain division of this group of models, variations of the VAR model, however to argue the use of these kind of models we ought to present the alternatives and discuss limitations to exemplify the choice of our model.

The relevant model that dates back the furthest in adamic literature is the *Dynamic Stochastic General Equilibrium* (DSGE). The DSGE model, which use originated in 1980s, got developed as a reaction to the practical failure of neo-Keynasian models as a forecasting tools. The main criticism to these neo-Kaynesian models is known as the Lucas critique (Slanicay, 2014). The Lucas Critique, named after American Nobel laureate states it is naïve to try to fully predict the effects of monetary policy based on historical data. Among others, the DSGE model has been applied by Gertler & Karadi (2013), who find an increase of GDP and prices after both QE1, the FED's initial response to the fall of Lehman Brothers in 2008 and QE2, the FED's second round of quantitative easing late 2010, applying a DSGE model. Likewise, Chen *et al.* (2012) find an increase in GDP and prices following QE 2, applying a DSGE model. Analysing the Euro area, Cahn, Matheron & Suvac find an increase in GDP following LTRO, Andrade *et al*. (2016) find an increase in GDP an prices as an effect of APP, both using DSGE models. Nobel laureate Joseph Stiglitz (2018) presents critiques of DSGE models, based on their inability to predict and provide guidance for appropriate policy responses, respectively leading up to and following the GFC. We therefore disregard applying the model in this research.

The second econometric model to discuss when looking at econometric models applied for measuring the effectiveness of monetary policy is the *Shadow Rate Term Structure Model* (SRTSM). SRTSM models follow the more classical *Gaugasian Arbitrage-free Affine Term Structure Models* (ATSM), which incorporate linear Gaussian factor dynamics as driving forces. The model differs due to the shadow short rate s_t being driven by the aforementioned factors rather than the actual short term interest rate r_t ATSMs models themselves would imply interest rates significantly going into negative territories and fail to accordingly take account of the inherent asymmetry in low interest-rate situations (Lemke & Valdu, 2016). The article by Lemke & Valdu is the first application of SRTSM models in the Euro area. The model had predominantly been applied on the Japan economy up until then. Key authors applying SRTSM models to analyse the effect of unconventional monetary policy are Wu and Xia. In their 2015 paper they find a reduction of 0.13 after implementation of unconventional monetary by the FED. Furthermore the authors extend their research in their 2018 paper looking at effectiveness of NIRP. SRTSM models are effective when looking specifically at NIRP, however logically cannot be implemented as research methodology analysing asset purchases and other non-interest rate monetary policy measures. Another alternative model, the *Structural Vector Error Correction* (SVEC) model, will be introduced in the Data & Methodology section of this paper.

2.4 The Effect of Monetary Policy on Asset Markets

Until now, the literature review has primarily introduced relevant methods, topics and policies the reader should understand with regards to research around the topic of unconventional monetary policy by the ECB. However we have not yet been able to form a hypothesis about our introduced PE variables. Because this research, to our knowledge, is unique by introducing two PE related variables into VAR related monetary policy research, we lack papers to compare results with. Therefore, we look at other investment asset classes and see what effect unconventional monetary policy has had on those asset classes.

Generally speaking investors have a wide choice when deciding in what asset classes to distribute their capital. However, most (retail) public market investors do not see PE as a substitute for public market investing due to the high entry barriers and the unavailability to invest in PE without significant capital available. Contrary, public market investing is a substitute for PE LPs. Investment portfolios of institutional investors, like pension funds for example, often consist of both public market assets and private market assets, which can be PE funds. We therefore consider public market as a good comparison and indicator of the response of PE variables to monetary policy shocks and continue by review papers looking at the effect of monetary policy on public asset classes.

Generally speaking the existing academic literature agrees that the effects of unconventional monetary policy on asset prices are sizable (Rossi, 2018). Rogers *et al.* (2014), performing a SVAR analysis, research the effect of unconventional monetary policy in the four major monetary unions in the world. Interestingly, the authors find a reduced pass-through effect of unconventional monetary policy into asset prices through government bond yields, in the Euro area versus the other monetary unions. Additionally Fratzscher *et al.* (2016), who looked at the financial markets impact of unconventional monetary policy between 2007 and 2012, find that the ECB's policy enhanced Euro area equity prices. Important to notice is the fact that this research was performed at a time the ZLB had not been reached yet. After having review the literature and before starting to do our own empirical research we hypothesise that the effect of unconventional monetary policy on our PE variables will be significantly positive. However the effects will probably less responsive due to the fact private markets respond slower.

3 Data & Methodology

In the previous section we have explained important theoretical economic concepts, looked at the unconventional monetary policy tools implemented by the ECB and discussed the relevant literature about the topic. We will now present our models, starting by introducing the variables included in the model.

3.1 Data & Model

In total we look at six endogenous variables. The first four variables in the model are included following the aforementioned paper by Gambacorta *et al.* (2012),[10] "The Effectiveness of Unconventional Monetary Policy at the Zero Lower Bound: A Cross-Country Analysis". Gambacorta *et al.* (2012) included four endogenous variables in their models, namely GDP, Prices, the VIX index and lastly assets on the ECB balance sheet. We proxy real GDP by industrial production and Prices by the HCIP following Peersman (2011). Industrial production, HCIP and the assets on the ECB balance sheet are retrieved from Statistical Data Warehouse, the VIX index's European version is called the VSTOXX. VSTOXX measures the implied volatility of the Eurostoxx50, which is an index of the 50 largest European public companies' near term options. VSTOXX is retrievable online from various sources. We add two variables to the model proposed by Gambacorta *et al.* (2012). These two variables are European PE fundraising and Euro area PE NAV. The fundraising data is retrieved from Preqin and is collected on a quarterly basis. PE investment fund data is retrieved from Statistical Data Warehouse. The data is captured by the ECB through *National Central Banks* (NCBs) reporting the data to the ECB. The ECB's Guideline (EU) 2021/831 cites which data is collected and how this data is collected. The guideline states the following "Private equity funds (PEFs) are unleveraged investment funds that predominantly invest in equity instruments and instruments that are economically similar to equity instruments issued by unlisted companies." Lastly we incorporate a variable as a replacement for the ECB's balance sheet variable for robustness check purposes. This variable is the monetary base variable denoted by MON. The monetary base is also retrieved from Statistical Data Warehouse. With including monetary base as a

[10] While we closely follow Gambacorta *et al.* (2012), we do defer from the paper by applying Bayesian methods. Gambacorta *et al.* (2012) fit a more standard SVAR model. We include the same variables and even incorporate the same proxies and will find non-stationarity. We therefore believe the model by Gambacorta *et al.* (2012) should suffer from non-stationarity by including these variables. We will thus apply Bayesian methods to VAR modelling. A more detailed explanation will follow.

replacement for the ECB's balance sheet, we follow Peersman (2011). All seven variables are shown in table 3.1.1.

Table 3.1.1 – Description of endogenous variables included in the model

Name	Label	Description
Gross Domestic Product	GDP	Industrial production as a proxy for GDP
Prices	PRC	HCIP as a proxy for prices
The VIX Index	VIX	The Eurostoxx 50 implied volatility index VSTOXX
ECB Assets	ASS	Total assets on the balance sheet of the ECB
European Private Equity Fundraising	RSG	Aggregate Private Equity fundraising in Europe
Euro area Private Equity Fund NAV	NAV	Aggregate Private Equity fund value in the Euro area
Monetary Base	MON	Euro area Monetary Base

While we have looked at the seven above shown variables, and the early part of the research includes all mentioned variables, we did not include them all in the eventual models. Estimating models including the prices variables returned error codes due to the variable being integrated. Hereafter we decided to drop the variable for the latter part of the research. We argue that, while prices, of course, is an extremely important variable in the context of unconventional monetary policy, it is not one of our variables of particular interest. Additionally, referring to the article by Gambacorta *et al.* (2012) a minus or plus sign is not imposed on the variable to identify an unconventional monetary policy shock using the balance sheet of the ECB or the monetary base for that matter.

The sample duration highlighted in this research is 2015m1-2022m12[11]. The restricting factor in the collection of the data is the availability of PE data. European fundraising data on Preqin is available quarterly starting from 2013q1, while the Statistical Data Warehouse data on PE investment funds is available quarterly starting from 2015q1. After collecting the data we will start by examining the possibility of stationarity within variables in our data set

[11] Using monthly data is the most common approach in academic literature on unconventional monetary policy, however this does require some statistical interpolation. Both European private equity fundraising and fund NAV are quarterly tracked, we argue using quarterly data (2015q1-2022q4) results in too little observations and thus the data requires interpolation into monthly data (2015m1-2022m12). Both variables require different methods of interpolation due to fundraising being a stock variable and NAV being a float variable. We argue that, because PE funds are generally raised over a longer period of time and the exact date when a fund is closed or partially closed can be somewhat arbitrary, that it is reasonable for research purposes that the amount of money raised in a quarter can be equally distributed over the three months in that specific quarter

3.2 Stationarity

We started by examining the presence of stationarity among the variables in our dataset. Macro-economic models often tend to contain variables which trend upwards due to growth in an economy. Therefore variables like GDP and price level can be non-stationary for any country or economic area researchers are looking at and researchers have looked at in most of the developed countries post WWII (Wasserfallen, 1986). Statistical examples of non-stationary processes common in macro-economic data are trends, random walks and cycles. Testing for stationarity is possible, there are a range of tests available, the most apparent test used in economic academic literature is the Dickey-Fuller test. Together with testing, theoretical thinking and visualisation can also be used to make statements about the stationarity of a time series. Peersman (2011) shows and argues, that all variables that form the base of the model in this research, Real GDP, HCIP, the VIX index and ECB assets, are non-stationary, except the stock market implied volatility (VIX) variable. Figure 7.A.1 - 7.A.4 in appendix A show visual representations of these included variables. Additionally, figure 7.B.1 and 7.B.2 show the visual representation of the interpolated variables NAV and RSG. We do not show the visual representation of the monetary base variable as it is merely used for robustness puproses in the later stages of this research. Following, we looked at non-stationarity by performing Dickey-Fuller tests. Because we did not know the eventually selected amount of lags, we performed the Dickey-Fuller tests applying a various amount of selected lags, after concluding the proper amount of lags, which we will show later, we eliminated all not relevant amount of lags from the Dickey-Fuller tables. The first row with t-statistics in table 3.2.1 shows the results of the Dickey Fuller on the included variables in our dataset, before taking the logarithmic value of the variables. The second row of t-statistics shows the results of the Dickey Fuller test after applying logarithmic values, with which we follow Peersman (2011) and Gambacorta *et al.* (2021). The Dickey Fuller test indicates stationarity of variables GDP, VIX and RSG, while RSG, ASS and NAV look to be non-stationary variables. Because some of the variables in the dataset are non-stationary we did not run our proposed VAR model before trying to eliminate this non-stationarity to avoid spurious results. A common way to eliminate non-stationarity in statistics, is by apply the differencing method, which is a technique in which the current value of a variable is subtracted from the previous value in order to transform a time series that looks to be non-stationary into a stationary one. However, proponents of the use of VAR models, including leading researcher Sims, argue that that differencing to induce stationarity should not be done. The purpose of the VAR estimation is to examine the relationship between the included variables, differencing will discard the long-run relationship between the included variables (Brooks, 2008).

The following method we considered to deal with non-stationarity is applying a variation of the SVAR model, called the SVEC model. SVEC models become particularly relevant due to their ability to solve non-stationarity problems in data sets. In order to consider applying a SVEC model, we first have to test whether cointegration exists within our data set and thus perform a cointegration analysis. Essential in understanding cointegration in a data set is the notion that variables, that are upwards trending for example, might look stationary, however, there might be an underlining motivation between a trend within a set of variables. To test the presence of cointegration among our variables we perform the Johansen's trace test, tables 3.2.3 to 3.2.5, show the results of the Johansen's trace test on all our specified models, we choose to primarily look at the Johansen's trace statistic over the Max-Eigen statistic, which is also acceptable in the academic literature.

Before applying the Johansen's trace test, we needed to find the proper amount of lags for each model. The amount of lags should not be too small, otherwise the model is mis specified. Additionally, the amount of lags should not be too large as this would mean that degrees of freedom are wasted. There are multiple tests to choose the lag length. We chose the Akaike's information criterion (AIC), research has shown that AIC, together with the final prediction error (FPE) are superior in case of a small sample size, as they minimize the chance of under estimation while maximizing the chance of recovering the right lag length (Khim-Sen Liew, 2004). Additionally AIC has been the preferred lag selection criterion in previous academic research on monetary policy. The title of table 3.2.2 to 3.2.4 includes the amount of selected lags proposed by the AIC. The optimal amount of lags for models{GDP, PRC, ASS, VIX, NAV} and {GDP, PRC, ASS, VIX, RSG}is four, while the optimal amount of lags for model {GDP, PRC, ASS, VIX, RSG, NAV} is six. We run the models where we replace the ECB's balance sheet for the monetary base with the same amount of lags. The results in table 3.2.2 and 3.2.3 show that the amount of cointegrations lays between zero and k, which is the amount of variables included in the model. We thus see that for these variables the null hypothesis of no co cointegration equation is rejected, and thus in these two models it is possible to explore the application of SVEC modelling further. However, we chose to apply the Bayesian approach. Our decision is threefold, first of all, Table 3.2.4 shows that results of the Johansen's Trace Test of the model which includes the variables GDP, ASS, VIX, RSG, NAV. The results show we cannot reject the null hypothesis of no cointegration. We therefore cannot continue with exploring the SVEC methodology for this specific set of variables, this is contrary to what we saw before for the other models. We could continue with the SVEC methodology for the other sets of variables however, we have chosen not to do so for consistency reasons. Additionally, Lütkepohl (2005) states SVEC models with cointegrated variables and long-term restrictions may result is singular reduced form residual covariance matrices, without this being apparent. Lastly inference regarding the immediate and long term effects of structural shocks can be tricky. Lütkepohl presents conditions that can help, however we currently believe this lays out of the scope of this research. Lastly, we found more familiarity with the Bayesian approach in the existing literature and value the earlier described comfort it provided in the better understanding of the techniques familiar in the academic literature on the topic. We thoroughly considered continuing this research with SVEC modelling following the conclusion of the Johansen's trace tests, and debated it versus the use of the Bayesian approach for VAR modelling

Table 3.2.1 – Dickey-Fuller tests for unit roots on variables using monthly data.

	GDP	PRC	VIX	ASS	RSG	NAV
T-Statistic	-3.351**	2.841	-4.237***	0.016	-4.279***	4.455
T-Statistic[12]	-3.568**	2.457	-4.237***	-2.326	-4.480***	1.186

Statistical significance levels are denoted as (***) = 0.01, (**) = 0.05, (*) = 0.10.

Table 3.2.2 – Johansen's Trace test using monthly data applying four lags {GDP, PRC, ASS, VIX, NAV}.[13]

Rank	Eigenvalue	Trace Statistic	5% crit. Value
0	.	78.349	68.52
1	0.341	40.869*	47.21
2	0.231	17.199	29.68
3	0.109	6.847	15.41
4	0.031	2.874	3.76

The letter r indicates the number of co-integrating relationships. * denotes the rejection at the 0.05 significance level.

[12] Variables GDP, PRC, ASS, RSG and NAV are in logarithmic form.

[13] The Johansen's Trace Tests were initially performed on models including the variable PRC. After finding out the including the variable resulted in problems surrounding integration, the Johansen's Trace Tests were redone without including the variable PRC.

Table 3.2.3 – Johansen's Trace test using monthly data applying four lags {GDP, PRC, ASS, VIX, RSG}.

Rank	Eigenvalue	Trace Statistic	5% crit. value
0	.	104.905	68.52
1	0.422	55.589	47.21
2	0.259	28.613*	29.68
3	0.052	5.156	15.41
4	0.004	0.377	3.76

The letter r indicates the number of co-integrating relationships. * denotes the rejection at the 0.05 significance level.

Table 3.2.4 – Johansen's Trace using monthly data applying six lags {GDP, ASS, VIX, RSG, NAV}.

Rank	Eigenvalue	Trace Statistic	5% crit. value
0	.	59.611*	68.52
1	0.249	23.455	47.21
2	0.176	17.437	29.68
3	0.114	6.745	15.41
4	0.066	0.753	3.76

The letter r indicates the number of co-integrating relationships. * denotes the rejection at the 0.05 significance level.

After disregarding differencing and SVEC modelling as viable methods to tackle stationarity, we decided to pursue with the Bayesian approach, applying the aforementioned Minnesota prior for the estimation of our models. The choice of the Minnesota prior follows leading researchers like Litterman (1980) and Sims (1989). Another common prior applied in the research is the Normal inverted-Wishart prior. We acknowledge the Normal inverted-Wishart prior is suitable, however the selection of this specific prior is not supported by the BVAR package in R-Studio. Redoing the research but substituting the Minnesota prior for the Normal inverted-Wishart prior is an interesting area of future research. This would allow the researcher to compare results across the use of different Bayesian priors.

After determining stationarity of the endogenous variables and having selected the proper amount of lags, we have to ensure that our models satisfy the stability conditions. If all eigenvalues are inside the unit root circle , the VAR stability condition is satisfied (Durlauf & Blume, 2010). If our model is not stable, tests conducted are invalid and resulting impulse response function standard errors are not going to be valid. Following a conclusion of stability of the model, autocorrelation among residuals is to be tested. Academic theory on regressions assumes residuals are serially independent and thus the mean of these residuals is zero (Poole & O'Farral, 1971).

3.3 Identification[14]

In the literature review we introduced two different identification methods, Choleski decomposition and sign and zero restrictions, as proposed by Uhlig (2005). We apply both identification methods in this research. Using both methods allows us to make some observations about the differences between the identification methods.

The first identification scheme we look at is the Choleski decomposition. As a basis we follow common literature, which assumes that there is only a lagged impact of shocks to the central bank balance sheet[15] on output and prices. Additionally we assume innovations to output and consumer prices are allowed to have a contemporaneous effect on the balance sheet and stock market volatility. Stock markets react instantly to central bank innovations and central bank policy announcements, stock market volatility is therefore ordered last. The standard ordering thus is {GDP, PRC, ASS, VIX}. Additionally we are adding the private market variable. We assume that both PE fundraising and PE fund value conclude the series. The final orderings therefore are {GDP, PRC, ASS, VIX, RSG} and {GDP, PRC, ASS, VIX, NAV}.

For the sign restriction identification scheme part of our analysis we are building our model upon the model presented by Gambacorta *et al.* (2012). For a detailed explanation on how and why the particular zero and sign restriction are chosen we therefore refer to the aforementioned article, additionally table 3.3.1, 3.3.2 and 3.3.3 show the identification assumptions for both specified models. We were unable to generate impulse responses using sing restrictions for the model including both the fundraising and NAV variables. We found no matrix fitting for the sign restrictions applied[16].

Because we are adding new variables to the model we do have to make decisions on the signs of those particular variables to identify the monetary policy shocks. In line, and according to the same logic, with the aforementioned Choleski decomposition identification, we assume that an unconventional monetary policy shock only has a lagged impact on our PE fundraising

[14] The ordering of the variables in the Choleski decomposition identification techniques, as well as setting the sign and zero restrictions were theorised before disregarding PRC as a variable. Consider the eventual ordering and sign restriction applied the same but with exclusion of the PRC variable.
[15] For robustness check purposes we substitute the ECB balance sheet variable with the monetary base. The ordering stays the same.
[16] While we did not found a matrix fitter for the identification restrictions in table 3.3.3, we still show the restrictions we theorised in the table.

and PE NAV variables. We do not look at the effect of the fundraising variable on the fund value variables using the sign restrictions. We argue that the other variables included in the research will not have any contemporaneous negative or positive effect to create a shock in the fundraising variable due to the characteristics of private markets. Specifically commitments to PE funds generally follow months of *Due Dillignce* (DD). Thus identifying this shock using sign and zero restrictions is not relevant. Now that the schemes for the unconventional monetary policy shocks are identified, we look at the generated impulse response functions.

Table 3.3.1 – Identification scheme using Uhlig's (2005) sign restrictions {GDP, PRC, ASS, VIX, RSG}.[17]

GDP	PRC	VIX	ASS	RSG
0	0	<= 0	>0	0

Table 3.3.2 – Identification scheme using Uhlig's (2005) sign restrictions {GDP, PRC, ASS, VIX, NAV}.

GDP	PRC	VIX	ASS	NAV
0	0	<= 0	>0	0

Table 3.3.3 – Identification scheme using Uhlig's (2005) sign restrictions {GDP, PRC, ASS, VIX, RSG, NAV}.

GDP	PRC	VIX	ASS	RSG	RSG
0	0	<= 0	>0	0	0

[17] For robustness check purposes we substitute the ECB balance sheet variable with the monetary base. The sign restriction for the monetary base is the same as the ECB balance sheet variable in all zero and sign restriction identification schemes.

4 Results

The next section provides a detailed description of the results obtained through the above presented models. In the above sections we introduced stationarity testing, lag selection, cointegration, stability conditions and autocorrelation. In the following section it is assumed the reader understands the methods we used. For each model, the results are primarily presented through IRFs. The text will often refer to IRFs displayed in the Appendix. The title of the referred to figure includes the model specification, the text will therefore not specify which model is looked at. The BVARs were generated drawing 10.000 samples of which 1000 successful draws were kept. The horizon of the IRFs is set at 36, representing three years. Before we look at the IRFs, after having set the identifying restrictions on these IRFs, we show the coefficients of the models {GDP, ASS, VIX, RSG} and {GDP, ASS, VIX, NAV}. Table 7.D.1 in the appendix shows the coefficients of the parameters in the model. We limit our view on the effect on our two variables of particular interest, PE fundraising and PE NAV. The table show that in actuality the variables in the model have quite a small effect on these two variables. Relatively speaking an increase in the balance sheet of the ECB seems to have a larger effect on the PE NAV variable, rather than the PE fundraising variable.

The result section of this paper will now proceed, first by looking at the results applying the Choleski decomposition method, followed by the results incorporating Uhlig's sign restrictions. We will prominently look at the included private marker variables RSG and NAV, however for the validity of our model and the availability of the results, we will additionally also look at the effects unconventional monetary policy shocks have on the other variables included in our models. We will predominantly refer to existing literature in the sign restriction part of the results as these are the main results of interest. To examine the robustness of our results variations to the model are taken into consideration. Applying both identification methods, we substitute the total assets on the balance sheet of the ECB by the monetary base following Peersman (2011). Identical to the ECB balance sheet variable, the monetary base variable is in logarithmic form. Lastly, while the impulse response analysis is our predominant method of research we also forecasted and tested for Granger Causality.

4.1 Choleski Decomposition

We started our research by analysing the results for the Choleski decomposition identification method. In the literature review we stated this method was the prominent method to use in the early days of academic research on monetary policy and it since has been replaced by more sophisticated methods, like the, in this research prominently mentioned, sign restrictions proposed by Uhlig (2005). We therefore have not considered the results to be leading when making claims about the effect of unconventional monetary. We acknowledge the results are relevant, but more as an addition to the results applying sign and zero restrictions and a necessity to include in order to give the reader a holistic view on the topics of VAR, an SVAR, BVAR identification and unconventional monetary policy that we talked about in previous section of this research.

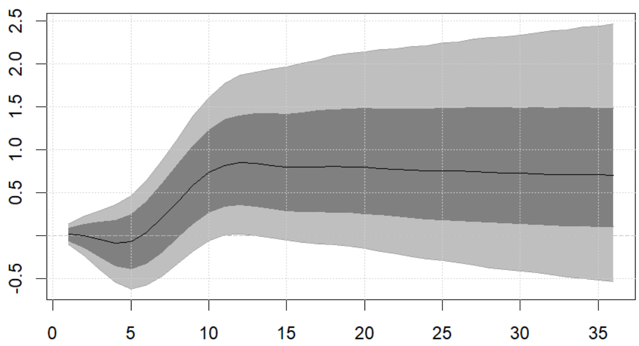
First of all, the IRFs in figure 7.D.1 to 7.D.3 show a positive effect of a unconventional monetary policy shock on GDP, or output as a proxy. In Figure 7.D.1 and 7.D.3 this effect is insignificant throughout the selected horizon, in figure 7.D.2, the effect is shortly negative after the initial shock, however the effect becomes significant and stays significant until month ten. The effect converges towards zero in the long run. In all three models the IRF displaying the effect of the shock on the ECB's balance sheet is positively significant. In figure 7.D.1 the effect remains significant until month 35, in figure 7.D.2 the effect stays significant until month 15, the IRF in figure 7.D.3 shows a similar result. Lastly, before looking at the effects of our variables of particular interest we look at the effect on stock market volatility. All three models show an initial positive effect before turning negative. Figure 7.D.1 shows the least strong result. Figure 7.D.2 and 7.D.3 both show a significant negative effect between month five and fifteen, however in the long run both IRFs show a contrary effect.

The aforementioned effects have been extensively analysed and therefore are only of marginal interest in this research. We will now continue with the analysis of unprecedented effects. Figure 7.D.1 shows an insignificant positive effect of an unconventional monetary policy shock on private market fundraising, the effect remains positively insignificant in the long run. Additionally in figure 7.D.2, we see that an unconventional monetary policy shock has an insignificant positive effect on PE NAV, the effect is persistent however remains insignificant throughout. Lastly, we look at the model including both the PE fundraising and PE NAV variable. The fundraising IRF shows an initial significant positive effect, however the effect turns insignificant soon. The effect is insignificantly negative between months five and twenty-two, before the effect turns insignificantly negative.

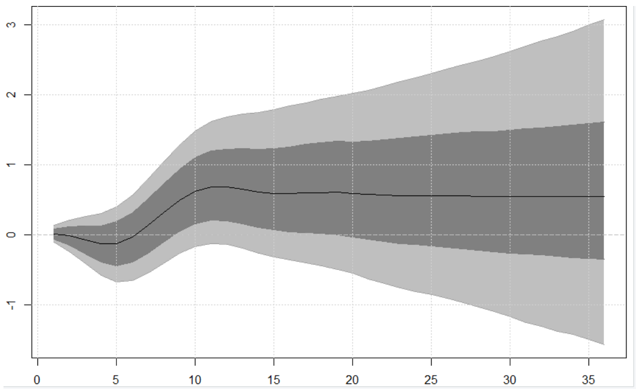
Table 7.F.1 - 7.F.3 shows the impulse response functions of the models in which the ECB's balance sheet is replaced by the monetary base variable. Summarising the displayed results we largely see similar monetary shock responses comparing the effects in table 7.F.1 – 7.F.3 to 7.D.1 – 7.D.3. Additionally graph 4.1.2 and 4.1.1, which display the effect the PE

fundraising variable has on the PE NAV variable look very similar. Both start insignificantly negative before tuning insignificantly positive. We believe the lag in the positive effect of fundraising on NAV can be explained by the time it takes funds to allocate the capital it raised to new portfolio companies.

Graph 4.1.1 Effect of a fundraising shock on the PE NAV variable (x100)



Graph 4.1.2 Effect of a fundraising shock on the PE NAV variable (x100) in the model including MON.



4.2 Sign Restrictions

This study proceeds by looking at the results of the IRFs generated applying sign and zero restrictions. Due to this identification method being an advancement, in the literature, over the more standard Choleski decomposition method, we consider the results in this section of increased importance over the afore reported results. Again, we start by looking at the IRFs created for the non-private market variables.

We see a similar effect of an unconventional monetary policy shock on GDP in both models applying the sign restrictions, displayed in figure 7.D.4 and 7.D.5. Initially, the shock is significantly positive before turning insignificantly negative and remaining insignificantly negative while converging towards zero. The positive shock is consistent with existing literature, example are; Darracq-Paries & De Santis (2015) and Cahn, Matheron, & Sahuc (2014), The response of ECB assets is in both models insignificantly persistent, the initial effect seems stronger for the model displayed in figure 7.D.4, however both display very similar tendencies. The responses on our stock market volatility variables differ greatly from the afore generated using the Choleski decomposition method. Applying a negative sign restriction clearly impacts the way the IRFs are generated significantly. The effect of an unconventional monetary policy shock on stock market volatility start significantly negative before turning insignificantly negative and converging towards zero, this effect is consistent with existing academic literature, it for example follows a similar trend as Gambacorta *et al.* (2012). This effect is the same in the generated IRFs in both 7.D.4 and 7.D.5.

Lastly we look at the generated IRFs for the private market variables again. Confirming what we already saw at the IRFs generated by applying the Choleski composition, 7.D.4 and 7.D.5 both show no significant effect of an unconventional monetary policy shock on the private investment market variables. 7.D.4 shows an initial insignificant positive effect, turning into an insignificantly negative effect, before becoming positively insignificant again. Figure 7.D.5 shows a persistent positive insignificant effect. Again substituting the ECB's balance sheet variable for the monetary base variable produces very similar results. We will thus say that monetary base is a good substitute for robustness purposes for a balance sheet variable.

4.3 Additional Analysis

During the literature review we showed that the existing empirical research on the effect of monetary policy on asset prices is apparent. Research has generally shown a sizable significant effect (Rossi, 2018). Hereafter we hypothesised that there would be a present effect of unconventional monetary policy on our PE variables. In the previous section we have seen that our impulse response analysis indeed shows there is some effect of unconventional monetary policy on our PE fund variables, however the effect is not always significant and when it is significant it turns insignificant quickly. Additionally, we perform the Granger Causality test, which results are shown in Table 4.3.1.

Table 4.3.1 – Granger Causality tests

H_0	ASS does not cause RSG		ASS does not cause NAV	
Lag	**F-Statistic**	**p-value**	**F-Statistic**	**p-value**
3	4.285	0.007**	0.620	0.603
4	2.92	0.026*	1.071	0.376
5	3.926	0.003**	0.707	0.620
6	4.512	0.001***	0.799	0.574
7	4.102	0.001***	0.806	0.585

Statistical significance levels are denoted as (***) = 0.01, (**) = 0.05, (*) = 0.10.

We interpret the results by looking at the p-values. The table shows that the ECB's balance sheet does Granger cause the PE fundraising variable. This results are significant for all included lags at the 90% confidence level. Additionally the result show that the ECB's balance sheet does not Granger cause our PE NAV variable. Important to note is that we are not looking at balance sheet innovations with this test. The results therefore suggest that identification plays an important role in distinguishing the effect unconventional monetary policy has on our PE NAV variable. Figure 7.H.1 – 7.H.6 display the forecasts for the all the variables in the model. We include both the models with the ECB's balance sheet variable, as well as the models in which this variable is replaced by the monetary base variable for robustness purposes. We conclude that our research expects PE fundraising to stay relatively stable while NAV is expected to continue to trend upwards. While the VIX index is not of our primary interest, the forecast result does produce unrealistic results. Historically the VIX index consistently fluctuates somewhat, this is not generated in this forecasting method. We will thus conclude the forecasting has not produced credible results for the VIX index. Lastly we show the forecasts when removing all values from mid-2021 onwards. We argue that this, conservatively, is the time the macro-economic conditions started to change. 7.I.1 – 7.I.6 shows these forecasts. Results are generally in line with the previous forecasts, however GDP is expected to decrease in figure 7.I.2 and 7.13 which is surprising

5 Conclusion

This thesis examined the effect unconventional monetary policy tools, implemented by the ECB post GFC, have had on the private market investment class. The thesis reviewed and described all implemented monetary policy tools by the ECB in the mentioned time period using existing academic literature, and conceptualised all key economic principles to consider when theorising about the field of monetary policy and unconventional monetary policy in particular. Incorporating common variables used in existing literature allowed us to follow said literature and provide an updated view on this exiting literature, while incorporating the PE variables gave us the chance to further enrich knowledge on the topic of unconventional monetary policy. Focussing on these unexplored, in this context, variables hopefully allows policy makers to make better informed decisions during future similar macro-economic environments. While private investment markets should never be of primary concern when policy makers dictate monetary policy, it is preferred for policy makers to be informed about some of the potential side effects their policy implementations can have.

The research method applied in this thesis is the BVAR model, a method that has seen extensive prior use in the academic literature on monetary policy. The identification techniques applied were both the Choleski decomposition method and zero and sign restrictions, both of which are also standard in the literature. These identification techniques allow the researcher to do some theoretical thinking about potential effects, however in this research we predominantly have used an referred to previous literature to make these claims. Important notice goes to Gambacorta *et al.* (2012), who provided a strong basis to build this research on both in terms of the variables included in the model as well as the sign restrictions applied.

We found no significant effect of unconventional monetary policy shocks by the ECB on our private investment market variables, PE fundraising and PE NAV. This result is consistent for both identification techniques, the Choleski decomposition and sign restrictions. Replacing the ECB's balance sheet variable with the monetary base for consistency purposes and following Peersman (2011), also did not result in any significant differences. We therefore note that monetary base is a suitable replacement for a central bank's balance sheet in VAR methodology. The effects of the unconventional monetary policy shocks on the other variables included in the model were generally consistent with documented academic literature.

A major drawback of this thesis, and of research on unconventional monetary policy in general, is that some of the variables included in the model are interpolated and some others are proxied. The unavailability of frequent data in the field of private investment markets is a tale as old as time and has impacted many thesis's before this one. In this study we decided to interpolate quarterly data, which was the most frequent data available, into monthly data. Applying the same techniques on quarterly data would have resulted in too few observations and this would have produced incredible results. Additionally, the variable GDP was proxied by output, which is quite standard in the literature and again follows, among others, Peersman (2011). In future literature, this research can be expended to other monetary areas, research could, if data is available, look at different time periods, or chose different parameters. For example, researchers could impose a Normal inverse-Wishart prior instead of the Minnesota prior.

While, to our knowledge, this study is unique in its focus on the private investment markets variables, we do acknowledge that the model fairly simplified. Over time various different methods have appeared to distinguish monetary policy shocks. Additionally, the model is partially based on theoretical thinking about potential effects and is sensitive to the parameters chosen, like the amount of lags selected or the prior, and its consequences chosen. Academic literature on the topic of unconventional monetary policy is still a fairly your discipline. As we showed before, leading researchers are sometimes sill not in agreement over the methods and techniques applied. We therefore welcome any further advancement in the field, which will additionally result in a more sophisticated research on the topic of interest in this thesis.

6 References

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7 Appendix

7.A Visual Representations of Standard Variables

Figure 7.A.1 – Visual representation of GDP

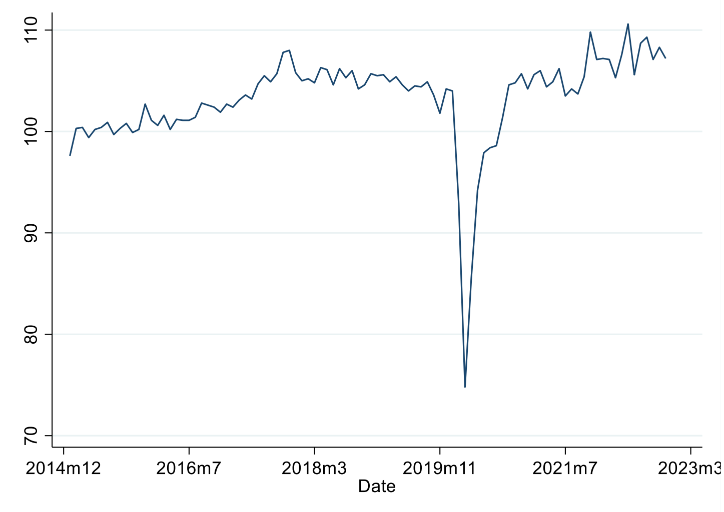


Figure 7.A.2 – Visual representation of PRC

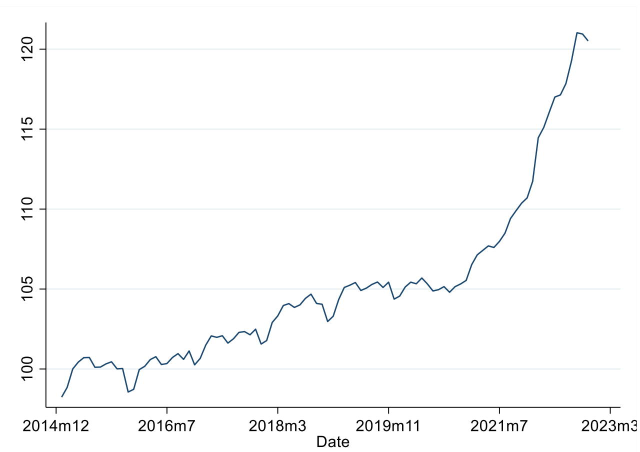


Figure 7.A.3 – Visual representation of ASS

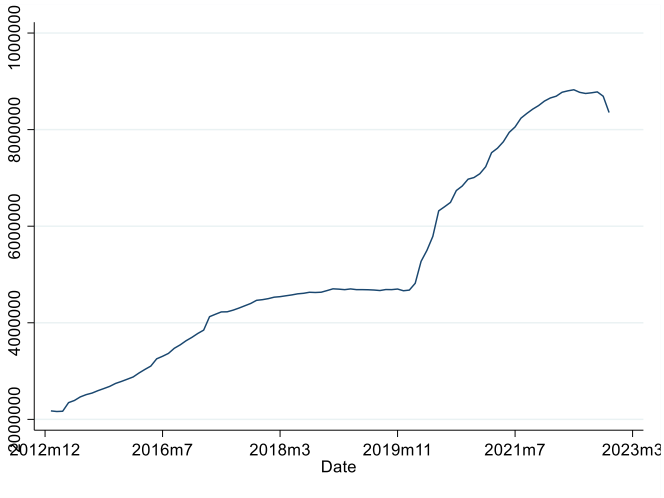


Figure 7.A.4 – Visual representation of ASS

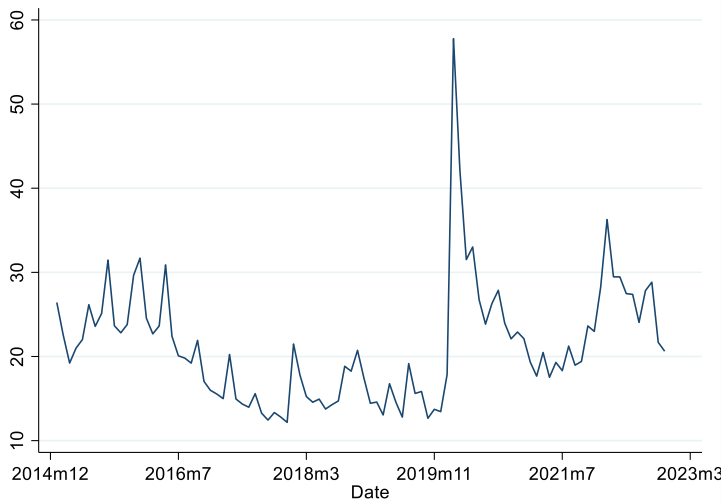
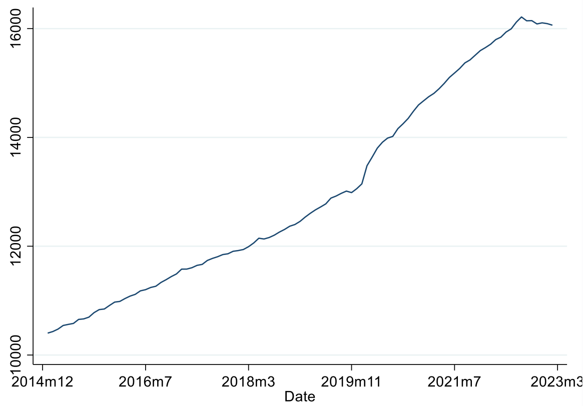


Figure 7.A.5 – Visual representation of MON (in billion EUR).



7.B Visual Representations of Interpolated Variables

Figure 7.B.1 – Visual representation of interpolated variable RSG

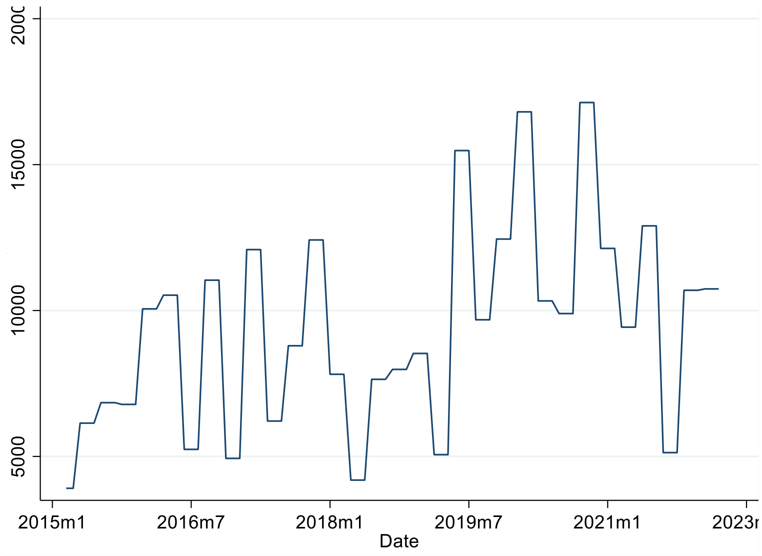
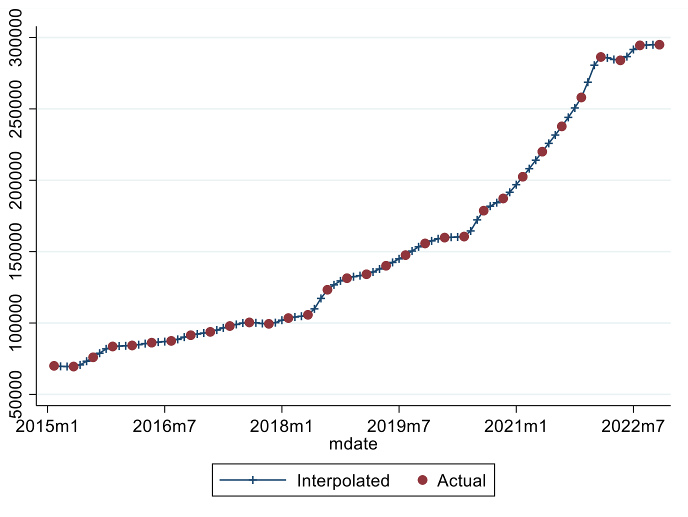


Figure 7.B.1 – Visual representation of interpolated variable NAV



7.C Sign Restrictions Identified

Table 7.C.1 – Identified sign restrictions as displayed in R Studio.

```
                        Shock to
                         Var1     Var2     Var3     Var4
Response of     Var1     +        0        +        +

                Var2     +        +        +        +

                Var3     +        -        +        +

                Var4     +        0        +        +
```

7.D Coefficients BVAR Analysis

Table 7.D.1 – Description of endogenous variables included in the model

Variables	**Coefficient** {GDP, ASS, VIX, **RSG**}	**Coefficient** {GDP, ASS, VIX, **NAV**}
logGDP(-1)	-0.406	-1.058
logGDP(-2)	-0.131	-1.032
logGDP(-3)	-0.064	-0.303
logGDP(-4)	-0.015	0.222
logASS(-1)	0.181	1.092
logASS(-2)	-0.093	0.171
logASS(-3)	-0.004	-0.012
logASS(-4)	0.018	-0.150
VIX(-1)	-0.001	-0.003
VIX(-2)	-0.002	-0.022
VIX(-3)	0.002	0.021
VIX(-4)	0.002	0.009
logRSG(-1)	1.363	
logRSG(-2)	-0.731	
logRSG(-3)	-0.022	
logRSG(-4)	0.116	
logNAV2(-1)		1.861
logNAV2(-2)		-1.057
logNAV2(-3)		0.096
logNAV2(-4)		0.085
Constant	4.112	4.221

7.E Impulse Response Functions

Figure 7.E.1 – Effects of a ECB Assets shock on other included variables using Choleski decomposition identification method. {GDP, ASS, VIX, RSG}

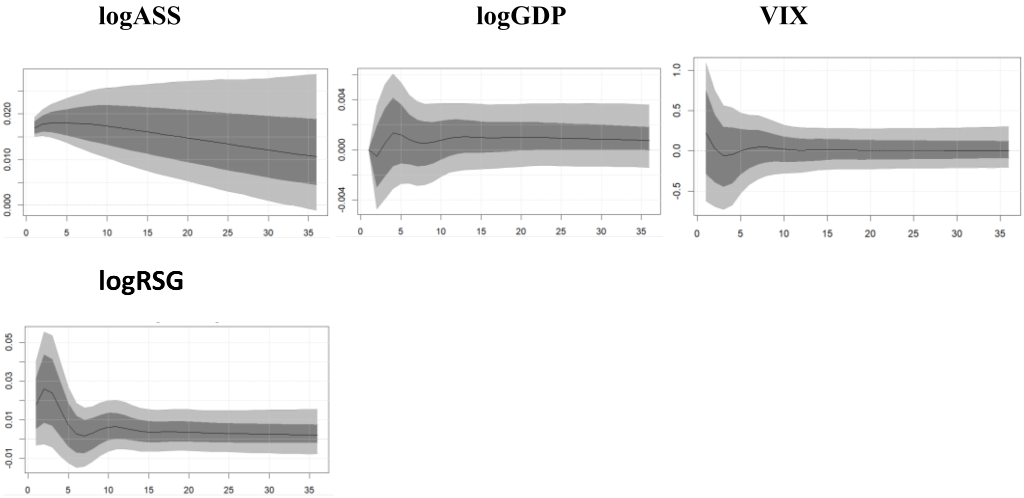


Figure 7.E.2 – Effects of a ECB Assets shock on other included variables using Choleski decomposition identification method. {GDP, ASS, VIX, NAV}

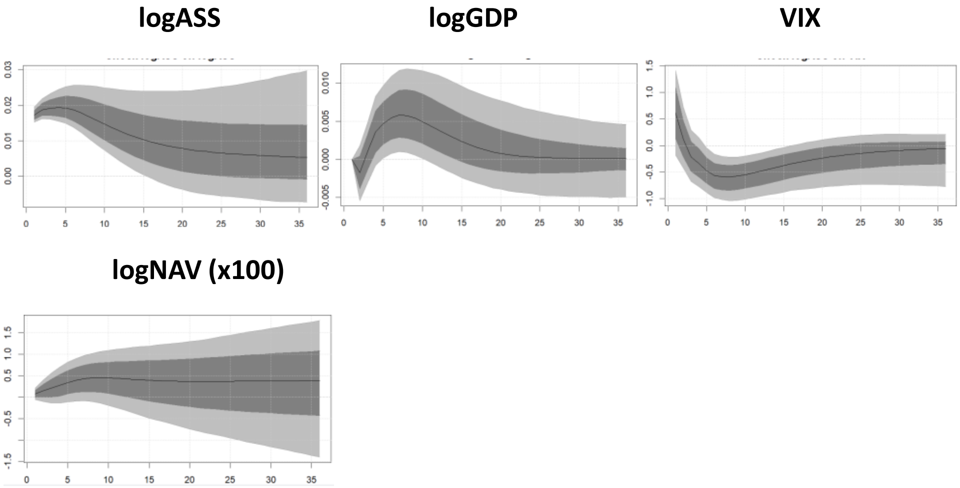
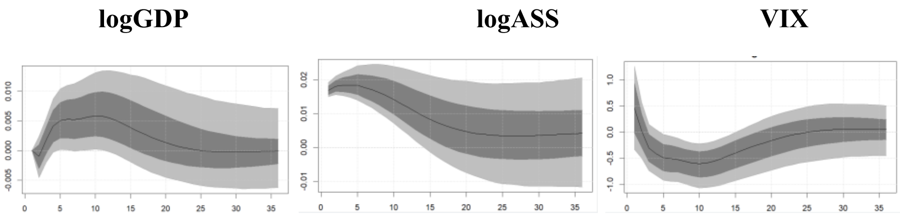
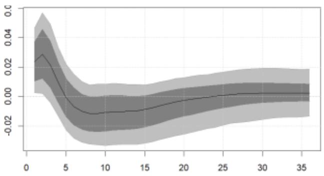
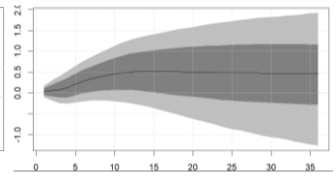


Figure 7.E.3 – Effects of a ECB Assets shock on other included variables using Choleski decomposition identification method. {GDP, ASS, VIX, RSG, NAV}



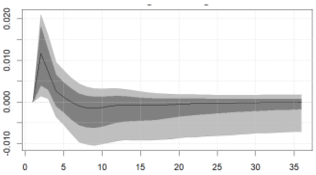
logRSG **logNAV(x100)**

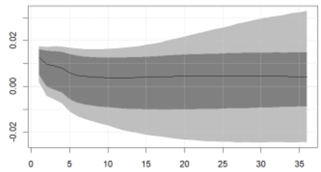


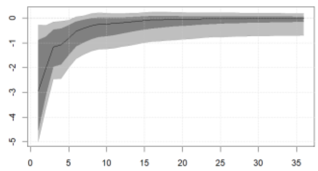


7.E.4- Effects of a ECB Assets shock on other included variables using Uhlig's (2005) sign restriction method {GDP, ASS, VIX, RSG}.

logGDP **logASS** **VIX**







logRSG

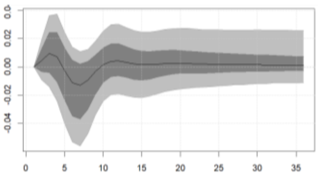
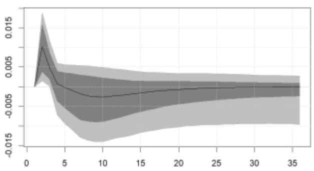
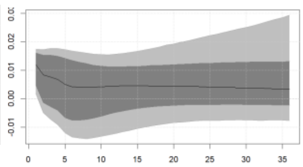
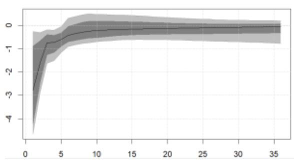


Figure 7.E.5 - Effects of a ECB Assets shock on other included variables using Uhlig's (2005) sign restriction method {GDP, ASS, VIX, NAV}.

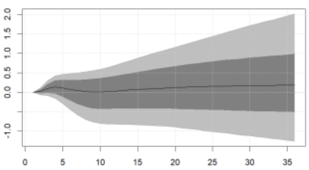
logGDP **logASS** **VIX**







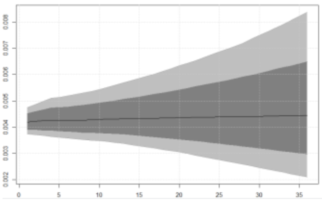
logNAV (x100)



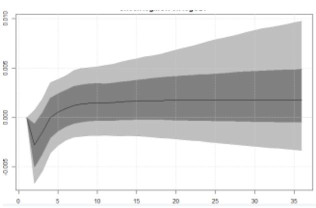
7.F Impulse Response Functions Robustness Checks

Figure 7.F.1 – Effects of a ECB Assets shock on other included variables using Choleski decomposition identification method. {GDP, MON, VIX, RSG}

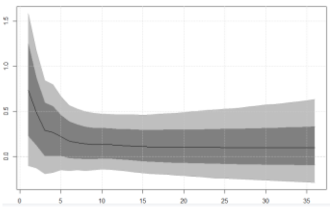
logMON



logGDP



VIX



logRSG

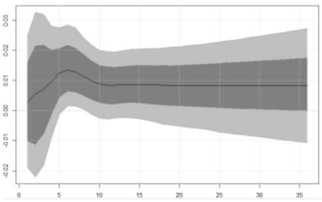
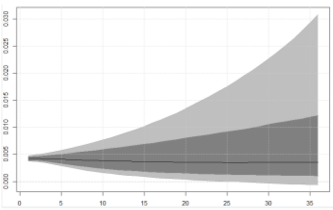
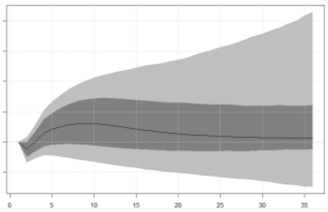


Figure 7.F.2 – Effects of a ECB Assets shock on other included variables using Choleski decomposition identification method. {GDP, MON, VIX, NAV}

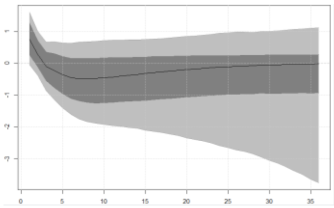
logMON



logGDP



VIX



logNAV (x100)

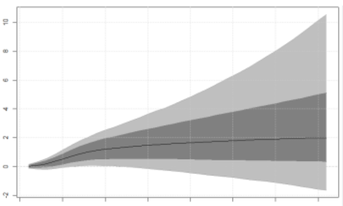
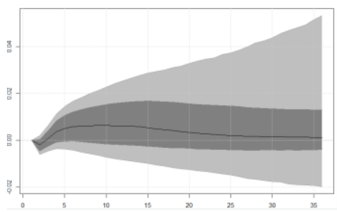
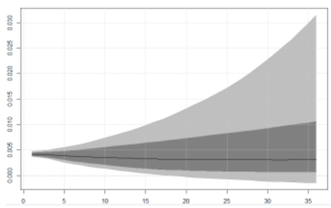


Figure 7.F.3 – Effects of a ECB Assets shock on other included variables using Choleski decomposition identification method. {GDP, MON, VIX, RSG, NAV}

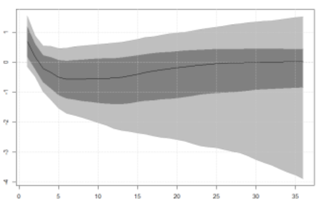
logGDP



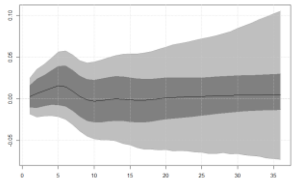
logMON

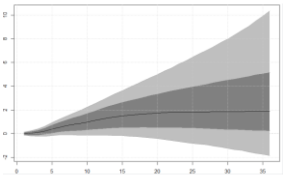


VIX



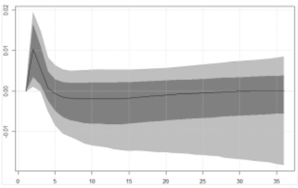
logRSG logNAV(x100)

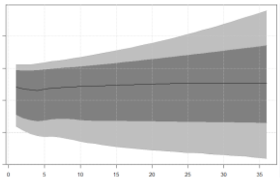


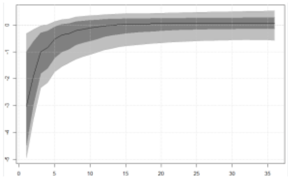


7.F.4- Effects of a ECB Assets shock on other included variables using Uhlig's (2005) sign restriction method {GDP, MON, VIX, RSG}.

logGDP logMON VIX







logRSG

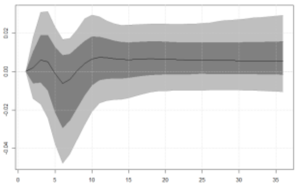
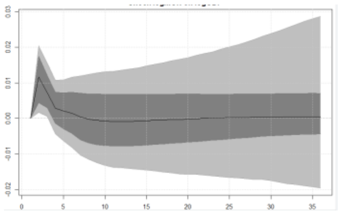
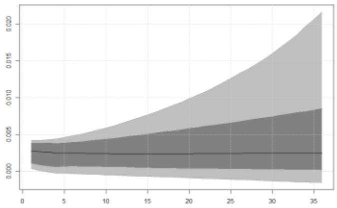
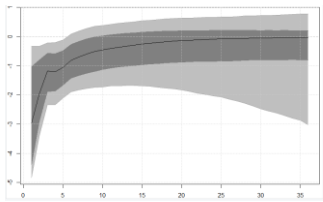


Figure 7.F.5 - Effects of a ECB Assets shock on other included variables using Uhlig's (2005) sign restriction method {GDP, MON, VIX, NAV}.

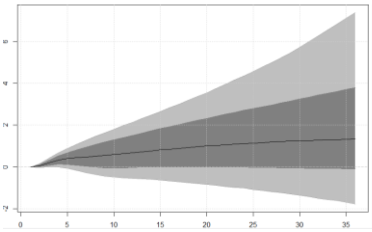
logGDP logASS VIX







logNAV (x100)



7.G Granger Causality Test Robustness Check

Table 7.G.1 – Granger Causality Wald tests replacing ASS by MON.

H_0	MON does not cause RSG		MON does not cause NAV	
Lag	X^2	p-value	X^2	p-value
3	3.156	0.028*	0.784	0.506
4	2.323	0.064	0.488	0.744
5	2.552	0.034*	0.310	0.905
6	2.217	0.050	0.399	0.878
7	1.571	0.158	0.337	0.934

Statistical significance levels are denoted as (***) = 0.01, (**) = 0.05, (*) = 0.10.

7.H Forecasts Using Data 2015m1 – 2022m12

Figure 7.H.1 – Forecasts of variables in the model {GDP, ASS, VIX, RSG}.

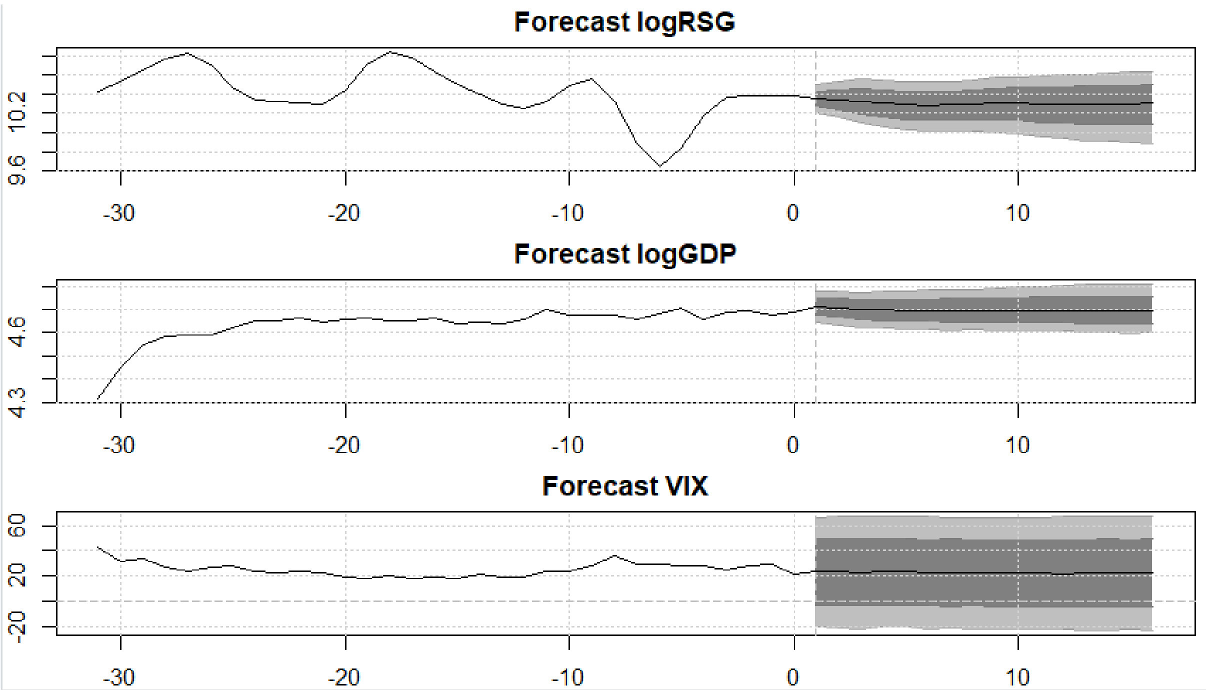


Figure 7.H.2 – Forecasts of variables in the model. {GDP, ASS, VIX, NAV}

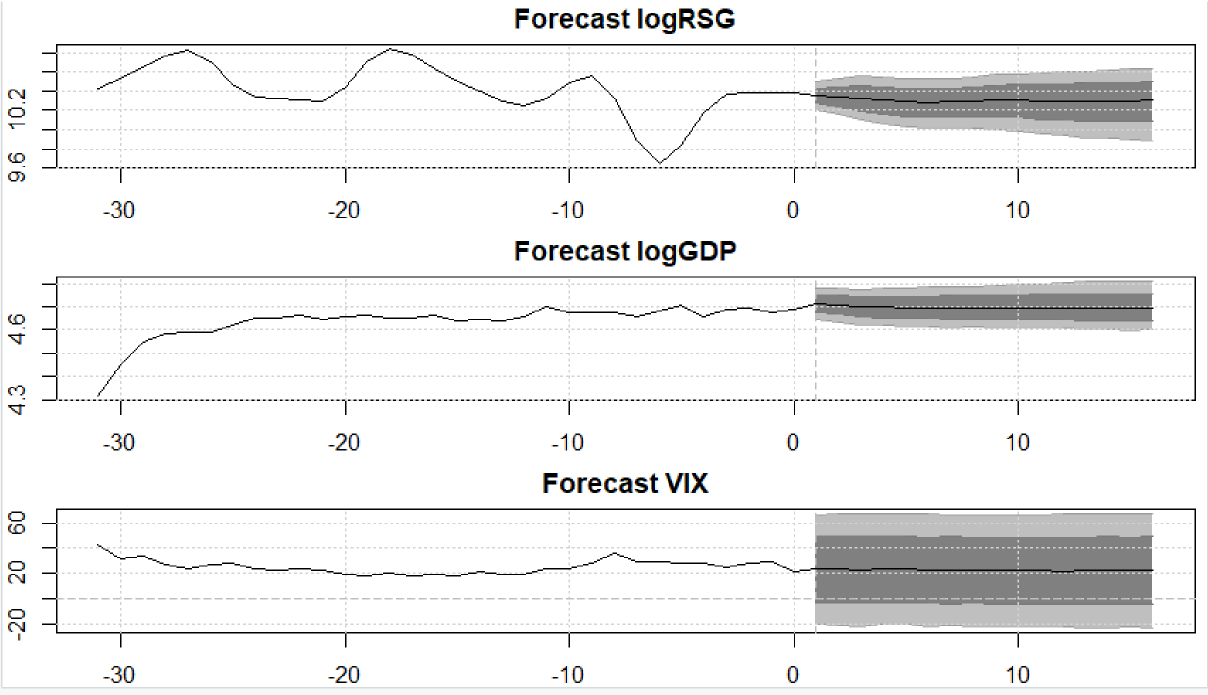


Figure 7.H.3 – Forecasts of variables in the model applying the zero and sign restrictions identification technique. {GDP, ASS, VIX, RSG, NAV}

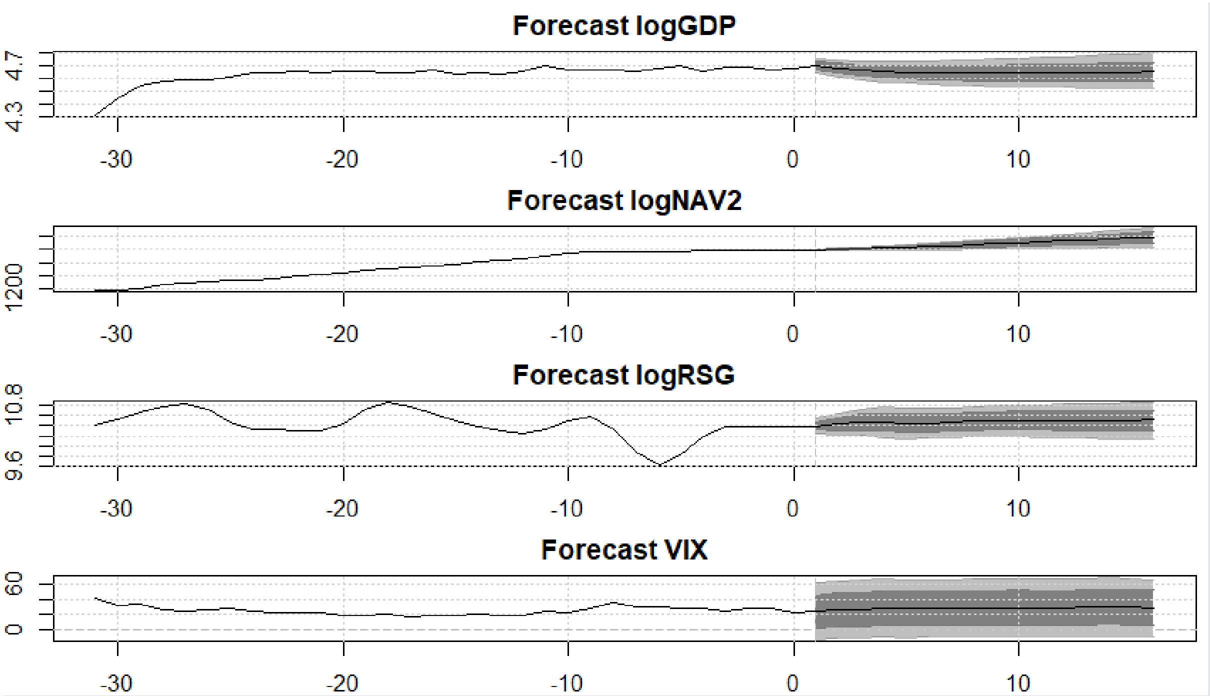


Figure 7.H.4 – Forecasts of variables in the model replacing ASS by MON. {GDP, ASS, VIX, RSG}

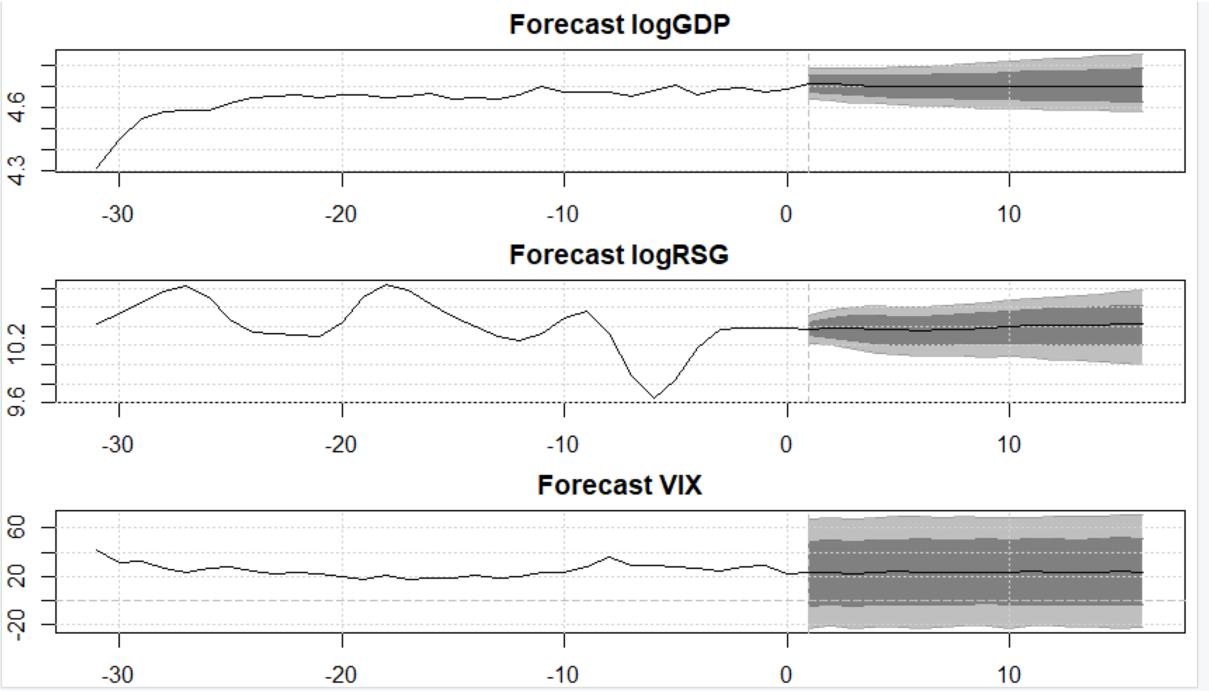


Figure 7.H.5 – Forecasts of variables in the model replacing ASS by MON. {GDP, ASS, VIX, NAV}

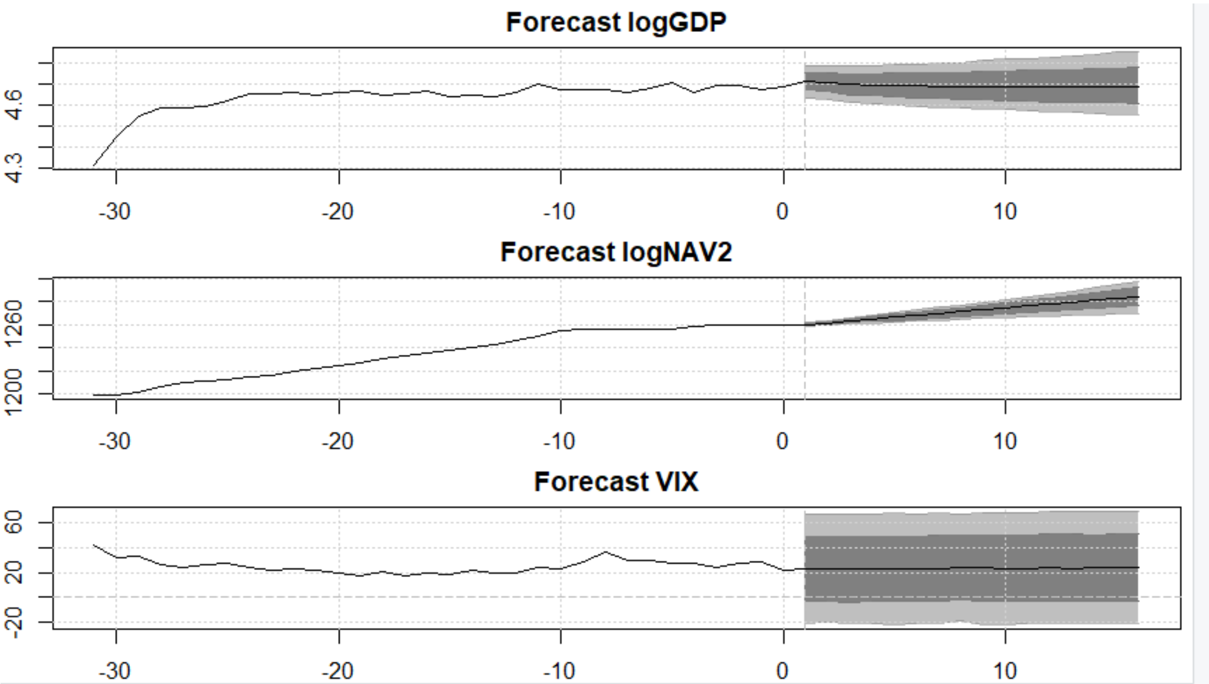
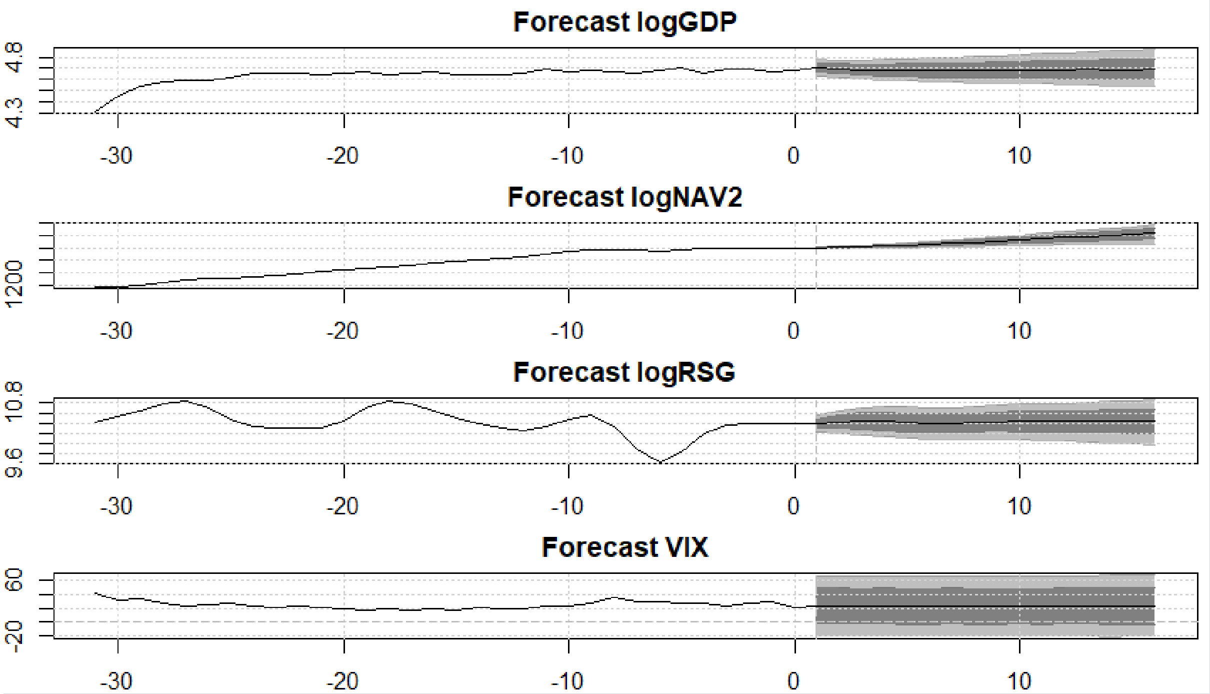


Figure 7.H.6 – Forecasts of variables in the model replacing ASS by MON. {GDP, ASS, VIX, RSG, NAV}



7.I Forecasts Using Data 2015m1 – 2021m6

Figure 7.I.1 – Forecasts of variables in the model {GDP, ASS, VIX, RSG}.

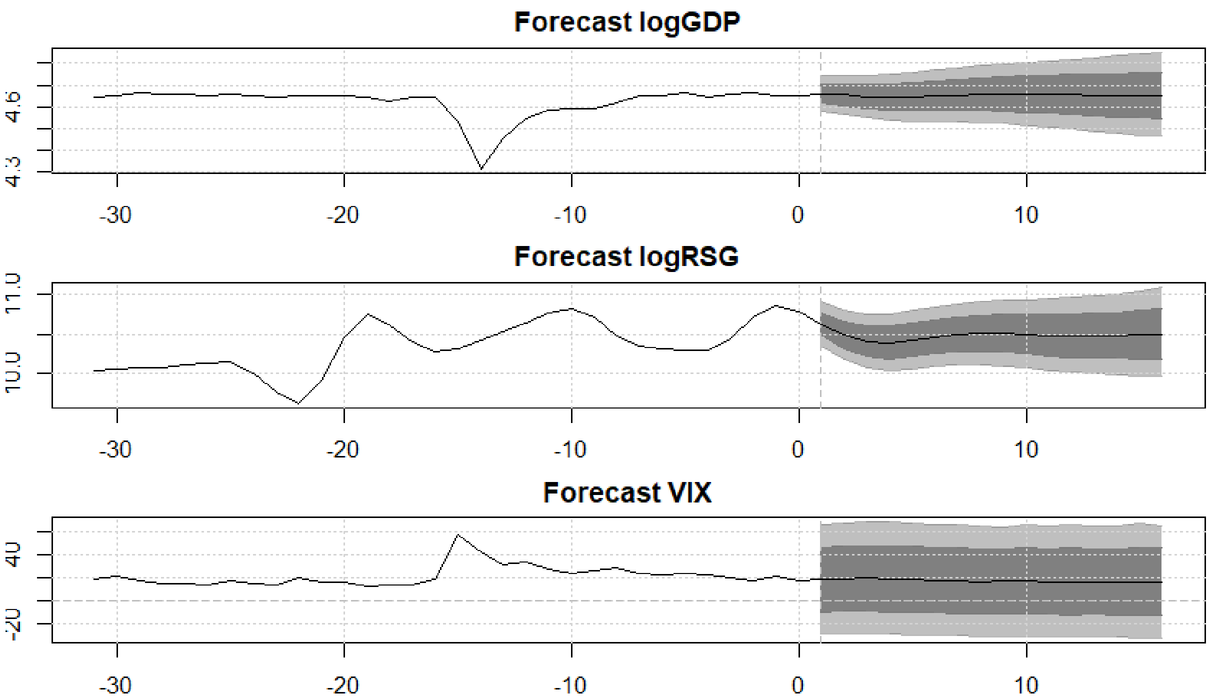


Figure 7.I.2 – Forecasts of variables in the model. {GDP, ASS, VIX, NAV}

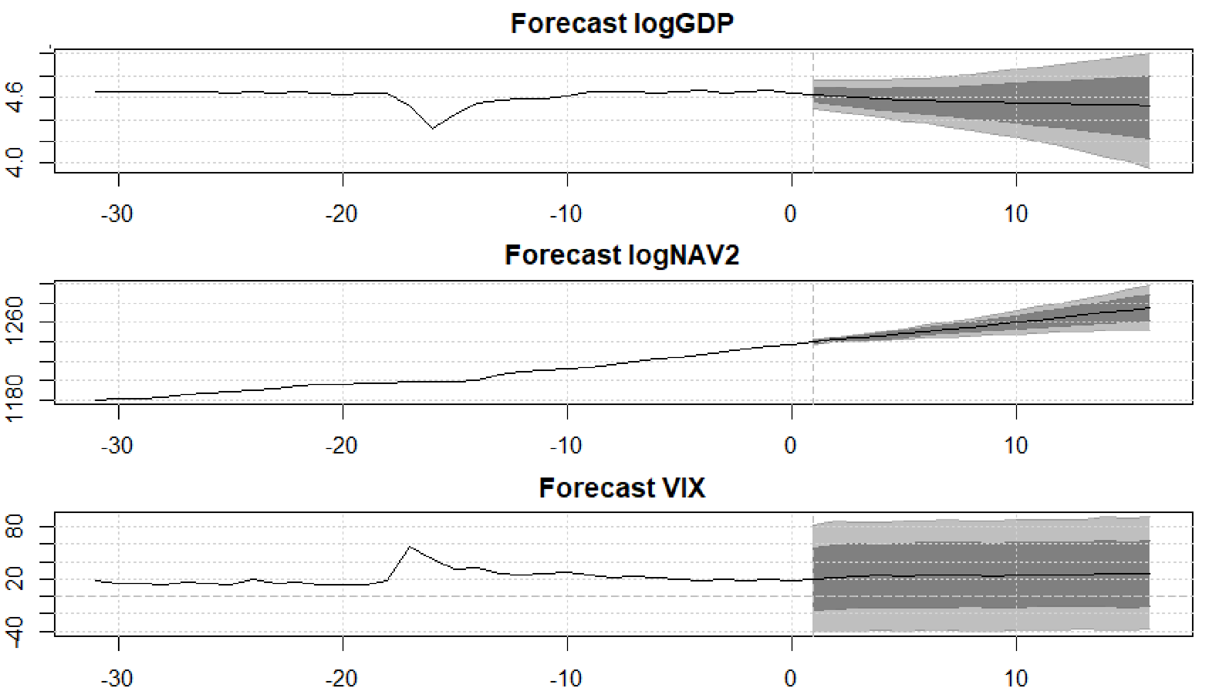


Figure 7.I.3 – Forecasts of variables in the model applying the zero and sign restrictions identification technique. {GDP, ASS, VIX, RSG, NAV}