Hovedoppgave

NTNU
Norges teknisk-naturvitenskapelige universitet
Fakultet for økonomi
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The transmission channels of Quantitative Easing

How do large-scale assets purchases affect the real economy?

Hovedoppgave i Samfunnsøkonomi
Veileder: Fredrik Carlsen
Juni 2022

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NTNU
Kunnskap for en bedre verden

Preface

The master thesis accounts for 30 credits, and marks the end of our two-year degree at NTNU. We want to thank all of our professors for helping us along this journey, but a special thanks to Fredrik Carlsen, our supervisor, for his guidance in helping us finishing our assignment.

The content of this thesis is at the expense of the authors.

Trondheim, June 2022.

Håkon Langli
Marius Kirkaune

Abstract

In this paper, we investigate how quantitative easing (QE) pursued by the Federal Reserve is transmitted to the real economy via its transmission channels. Using two different models and several different model specifications, we try to estimate how effective the different transmission channels of QE are at transmitting to the real economy, and how the effects of large scale asset purchases (LSAP) have differed in the four distinct QE-programs. We find that the effectiveness of the transmission channels corresponds with the literature. Through the portfolio balance channel LSAPs decrease the yield of long-term bonds. As for the different QE-programs, we find that QE-1 and QE-4 were the most impactful. QE-4 did have a much wider range of effects on the economy, which may be attributed to the global supply chain turmoil in the wake of the COVID-19 pandemic. Overall, we found significant relationships between the sets of variables in our model. The increase of the Fed's balance sheet through LSAPs will lead to higher inflation, and QE will also reduce unemployment and increase industrial production. These effects die out after roughly a year, which may be why the Fed has had to employ several rounds of QE to sustain their effects. The effects on industrial production seems to be the strongest, while the effects on unemployment are weaker and more vague. Our results are, however, very ambiguous, and our data material might be too weak to effectively quantify the effects of QE, though we find some meaningful information on the different transmission channels, the effectiveness of quantitative easing and how it transmits to the real economy.

Sammendrag

I denne oppgaven har vi undersøkt hvordan the Federal Reserve sin bruk av kvantitative lettelser (QE) overføres til realøkonomien gjennom sine transmisjonskanaler. Vi har tatt i bruk to forskjellige modeller og flere modellspesifikasjoner for å estimere hvor effektiv de forskjellige transmisjonkanalene er til å påvirke realøkonomien, samt hvordan QE har hatt forskjellig effekt i de fire distinkte QE-programmene. Vi finner at effekten av transmisjonskanalene er likt det vi finner i litteraturen fra før. Yielden på langsiktige obligasjoner blir redusert gjennom portefølje rebalanserings kanalen. Når det kommer til de forskjellige QE-programmene finner vi at QE-1 og QE-4 har hatt størst effekt på økonomien. QE-4 har dog en mye bredere effekt, noe som kan skyldes forstyrrelser i den globale forsyningskjeden i etterkant av COVID-19 pandemien. Totalt sett har vi funnet signifikante forhold mellom variablene i modellen vår. En økning i Fed sitt balanseregnskap vil øke inflasjon, redusert arbeidsledighet og øke industriell produksjon. Vi finner også at disse effektene vil avta og dø ut etter ca. ett år, noe som kan være grunnen til at Fed har måttet anvende flere runder med QE for å bevare effekten. Effektene på industriell produksjon ser ut til å være sterkest, mens effekten på arbeidsledighet er svakere og mer vag. For å konkludere, så er resultatene våre usikre, og datamaterialet vårt er kanskje for svakt til å kunne effektivt kvantifisere effekten av QE. Vi har dog funnet nyttig informasjon om de forskjellige transmisjonskanalene, effekten av kvantitative lettelser, og hvordan det overføres til realøkonomien.

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List of Abbreviations

CM Constant maturity

CPI Consumer Price Index

DF Dickey-Fuller

Fed The Federal Reserve

FFR Federal Funds Rate

FOMC Federal Open Market Committee

FRED Federal Reserve economic data

GDP Gross Domestic Product

GSE Government-sponsored enterprise

LSAP Large scale asset purchases

MBS Mortgage backed securities

MEP Maturity Extension Program

PCE Personal consumption expenditure

QE Quantitative easing

QT Quantitative tightening

SVAR Structural Vector Autoreggressive

TREAST 10-year Treasuries

US United States

VAR Vector Autoreggressive

ZLB Zero lower bound

1. Introduction

The primary monetary policy tool that the Federal Reserve has to either ease or tighten the economy is the target range of the Federal Funds Rate (FFR). The target range of the FFR has historically been guided in accordance with macroeconomic indicators such as unemployment, inflation and output gap known as "Taylor Rules"(Joyce et al., 2012). Before the great recession of 2008, the main line of though was that monetary policy, though effective at keeping inflation low, was not effective at preventing instability in the financial markets. Monetary policy was thought to be more effective at dealing with the aftermath of a burst bubble than preventing it's build-up (Joyce et al., 2012). This view has widely changed the last two decades, with central banks now paying much more attention to financial stability when determining their monetary policy.

In the aftermath of the great recession, the Federal Reserve was faced with a conundrum; how do you stimulate the economy while the interest rate is already near its lower bound and the Taylor Rule calls for a negative interest rate? The answer was unconventional monetary policy. The Federal Reserve began large-scale purchases of Treasury bonds, mortgage backed securities (MBS), agency debt and other assets. This process is known as quantitative easing (QE), and is intended to provide liquidity to banks, signal the Fed's intention to keep the rate at a low level, and put downward pressure on long-term rates. Through these mechanisms, QE is theorised to stimulate economic growth, reduce the unemployment rate, and raise inflation towards its targeted rate, even when conventional monetary policy is ineffective.

After Ben Bernanke announced his resignation as a board member for the Federal Reserve, he said: "The problem with quantitative easing is that it works in theory, but not in practice" (Bernanke, 2014). This quote has famously induced scepticism to this new, and to many, unfamiliar monetary tool that is quantitative easing. There are many sceptics who argue that QE is ineffective, and that it can have damaging consequences to the economy. The most significant fear is that the substantial monetary easing caused by QE can cause high and persistent levels of inflation. This fear has become especially evident in light of the Fed's most recent QE program aimed at aiding economic recovery in the aftermath of the Covid-19 outbreak. The Fed added approximately $4.2 trillion to their balance sheet from March 2020 to March 2022. Conversely, the the year-on-year inflation rate increased from 5% in May of 2021 to a as high as 8.5% in May of 2022 (Bureau of Labor Statistics, 2022), inflation levels not seen in the US for 30-40 years (Rugaber, 2022). In early 2022 the Fed walked back their comments on the transitory nature of this increased inflation and assumed a hawkish[1] position with rate hikes and quantitative tightening (QT) being introduced in the first half of 2022.

Due to the recent heightened discourse around QE, its effectiveness and how it might impact the wider economy, we wanted to investigate this ourselves. Our research question is therefore: how has quantitative easing, via its transmission channels, effected the real economy?

[1]Hawkish = favouring tight monetary conditions to combat inflation

2. Timeline of QE

In this section we will add some overarching context to the use of quantitative easing by the Federal Reserve. Analysing when, why and how these QE programs were executed will help contextualize the literature on QE, as well as provide a foundation for how we will analyse our research question and subsequently interpret the findings of said analysis.

Since 2008, the Federal Reserve has implemented four distinct QE programs, as well as one maturity extension program (MEP) and one period of quantitative tightening with another one announced to start in June of 2022. The different QE and QT programs are visualized in figure 3. A trend clearly emerges from this visualization; the Federal Reserve has, in the wake of the two latest financial recessions, added trillions of dollars to their balance sheet. After four rounds of QE the Federal Reserve balance sheet has gone from below \$1 trillion to almost \$9 trillion. We also see that the periods of quantitative easing has corresponded with periods where the Fed Funds Rate has approached the zero lower bound, visualised in figure 2.

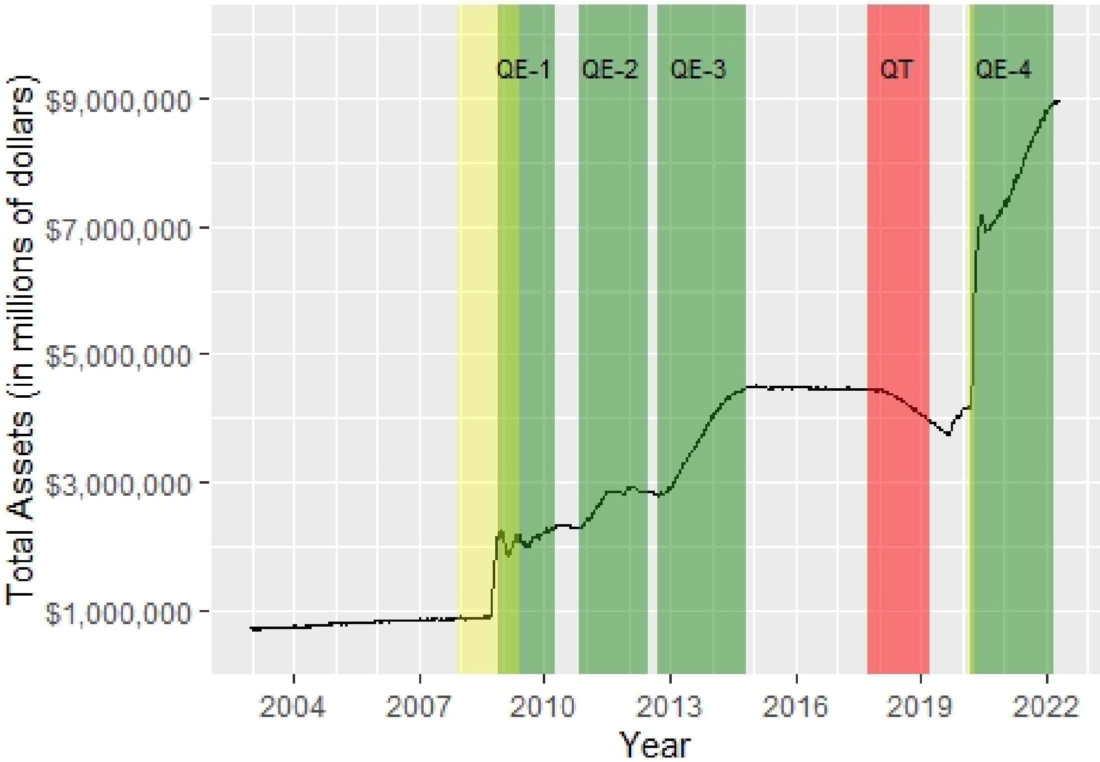

Figure 1: Federal Reserve's balance sheet. QE programs are marked in green, QT is marked in red, while recessions are marked in yellow. Data from: (Board of Governors of the Federal Reserve System (US), 2022)

In the subsequent sections we will discuss each round of quantitative easing, as well as the maturity extension program and the period of quantitative tightening, creating a timeline of the unconventional monetary policy pursued by the Fed.

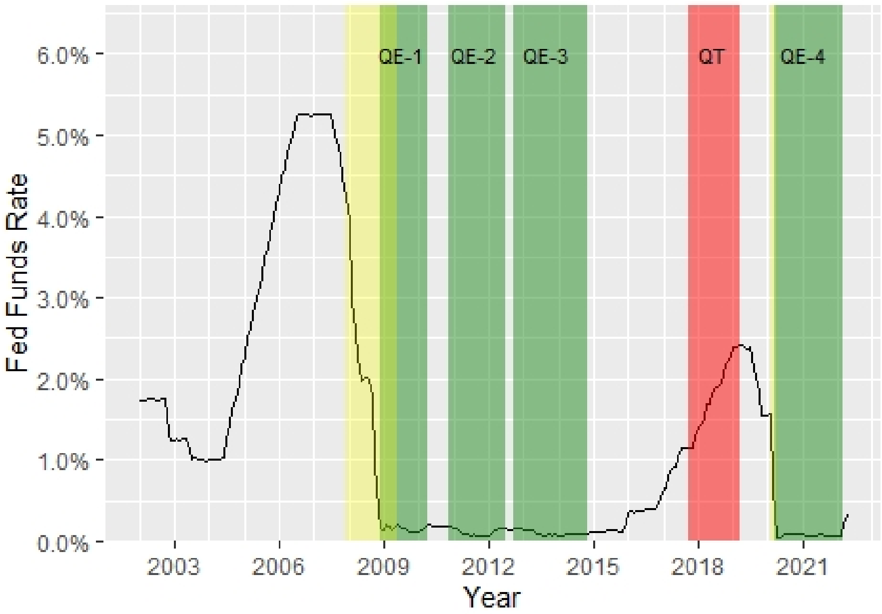

Figure 2: Federal Funds Rate. QE programs are marked in green, QT is marked in red, while recessions are marked in yellow. Data from: (Federal Reserve Economic Data, 2022)

2.1. QE-1, The Financial Crisis

At the end of 2008 the financial markets were in free fall. The US economy was rapidly contracting, with fears of a deflationary spiral looming. The economy needed further stimulation, and additional monetary easing (Ashworth, 2020). With the Federal Funds Rate approaching the zero lower bound, the Federal Reserve turned to unconventional monetary policy, which along with forward guidance were the only tools left to stimulate the economy. On the 25th of November 2008, the Federal Open Market Committee (FOMC) announced that they would purchase up to $100 billion in government- sponsored enterprise (GSE) bonds and up to $500 billion in mortgage backed securities. This round of large-scale asset purchases (LSAPs) is known as QE-1, and would last until its termination by March of 2010. The Fed added $1.25 trillion of MBS, $175 billion in agency debt and $300 billion in long-term Treasury securities to its balance sheet, roughly doubling the size of the U.S monetary base (Fawley et al., 2013). The purchases represented almost a quarter of the stock of these assets outstanding when the purchases began (Gagnon et al., 2011). The timeline of QE-1 and subsequent announcement from the FOMC can be found in table 1.

The first round of quantitative easing by the Fed is also found to be the most successful in much of the literature. Chung et al. (2012) found that QE-1 reduced long-term interest rates by 50 basis points.

QE-1 differed from other LSAP programs, as it prioritized housing credit market due to these markets being hit especially hard during the 2008 financial crisis. Over 80% of the assets purchased during QE-1 were directly inked to housing market credit (Fawley et al., 2013). A lot of these assets were so called "toxic assets", which the Fed could absorb due to its unlimited ability to create new dollars to cover said toxic assets.

Date	Announcement	Note
25.11.2008	QE-1 Announced	The Federal Reserve announce a program to purchase up to \$100 billion in GSE direct obligations and up to \$500 billion in MBS
18.03.2009	QE-1 Expanded	Fed will purchase up to an additional \$750 billion in MBS, increase its purchase of agency debt by up to \$100 billion, and to purchase up to \$300 billion in longer-term Treasury securities.
31.03.2010	QE-1 Terminated	The purchases of \$1.25 trillion in MBS, \$175 billion in agency debt, and \$300 billion in long-term Treasury securities were completed by the end of March 2010.
10.08.2010	QE-1 Rollover	Fed announced that they would keep their balance sheet at the current level by reinvesting principal payments of their holdings in longer-term Treasury securities.

Table 1: Timeline of QE-1. Source:(Federal Reserve, 2008-2022)

2.2. QE-2

With the economic recovery faltering after the termination of QE-1, the Fed announced yet another round of LSAPs in November of 2010. In this round of QE the Fed purchased \$600 billion of long-term Treasury securities, now focusing on putting downward pressure on the yield of long-term Treasuries instead of the housing credit market which was prioritized in QE-1. The Federal Reserve's asset holding reached about 17% of Treasury securities outstanding during the program (Meaning and Zhu, 2012). Meaning and Zhu (2011) estimated that QE-2 on average lowered the yield curve by 21 basis points, with some maturities with remaining maturity of around 20 years having a maximum impact of 108 basis points. They also found that though twice as large a QE-1, the second round of LSAPs were less effective per billion dollar spent than the first round. They attributed this finding to QE-1 including purchases of agency debt and MBS.

Date	Announcement	Note
03.11.2010	QE-2 Announced	Fed announced that they would continue reinvesting principal payments, as well as purchasing an additional $600 billion in long-term Treasury securities by the end of q2 2011.
29.06.2012	QE-2 Terminated	The Federal Reserve purchased $827 billion in US Treasuries under the QE-2 program

Table 2: Timeline of QE-2. Source:(Federal Reserve, 2008-2022)

2.3. Maturity Extension Program

On September the 21th of 2011, the FOMC announced a maturity extension program. This program, unlike QE-1 and QE-2, did not add to the Fed's balance sheet, however it did alter the composition of the assets within the balance sheet. The aim was to extend the average maturity of the Fed's Treasury holding by selling short-term Treasury bonds and replacing them with long-term Treasury bonds. During the program the Fed bought $667 billion of longer-term Treasury securities and reduced its holdings of short-Term Treasury bills by an equivalent amount (Gagnon et al., 2018). This was intended to "twist" the yield curve by pushing the long-term yield down while holding short-term yields at their current level. Swanson (2011) found that Operation Twist reduced the US 10-year Treasury bond yield by an estimated 15 basis points.

Date	Announcement	Note
21.09.2011	MEP announced	Fed announces a maturity extension program intended to extend the average maturity of its holding of securities by selling short-term Treasury bonds and replacing them with longer-term Treasury bonds.
20.06.2012	MEP Extended	FOMC statement announces the extension of MEP throughout the end of 2012
31.12.2012	MEP terminated	MEP ended and is replaced by Treasury bond buying program.

Table 3: Timeline of MEP. Source:(Federal Reserve, 2008-2022)

2.4. QE-3

With the unemployment rate still being high and concerns about the economic growth not being strong enough to substantially improve the labour market (Ashworth, 2020), the Federal Reserve announced their third LSAP program to ease financial conditions in September of 2012. This program differed from previous LSAP programs in two distinct ways; this round had no announced termination date and the Fed announced a monthly flow of asset purchases, instead of the previous rounds where the Fed announced an overall amount of assets to be purchased (Gagnon et al., 2018). The changes in the LSAP program to be on an open-ended basis until the conditions of the labour market improved was to rectify the shortcomings of the previous rounds. Several FOMC members felt that an ongoing program where the scale of asset purchases could be adjusted in line with economic data would be preferable to QE-1 and QE-2, where stimulus was abruptly removed as soon as the program ended and would need to be followed up with additional rounds of LSAPs (Ashworth, 2020). Table 4 shows the development of the open-ended QE-3 program, where the Fed adjusted the rate of asset purchases in line with economic data. QE-4 was terminated in October of 2014, with the Fed's balance sheet reaching ca. 25% of GDP (Ashworth, 2020).

Date	**Announcement**	**Note**
13.09.2012	QE-3 Announced	FOMC statement announcing their intention to purchase additional MBS at a rate of $40 billion per month, as well as reinvesting principal payments from their holdings in agency MBS. These actions will increase their holdings of longer-term securities by about $85 billion each month throughout the end of the year.
12.12.2012	QE-3 Expanded	Fed will purchase an additional $40 billion worth of agency MBS per month, as well as purchasing longer-term Treasury securities at a pace of $45 billion per month.
18.02.2013	QE-3 tapering begins	FOMC statement announcing that they will begin tapering down the rate of asset purchases, with the intention of reducing the purchase of agency MBS from $40 billion to $35 billion per month and purchase longer-term securities at a rate of $40 billion per month rather than $45 billion per month
29.10.2014	QE-3 terminated	FOMC announce that they will concluded its asset purchase in October of 2014, while still reinvesting principal payments from its holdings in agency MBS and continuing the rollover of maturing Treasury securities.

Table 4: Timeline of QE-3. Source:(Federal Reserve, 2008-2022)

2.5. QT

With the economy recovering substantially, the Federal Reserve announced that they would begin balance sheet normalization (known as quantitative tightening or QT) in October of 2017 (Federal

Reserve, 2008-2022), a process in which they reduce the size of their balance sheet by either selling their assets, letting them mature and not reinvesting principal repayments, or a combination of both. The Federal Reserve reduced its balance sheet by over $700 billion during the period of quantitative tightening, a reduction of over 20% (Ashworth, 2020).

2.6. QE-4, The Coronavirus Pandemic

In early 2020, the Federal Reserve was once again faced with major economic downturn and deflationary fears. The covid-19 pandemic caused major panic in the worldwide economy, and financial markets were in turmoil. The pandemic created a demand shock, supply shock, and a financial shock all at one (Triggs and Kharas, 2020). The Fed announced that the Federal Funds Rate (FFR) would be lowered to 0-1/4% on March 15th 2020. With the funds rate nearing the zero lower bound, they also announced a new round of LSAP, with their Treasury securities to be increased by at least $500 billion and their holdings of agency MBS to be increased by at least $200 billion. The timeline of QE-4 announcements are showed in table 5. The Fed further expanded the program only a week after they announced QE-4. With inflation rapidly increasing to levels not seen in decades, the Federal Reserve began signalling their intentions to tighten the economy in early 2022. QE-4 was terminated in January, and the target range for the FFR was increased. In March, they announced a further rate hike to 3/4-1%, and that they would being quantitative tightening in June. During QE-4, the Fed added approximately $4.2 trillion to their balance sheet, reaching a peak of $8.96 trillion in March of 2022 (FRED, 2022).

Date	**Announcement**	**Note**
15.03.2020	QE-4 announcement	To combat the economic effects of the coronavirus pandemic, the Federal Reserve announced they would lower the target range for the federal funds rate to 0 to 1/4%, approaching the zero lower bound. They also announced they would be increasing its holding of Treasury securities by at least $500 billion and its holdings of agency MBS by at least $200 billion, marking the beginning of a new QE program.
23.03.2020	QE-4 expanded	FOMC announced that they would increase their holdings of Treasury securities and MBS in the amounts needed to support smooth functioning of markets for Treasury securities and agency MBS.

15.12.2021	QE-4 tapering	Due to the improvement in unemployment rate and the economy at large, and with the Fed committed to decreasing the level of inflation which had exceeded the target rate of 2% for some time, the FOMC announced that they would reduce the monthly pace of their net assets purchases. The purchases of Treasury securities were reduced by $20 billion while agency MBS purchases were reduced by $10 billion. The FOMC were also prepared to further reduce the pace of net asset purchases each month, based on new economic data and outlook.
26.01.2022	Signalling rate hikes and termination of QE-4	With economic activity and employment continuing to improve, and inflation still being at an elevated level, the FOMC announced that increasing the target rate of the FFR might soon be appropriate. They also announced that they would further slow down their net asset purchases, and terminate the QE program in early March 2022.
16.03.2022	Rate hike and signalling QT	The FOMC announced that it would raise the target range for the FFR to 1/4-1/2%, with expectations of further rate hikes. They also announced that they were expecting to begin reducing their holdings of Treasury securities, agency debt and agency MBS at a coming meeting, signalling their intentions to begin quantitative tightening.
04.05.2022	Rate hike and QT	FOMC announcing a hike in the target range of the federal funds rate to 3/4 to 1% as well as signalling further hikes in the near future. They also announced that they on June 1 will begin decreasing their holdings of Treasury securities, agency debt and agency MBS.

Table 5: Timeline of QE-4. Source:(Federal Reserve, 2008-2022)

3. Theory and relevant literature

In this section we will explain some insight from previous literature on the unconventional monetary policy, and investigate the different transmission channels and how they may affect the real economy. While the theoretical framework for QE and its effect on the real economy is quite scarce in comparison to conventional monetary policy, there are some models which we can present to give us further grounds for our choice of variables in our extended VAR model. In this section we will first give some insight to conventional monetary policy, before describing and discussing the theoretical foundations of quantitative easing as a policy tool.

3.1. Conventional monetary policy and zero lower bound

In conventional monetary policy, the overnight call rate (or Fed rate for the US) is often a tool to expand or contract the economy. When inflation is high, the central bank would usually increase its rate, so that borrowing and spending money would come at a greater cost. And reversely, if the inflation is too low, then the central bank would lower the overnight call rate, so that banks could loan out more, and people would spend money more freely, since lowering the overnight call rate also lowers the return on savings and reduces the cost of capital. However, in recent times there have been occasions in which the overnight call rate is already at a low point, and the economy is still not sufficiently stimulated, to the point where decreasing it further will have little to no effect. This state of the economy is referred to as a "zero lower bound". Looking backwards, central banks learnt a vital lesson, when Japan hit a zero lower bound, and still could not stimulate the economy. They were stuck in what is referred to as a "liquidity trap", and the takeaway from this was the that prevention is far better than the cure. In particular zero inflation is something to be avoided (Blinder, 1995).

However, multiple central banks have reached the zero lower bound, as shown in the figure 3.

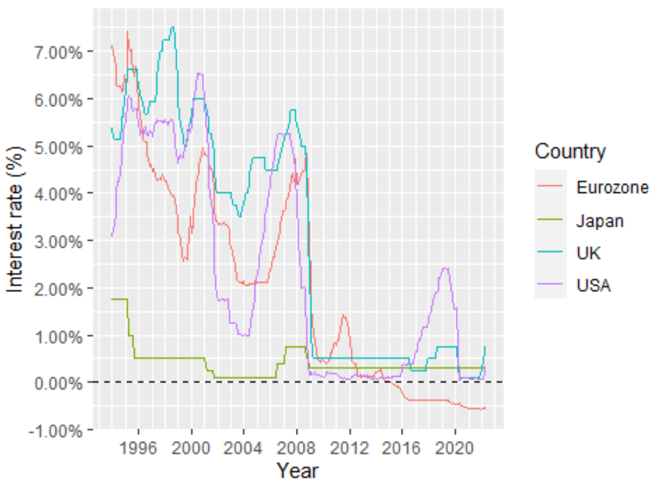

Figure 3: Empirical interest rates for the Eurozone, Japan, the UK and the US, from 1990 to 2022. Data from: (European Central Bank, 2022), (Bank of Japan, 2022), (Bank of England, 2022), and (Federal Reserve Economic Data, 2022)

As multiple big economies around the world arrived at a zero lower bound, more unconventional approaches to monetary policy were tried. Japan, were the first pursue quantitative easing in the late 1980s, and continued to use quantitative easing for over 15 years to try and prop up prices and recapitalize businesses. Though it was not yet called quantitative easing at the time. However, just as economic growth started to return in the early parts of the 2000s, it completely vanished in 2007. Quantitative easing became a central part of the Fed's strategy during and after the

Great Recession. The solvency of systematically important financial institutions like Bear Sterns and Lehman Brothers in the US marked one of the darkest periods of the Great Recession. This completely disrupted the financial markets, resulting in a decline in economic activity across the major economies that has not only been severe by historical standards, but also protracted and followed by a sluggish yet incomplete recovery (Bowdler and Radia, 2012).

Despite the relatively newfound relevance of quantitative easing and expansive unconventional monetary policy, there has still been arguments on the effects of money supply even long before the Japanese asset price bubble in 1986. The mercantile[2] believed that an increase in supply of money, would simply decrease the interest rates. Since interest rates works as "rental price" on money, a supply shock of money would according to the logic of the mercantile era, reduce the interest rates. Unfortunately, it is not that simple. The theoretical foundations was not as strong in the mercantile era as it is today, but their thought on interest rates and money supply is still an interesting one.

David Hume quickly shut down the mercantile thoughts (Carr and Smith, 1972). Hume pointed out that an increase in the supply of money would lead to a proportionate increase in the price level, and interest rates would remain the same. Hume further explained that the price level would not adjust instantaneously to the changes in money supply, and even in some situations he thought that an increase in the money supply and the price level could lead a fall in the interest rates.

John Maynard Keynes famously argued that an increase in the supply of money would lead to a fall in the interest rates. His theory and especially the LM-curve would be one of the fundamental ideas behind conventional monetary policy and interest rate strategy for years to come (Moggridge and Howson, 1974). His theories had a lot of similarities to the mercantile theory, however, he qualified his theory by assuming that prices were fixed. Which from a historical point of view could be because the price level and long-term interest rates were relatively stable over considerable periods of time (Moggridge and Howson, 1974). As such, his effect of money on interest rates can be interpreted as a short-run effect (Carr and Smith, 1972).

Similar for the theories above is that they assumed that if the price level changed, it would be a once and for all change. In other words they assumed that expected rate of inflation was zero. Monetary policy in recent times reject this assumption as for the US along side other inflation-targeting regimes, the central banks in general aim for a positive inflation as most economists have agreed that a small percentage change in the personal consumption expenditure(PCE) promotes a healthy and stable economy (Reserve, 2012).

In the early literature of Carr and Smith (1972), the effect of changes in the money supply affected the interest rates through two main channels: one associated with Irving Fisher, and the other with Knut Wicksell.

Fisher's hypothesis begins by postulating the premise that the nominal interest rate i, is identically equal to the real rate of interest r plus the expected rate of inflation $(\Delta P/P)^e$, which is illustrated by the equation:

$$i = r + \left(\frac{\Delta P}{P}\right)^e$$

which argues that the expected rate of inflation is affected by the current growth rate of the money supply, trough the current rate of inflation. Fisher emphasized that this effect is not instantaneous, and since time is required for variation in money to be reflected in the rate of inflation, then there is also a lag for changes in the expected rate of inflation. However, the extent to which an increase in the current rate of inflation alters the expected rate of inflation is crucially dependant on how the public forms their expectations and how rapidly they discount previous rate of inflation in their formulation of their expectations. Fisher also suggest a model for the formulation of expected inflation with respect to past rates of inflation, with his model:

[2]Mercantile is used to refer to economic thought and policy from the end of the middle ages to the age of laissez faire(Wiles, 1974).

$$\left(\frac{\Delta P}{P}\right)_t^e = \sum_{i=0}^{\infty} \lambda(1-\lambda)^i \left(\frac{\Delta P}{P}\right)_{t-i}$$

Fisher found very large average gaps, up to ten years, in the formulation of expectations of inflation[3]. His model implies that the effect of an increase in current rate of inflation, only marginally affects people's expectations to future rates of inflation. Consequently, a permanent shift in the inflation rate will gradually cause the inflationary expectations to reach the new permanent level of inflation (Carr and Smith, 1972). The speed in which the expectations adjust to the actual rate of inflation is the parameter λ.

We should also point out that higher expected rates of inflation makes real assets more attractive than liquid cash. Since it is expected that the return on having cash on hand is negative if the inflation is high, demand for real assets could increase. This could lead to an increase in the real price of assets and lower the interest rate (Carr and Smith, 1972)[4].

Knut Wicksell's postulation of the relationship between money and the rate of interest, is the temporary effect changes in the money supply upon the real interest rate. Wicksell's model is rooted in the demand and supply of real loan-able funds.

Wicksell explained that when the money supply initially increased, the banks would be enabled to increase their loans, as the total real supply of loan-able funds would be temporarily increased. This causes the market rate of interests to fall below its natural level[5]. However, with time the increase in the money supply would increase the price level, which in turn decreases the real value of cash and decreases the supply of loan-able funds. Wicksell created a static model which illustrated how an increase in the money supply initially caused the real interest rate to decline, eventually moving in reverse, back to its original value. So, according to Wicksell, increasing the money supply would only have a temporary effect. This effect which in later work would be coined as, "Wicksell effect" has been hard to quantify in dynamic models where the increase in money supply is continuous.

There was an attempt by Sargent (1969), to empirically define the Wicksell effect, he did so by using the percentage change in the real money stock $\Delta(mP)/mp$. The argument for the use of this variable to capture the effect was that when the money supply initially increases, prices will not adjust instantaneously, so real cash balances rise, but with time and as the prices rise, real balances will decline back to their original value. This captures the intuition behind the idea of Wicksell quite well.

We have now discussed some traditional views to monetary policy, which is useful for comparison to the relatively new policy tool, which is quantitative easing.

3.2. Transmission channels of QE

When conventional monetary policy is not sufficient to stimulate the economy, central banks turn to unconventional monetary policy. As discussed in chapter 2, the policy of choice has since 2008 been quantitative easing, and in this section we discuss in which way QE can affect the real economy trough different channels, which in economic theory is defined as the *transmission channels*.

In figure 4, we see the transmission channels of QE. This figure is inspired by Gern et al. (2015) and some classical transmission channels of monetary policy, and it describes the channels which QE runs trough. The financial market frictions are the channels which the money runs trough, and for most financial markets, the cost of moving money are defined as "frictions". The provision of more money to the financial markets is supposed to increase the banks' reserves and consumers

[3]Although Fisher found large average lags of adjustment, more recent studies by Federal Reserve Bank of St. Louis indicate shorter lags (Carr and Smith, 1972).

[4]If this happens, the nominal rate will not increase by the full amount of the increase in the expected rate of inflation

[5]Wickell defined the natural (real) rate of interest as the rate which equates desired saving and desired investments (Carr and Smith, 1972)

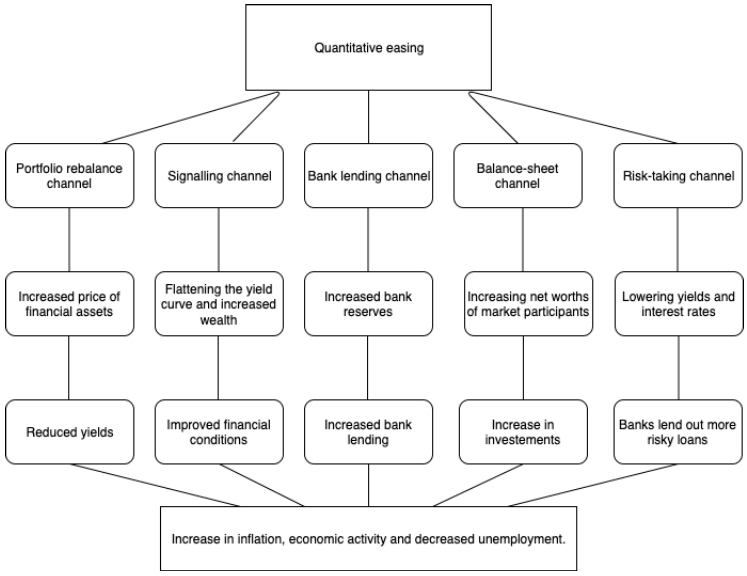

Figure 4: Transmission channels of QE

confidence, flatten the yield curve, while simultaneously increasing the price of assets. The two most prominent channels are the signalling and portfolio re-balancing channels. Both of these are targeted at flattening the yield curve and increasing asset prices. While the signalling channel affects the expectations of short-term interest rates, the portfolio re-balancing channel is targeted at reducing the risk premium. The risk-taking channel, balance-sheet channel and the bank lending channel are more classical transmission channels, which are also linked to conventional monetary policy. Previous literature does not pay as much attention to the three transmission channels on the right side of figure 4, but we also include these as we are interested to see if and how QE can transmit to the real economy.

3.3. Portfolio balance channel

The portfolio re-balancing channel will only work if short-term and long-term bonds are imperfect substitutes(Christensen and Rudebusch, 2016). Tobin (1969) built a new framework of economic theory, when he emphasized that portfolio balancing works as a transmission channel through which central banks can influence macroeconomic aggregates with monetary or fiscal policies. This section will give context to the effects quantitative easing has on the market participants through the portfolio balance channel.

By buying U.S. Government debt and mortgage backed securities, the Fed reduces the supply of these bonds in the broader market. The private investors and non-bank financial institutions who desire to hold these same securities will then bid up the prices of the remaining supply, reducing their yield. This is what is referred to as the "portfolio balance" effect. This mechanism has been one of the most important tools for central banks around the world in periods of crisis. Even when short term rates have fallen to effectively a zero lower bound, long-term rates have often remained above this effective lower bound, providing more space for purchases to stimulate the economy.

The lower Treasury yields are a benchmark for other private sector interest rates, such as corporate bonds and mortgages. With low rates, households are more likely to take out mortgage or car loans, and businesses are more likely to invest in equipment and hiring workers (Milstein et al.). Lower interest rates are also associated with higher asset prices increasing the wealth of households and thus stimulating the overall consumption(Rashid et al., 2022). This as well as the Fed's bond purchases can have an impact on the public expectations on the future path of monetary policy.

To explain the transmission mechanism of Federal Reserve's purchases of long term bonds we can consider a model for the portfolio balancing effect by Christensen and Krogstrup (2019).

3.3.1. A model for portfolio balancing with QE

The simple model setup which we extract from their working paper has one traded asset, which makes this model very tractable. However this limits the model to illustrate how the central banks purchases of one asset can affect the other assets through reserve induced effects. Supply is denoted as L and the supply price is P_L. Furthermore the central bank reserves are denoted as R. As is common in portfolio theory, the model assumes that assets are imperfect substitutes. Also, in the real world, non-bank financial institutions cannot hold reserves. Instead they hold deposits to their corresponding banks. Without any dynamics in this model, the difference between the price of the long-term bond and its nominal value of 1, it can be interpreted as capturing its long term premium. The term premium solely arise from imperfect substitution between bonds, reserves and deposits. It does not account for liquidity or credit risk premiums. It is also assumed that the risk premium is positive, otherwise all actors would rather hold deposits.

As previously mentioned the authors keep the model simple by not accounting for dynamics, keeping the asset market equilibrium static. This means that the model studies the marginal changes to the central bank asset holdings, matched by the outstanding amount of central bank reserves which will affect the equilibrium price at a certain time, but does not take lagged effects into account.

The model denotes individual banks and non-banks with subscripts i and j respectively. While the central bank is modeled as a large actor, the continuum of banks and non-banks acts as small actors, who cannot strategically influence the price of the asset. The subscripts are dropped when aggregates for the sectors are included in the model.

Equity of banks and non-banks are denoted as E, while deposits are denoted as D.

The only assumption we make on the non-banks response to bond prices is that their preferences are normal and their asset substitutability is imperfect. In such manner, their price sensitivity is defined as

$$-\infty < \frac{\partial f_{NB}(P_L, E^j_{NB})}{P_L} < 0 \tag{3.1}$$

which is finite and negative.

Furthermore the author assumes that non-banks do not respond in real time to short-term changes in their equity values by changing their demand for bonds, which can be expressed as:

$$\frac{\partial f_{NB}(P_L, E^j_{NB})}{\partial E^j_{NB}} = 0. \tag{3.2}$$

Similarly the bank's demand for bonds can be expressed as

$$L^i_B = f_B(P_L, E^i_B + D^i_B), \tag{3.3}$$

where the funding of banks are the equity and deposits, which can be denoted as $F^i_B = (E^i_B + D^i_B)$.

The banks preferences are analog with the preferences of non-banks, except their demand is also a function of their deposits. Can be written as follows:

$$-\infty < \frac{\partial f_B(P_L, F^i_B)}{P_L} < 0. \tag{3.4}$$

While the banks response in demand to changes in funding can then be written as:

$$0 < \frac{\partial f_B(P_L, E_B^i + D_B^i)}{\partial F_B^i} < 1 \tag{3.5}$$

This means that the banks does not fully back their new deposits into reserves, but instead aim for a certain duration or return on their liquid asset portfolios. If banks opted to do so, the reserve-induced portfolio balance channel would shut completely down, as all the new deposits would be tied down in reserves.

3.3.2. Central bank

The central banks balance sheet is

$$P_L L_{CB} = E_{CB} + R \tag{3.6}$$

L_{CB} is the central banks holdings of long-term bonds, while E_{CB} is the central banks' initial equity, while R is the amount of outstanding reserves. Since we want to see the effect of QE we assume that the central banks' holdings of long term bonds is the policy tool, and R is decided at the residual. We rewrite equation (3.6) to find how changes in the central banks' equity affect the other variables:

$$dE_{CB} = dP_L L_{CB} + P_L dL_{CB} - dR \tag{3.7}$$

which means that given our assumptions means that changes in reserves are matched by changes in the central banks' holdings of long term bonds. With our setup, this means that $dR = P_L dL_{CB}$, since changes in the central bank's reserves are matched by changes in holdings of long term bonds at their new price. Additionally, this also means that changes in the central banks equity are solely due to changes in the bond price. Which implies that when the central bank engages in QE, they are exposed to interest rate risks on their balance sheet.

3.3.3. The non-bank financial sector

The continuum of non-bank financial firms are fully financed by a predetermined amount of equity. The non-bank financial firms holds a portfolio balance which is a combination of both bonds and deposits.

The asset and liabilities of firm j must satisfy

$$P_L L_{NB}^j + D_{NB}^j = E_{NB}^j \tag{3.8}$$

L_{NB}^j is firm $j's$ holdings of bonds, D_{NB}^j is its holdings of bank deposits, and E_{NB}^j which is the initial value of the equity of firm j. The changes in its equity is decided at the residual from the cash flow identity:

$$dE_{NB}^j = dP_L L_{NB}^j + P_L dL_{NB}^j + dD_{NB}^j \tag{3.9}$$

Due to the short term nature of the model, the firms do not issue new debt or equity. So the firms can only obtain deposits and equity by selling assets:

$$dD_{NB}^i = -P_L dL_{NB}^j. \tag{3.10}$$

$$dE^j_{NB} = dP_L L^j_{NB} \tag{3.11}$$

Equations (3.8) and (3.9) asserts that firm j can only change their equity value in response to changes in the price of long term bonds

So firms balance their portfolio between bonds and deposits (liquidity), since they need liquidity but also return on their equity in order to be profitable. There the model assumes that their demand for both is positive.

We can then show that with our given assumptions, that change in deposits for firm $j's$ bonds are purely driven by changes in bond prices:

$$dL^j_{NB} = \frac{\partial f_{NB}(P_L, E^j_{NB})}{\partial P_L} \partial P_L \tag{3.12}$$

we can then use equation (3.10) to show the driving mechanism in firm $j's$ deposits when changes in bond prices occur:

$$dD^j_{NB} = -P_L \frac{\partial f_{NB}(P_L, E^j_{NB})}{\partial P_L} \partial P_L \tag{3.13}$$

3.3.4. The banking sector

In the same manner as non-bank financial firms, the banks in the model are a continuum of individual banks. Bank $i's$ assets and liabilities must satisfy

$$R^i + P_L L^i_B = E^i_B + D_B \tag{3.14}$$

As we have previously mentioned, due to the short nature and simplicity of the model, banks' credit portfolios are fixed in the short run and hence, are normalized to zero. Here, the deposits are from non-bank financial firms, and are denoted as D^i_B, hence this is also endogenous from the banks perspective. Due to this restriction, the authors also assume symmetry across all banks, and that there is an equal amount of banks and non-bank financial firms, such that $D^i_B = D^j_{NB}$. The initial equity is denoted as E^i_B, and again, due to the short term nature of the model, the banks cannot issue new equity or debt. This means that banks can only increase its holdings of reserves by selling bonds. Additionally, their reserves can fluctuate as the bank's customers vary the deposits they have in the bank. Importantly, banks cannot take actions to change their deposit holdings and therefore we consider them exogenous in the model. To summarize, the changes in bank reserve flow is as following:

$$dR^i = dD^i_B - P_L dL^i_B \tag{3.15}$$

In general, changes in banks equity are determined as a residual from the flow equivalent of equation (3.14)

$$dR^i + P_L dL^i_B + L^i_B dP_L = dE^i_B + dD^i_B \tag{3.16}$$

From equation (3.16) which shows the change in reserve for bank i, it follows that

$$dE^i_B = L^i_B dP_L \tag{3.17}$$

So from the above equation we can see that changes in bank $i's$ equity are solely due to fluctuations in the bond price. Banks hold bonds and reserves in their liquid asset portfolios and consider them imperfect substitutes. It is also assumed that neither reserves nor deposits earn interest, but the long term bond does because $P_L < 1$. In principle an equal increase in deposits and reserves has no effect on a banks profitability in this model, since the balance sheet will stay the same. As described by (4), it is crucial that banks respond to autonomous changes in deposit funding by increasing their demand for bonds.

The bank's reserves are determined as a residual from the bonds given their available funding:

$$R_B^i = E_B^i + D_B^i - P_L f_B(P_L, E_B^i + D_B^i) \tag{3.18}$$

The flow equivalent of bank $i's$ bond demand in equation (3.4) is given by:

$$dL_B^i = \frac{df_B(P_L, E_B^i + D_B^i)}{dP_L} dP_L + \frac{df_B(P_L, E_B^i + D_B^i)}{dF_B}(dE_B^i + dD_B^i) \tag{3.19}$$

Since banks cannot react to contemporaneous changes in the valuation of their equity, they are determined *ex post*[6]. The model can interpret the changes in equity as loss/profit paid out to the shareholders, since this model does not allow for the bank to purchase bonds with the available fund. With this in mind, (3.19) is reduced to:

$$dL_B^i = \frac{df_B(P_L, E_B^i + D_B^i)}{dP_L} dP_L + \frac{df_B(P_L, E_B^i + D_B^i)}{dF_B} dD_B^i \tag{3.20}$$

3.3.5. Equilibrium

Furthermore we can use the equations above to aggregate banking and non-banking sector, by dropping the i and j subscripts. Since we then have normalized the continuum of institutions in each category to one, we can further use the individual demand equations as characterizing aggregate sectoral demand. So that the total demand will be equal to the total supply, and reserves and deposits are decided at the residual.

$$P_L(L - L_{CB}) = P_L(L_B + L_{NB}) \tag{3.21}$$

where the flow equivalent is found by deriving (3.21) with respect to the price of long term government bonds.

$$dP_L(L - L_{CB}) + P_L(dL - dL_{CB}) = dP_L(L_B + L_{NB}) + P_L(dL_B + dL_{NB}) \tag{3.22}$$

3.3.6. General solutions for two extreme cases

To arrive at these solutions, we simply derive the long-term bonds with respect to the central bank purchases of long term bonds.

First we assume a situation where non-bank financial institutions exhibit low asset substitutability, and all assets are purchased by the bank. While in the other case, the roles are reversed, and the banks exhibit very low asset substitutability. For these two cases, QE is mapped as in real life, with the central bank increasing its reserve liabilities and bond holdings without changing the total supply of bonds. In this way the increase in holdings for the central bank is symmetric with the decrease in the private sector holdings. This is expressed by:

[6] After the central banks purchases in period 1.

$$dL_{CB} > 0 \quad \text{and} \quad dL = 0 \quad \rightarrow \quad dL_{CB} = -dL_{NB} - dL_B. \tag{3.23}$$

First we can see the impact of change in bond supply and reserves on the price of bonds using the previously derived flow equations. We do so by inserting the aggregate versions of the non-bank bond demand response in equation (3.13) and (3.20) into equation (3.23) which gives us

$$dL_{CB} = -\frac{\partial f_{NB}(P_L, E_{NB})}{\partial P_L} dP_L - \frac{\partial f_B(P_L, E_B + D_B)}{\partial P_L} dD_B. \tag{3.24}$$

Furthermore, we insert the non-bank deposit response from equation (3.14) and get

$$dL_{CB} = -\frac{\partial f_{NB}(P_L, E_{NB})}{\partial P_L} dP_L - \frac{\partial f_B(P_L, E_B + D_B)}{\partial P_L} dP_L + P_L \frac{\partial f_{NB}(P_L, E_{NB})}{\partial P_L} \frac{\partial f_{NB}(P_L, E_B + D_B)}{\partial F_B} dP_L. \tag{3.25}$$

Now we can derive the equilibrium bond prices response to changes in the central banks holdings

$$\frac{dP_L}{dL_{CB}} = \frac{-1}{\frac{\partial f_{NB}(P_L,E_{NB})}{\partial P_L} + \frac{\partial f_B(P_L,E_B+D_B)}{\partial P_L} dP_L - P_L \frac{\partial f_{NB}(P_L,E_{NB})}{\partial P_L} \frac{\partial f_{NB}(P_L,E_B+D_B)}{\partial F_B}} \tag{3.26}$$

Equation (26) explains how the equilibrium bond price reacts to the central banks bond purchases, and depends on the sensitivity of market participants' demand for bonds to changes in the bond price. The first two terms in the denominator captures that standard supply-induced portfolio balance effects. Which is the effects of the central banks bond purchases on the price that is caused by the reduction in available bonds. Then the third term captures the reserve-induced portfolio effects. From the last equation we can tell that if the asset price sensitivity of non-banks' demand for long term-bonds is zero, or if the banks have no response to the changes in deposit funding by changing their demand for long-term bonds, then the reserve-induced portfolio balance effect is zero(Christensen and Rudebusch, 2016).

To further exhibit the two direct effects of the central banks purchases of long term bonds, we derive the the size of the banks' balance sheets, when a reaction to the central bank bond purchases happen. To see this we insert (26) into the market aggregate demand in (14) and obtain

$$\frac{dD_B}{dL_{CB}} = -P_L \frac{\partial f_{NB}(P_L, E_{NB})}{\partial P_L} \frac{dP_L}{dL_{CB}} \tag{3.27}$$

.

From the two corner solutions we can see that the intial impact of QE tends to be more significant when $\frac{\partial f_{NB}(P_L,E_{NB})}{\partial P_L}$ and $\frac{\partial f_{NB}(P_L,E_B+D_B)}{\partial P_L}$ are small, in other words, when demand for long term bonds are inelastic and investor behavior is characterized by preferred habitat. Conversely, when the demand is very price sensitives, and the derivatives of our equation system becomes larger and more complex, the effect of price will be more modest. Accordingly, the required amount of QE bond purchases need to be sufficiently large to have a notable price impact under these circumstances. Related studies of QE find mixed signs and effects for the portfolio balance effect, mainly because of issues with concentration of the effect the portfolio re-balancing effect has on the market.

On one hand it is shown that QE often drive interest rates and risk spreads down, thereby simulating risk-taking in financial markets. But, since asset purchases by the central bank change the composition of investment portfolios, risk-avers investors will most likely react by purchasing those assets which are close substitutes to the long-term government bonds. This means that the central banks purchases of long-term bonds simultaneously increases the price of its substitutes. However, these are not complete substitutes, and the non-bank financial market is not completely risk averse. Looking at previous literature, we see mostly event studies used for capturing the effect in short time windows, since this isolates the effects of changes in the balance sheet in a "quiet" environment. Which means that effects on the long- and short-term yields are less likely to be affected by omitted factors (Christensen and Krogstrup, 2019).

3.4. Signalling channel

The signalling channel is closely related to the forward guidance communication strategies the most central banks in recent times have used to manage the expectations of the public. Strategically informing about future decisions, to incentivize consumption and spending when the economy is down, signalling that the expansive polices under ZLB will continue going forward. QE strengthens the credibility of forward guidance, and if consumers expect the interest rates to stay low over a signification period of time, this could stimulate spending. An exit from this strategy would trigger a loss for the central bank, making the future path of the Fed rate more credible.

When the Federal Reserve announces its intention to pursue QE, it also announces a timetable with the total value of bonds to be purchased through the expected period of QE, which is usually a period from a year up to a few years. Because long rates are closely related to the expected path of short rates, an announcement related to an expansion on the Fed's balance sheet will be seen as a commitment to ease monetary policy for a significant period (Lenoël, 2020). This will cause the yields to decline at the announcement date, rater than the actual time of purchases. We refer to this effect as *the signalling channel*.

An important aspect of economic systems is the way information disperse across markets participants and policymakers. When the Federal Reserve expects an exogenous shock to inflation, they will in line with macroeconomic theory try to tighten the monetary policy to absorb this shock to reach their target inflation. This seems logical. However, raising the policy rate might also cause inflation to rise if this action signals to the unaware market participants that there is about to be an inflationary shock to the economy Melosi (2017).

This signalling effect will again influence the economy through two additional channels: the first is based on the central banks ability to affect the real interest rates due to price stickiness, and the second which is the actual information the market participants will convey from a change in the policy rate (Melosi, 2017).

3.5. Bank lending channel

In theory, QE could also affect the real economy through what is called a bank lending channel. This channel is understood as a supplementary channel of monetary policy which leads banks to increase their supply of lending (Buttz et al., 2015).

Joyce and Spaltro (2014) created a model for the effect of QE on bank lending, adapted by a well-known model proposed by Kashyap and Stein (1994). They were concerned with analyzing the effects on lending of unconventional monetary policy in a time period where short-term interest rates were constrained at their effective lower bound. In this sort of economic environment, asset purchases by the central banks have direct effect on bank reserves and also on deposits, to the extent that bonds are bought from non-bank financial institutions rather than banks. In these conditions, it may be plausible to think of monetary policy shock in term of shocks to deposits (Joyce and Spaltro, 2014).

In the paper by Joyce and Spaltro (2014), the authors presents a two-period model with a partial equilibrium. The model assumes the banks to have the following stylised balance sheet:

$$L + S = E + ND + D \tag{3.28}$$

where on the asset side we have illiquid loans (L) and liquid securities (S). On the liability side, banks have equity (E). D is the deposits, ND is non-deposit liabilities, and the lower notation is referring to time period t, $t = 1, 2..$

Loans yield a return of r and cannot be liquidated at time 2, capturing their illiquid nature. Banks can invest in liquid securities at time 1, and can liquidate their securities at zero cost in time 2, meaning that r is effectively a spread, which in this model illustrate the effectiveness of the bank lending channel. Since this model asserts that the level of deposits is determined by the monetary authority, then movements in r show how changes in monetary policy affects banks' return.

They calculate ρ and γ as the persistence of shock and variance of deposit shocks, respectively. And continue by deriving the profit function and maximization problem. Which will result in the following equation for lending supply:

$$L = \frac{3}{\alpha_2}r + \frac{r}{\alpha_1} + \rho D_1 + (1-\rho)D + E_1 - \frac{\gamma}{2} \tag{3.29}$$

Equation (27) suggests that an increase in deposits leads to an increase in lending supply, which in return would increase the bank deposits due to QE's apparent effect on lending. It also illustrates how higher level of equity (E) is related to higher bank lending. The model takes into account that reactions from banks will differ with their size, i.e., smaller banks react differently than bigger banks. Continuing they firstly derive the ledning supply equation with respect to deposits in period 1:

$$\frac{\partial L}{\partial D_1} = \left(\frac{1}{\alpha_1} + \frac{3}{\alpha_2}\frac{\partial r}{\partial D_1}\right) + \rho \tag{3.30}$$

And finally we assume a linear loan demand function of the form:

$$L_D = Y - kr \tag{3.31}$$

which simply states that demand for loans is a positive function of economic growth, Y, and a negative function of the loan return, r.

The model assumes heterogeneous banks, independent of size, which gives:

$$L_D = nL \tag{3.32}$$

where there are n number of banks.

Solving the equilibrium condition, we get:

$$r = \frac{1}{nb+k}(Y - n(\rho D_1 + (1-\rho)D + E_1 - \frac{\gamma}{2})) \tag{3.33}$$

[7]

And again, we derive this expression with respect to D_1 and obtain:

$$\frac{\partial r}{\partial D_1} = \frac{1}{nb+k}\left(\frac{\partial Y}{\partial D_1} - n\rho\right) \tag{3.34}$$

Where the last expression informs of a bank lending only if changes in deposits does not have a large impact in the economic activity, i.e., $\frac{\partial Y}{\partial D_1}$ is small. Then $\frac{\partial r}{\partial D_1} < 0$ and there is a bank lending channel (Joyce and Spaltro, 2013). This model is meant to form a few testable hypothesis, most

[7] where $b = \frac{1}{\alpha_1} + \frac{3}{\alpha_2}$

importantly for our paper, that bank lending supply is positively related to deposits, which means that we should expect QE to increase bank lending.

Joyce and Spaltros' paper also include an analysis of the British lending market during QE in the UK from 2009 to 2010. In this analysis Joyce and Spaltro (2014) find that historical movements in the deposit ratio have a small but statistically significant effect on bank lending growth, which suggests that QE may have led to an increase in bank lending through its effect on deposits. They find that the effects are likely to be small, both because the estimated marginal effects have been small, but also because their point of departure assume a full pass-through from QE to deposits, which in reality will likely overestimate the impact. They also find no evidence that the impact from QE caused a higher quantity of deposits in this period. Their findings also suggests that the lending of smaller banks are more responsive to the level of deposits than the lending of bigger banks. Further, they find that bank lending is positively related to how well capitalised banks are, which suggests that the impact of QE on bank lending may have been be weakened by lower levels of available capital during financial crisis. In this sense it would be expected and justified the emphasis the central banks gave to QE going around the banks. Consequently, it would suggest that macroprudential policy may potentially influence the effectiveness of monetary policy tools.

3.6. The balance sheet channel

The balance sheet channel is a a channel through which monetary policy can affect the borrowers' balance sheet through changes in interest rates and income statements (Bernanke and Gertler, 1989).

Bernanke and Gertler wrote a paper in which they presented a formal analysis of the role of the borrowers' balance sheet in the business cycle. And they argued that since there is a asymmetric information between actors of financial organizations and the savers from whom they borrow, there opens up a possibility of an interesting interaction between real and financial factors (Bernanke and Gertler, 1989).

More specifically, the aspects of balance sheets that are potentially interesting to macroeconomic theory is the borrowers net worth. It is believed that this is important for the following reason: Whenever there is an asymmetric access of information between borrowers and lenders, optimal financial arrangements will often include dead-weight loss, relative to the first-best perfect-information equilibrium. Through this seminal work of Bernanke and Gertler (1989), the transmission mechanism of the balance sheet channel first gained its attention (Angelopoulou and Gibson, 2009).

The balance sheet channel is a standard theoretical transmission channel, but it also has its significance in discussions to unconventional monetary policy, such as quantitative easing (Jouvanceau, 2019). Since central banks generally buys liabilites from non-financial firms or private investors (Goodhart and Ashworth, 2012), QE could cause a rise in both the net worth series for households and non-financial firms.

3.7. The risk-taking channel

Changes to the short-term policy interest rate, all else being constant, induce changes to medium and long term interest rates, as well as other financial indicators such as the exchange rate (Paligorova et al., 2012). Consequently, these changes will affect economic activity by decreasing the cost of mortgages when the prime rate falls, by making it cheaper for firms to borrow money when yields on corporate bonds decrease. This can again lead to changes in the economic activity.

The risk-taking channel implies that if the interest rates remain at a low level for a sufficient amount of time, then the banks will increase their risk tolerance, as stated in Rajan (2006) by "search for yield". The idea behind this thought is that periods of low interest rates could make market participants overconfident that good times are here to stay, and "generate an appetite for risk" (Boivin, 2011).

3.8. Relevant literature and empirical evidence

Most studies by the Bank of England and the Federal Reserve have focused on the effects QE has on the financial markets and more narrowly on government bond markets (Joyce et al., 2012). However, there are several other papers on the relatively new research question, on how QE can affect the real economy. We will not go into depth on the empirical studies on the financial markets, but there is a broad consensus in the literature that central bank assets purchases had economically significant effects, at least on government bond yields (Joyce et al., 2012).

Kapetanios et al. (2012), examined the macroeconomic impact of the first round of quantitative easing by the Bank of England. Through three different VAR-models, they found evidence that would suggest that QE may have had a peak effect on the level of real GDP of around 1.5% and a peak effect on annual CPI inflation by about 1.25%.

Krishnamurthy and Vissing-Jorgensen (2011) examined the effects of Fed's purchases of long-term Treasuries and other long-term bonds in QE1 and QE2, and found by an event-study methodology that there is sufficient evidence for a signalling channel, and a unique demand for long-term safe assets and an inflation channel for both QE1 and QE2. They also find that it is not appropriate to only use the Treasury rates as a policy target, since mortgage-backed securities purchases in QE1 were crucial for lowering MBS yields as well as corporate credit risk and thus corporate yields for QE1. These results coincide with Gagnon (2010) who finds that quantitative easing can be especially powerful during times of financial stress, but also has a significant effect in normal times, with no observed diminishing returns.

While most find that long-term yields drop when central banks pursue unconventional monetary policy, the effects which are estimated are vastly different. For example, while some studies find that the LSAP [8] has decreased the 10-year yield by up to 240 basis points (D'Amico and King, 2013) [9], while the lowest has been estimated to only about 15 basis points (Christensen and Rudebusch, 2016). While these studies mainly capture the portfolio effects, there are several recent studies who address effects to the wider economy.

For example Watzka and Schenkelberg (2011), who addressed the identification problem of VAR by applying sign restrictions based of the DGSE-models of Peersman and Straub (2006) and Canova et al. (2007). They find that a shock in QE will increase the industrial production by about 0.5% after two years, which in return will lead to an increase in reserves by about 8%. However, they do not find a statistically effect from QE to inflation, or address the effects that it may have on the unemployment rate.

4. Data

4.1. Variables of interest

Our main objective of the econometric model is to look at how QE has affected the real economy. So, the variables which we want to see the effects through, are *unemployment*, *index for industrial production* and *inflation*. This decision is based on our prior theoretical knowledge of monetary policy, as well as former literature.

Inflation

We find inflation by finding the growth rate of the consumer price index. Because consumer price index is a non-stationary variable, we first can transform the variable into percentage growth form

[8] Where purchases have been normalized to 10 percent of GDP
[9] 100 basis points = 1 percentage point

by taking the log of CPI into first difference form, in this way the CPI will be presented as a growth rate.

$$infl = \frac{l.CPI_t - l.CPI_{t-1}}{l.CPI_{t-1}} \tag{4.1}$$

In the figure below we can see historical level of the consumer price index (CPI).Inflation targeting is an important strategy for the Federal Reserve, and one of the main reasons the Federal Reserve deploys unconventional monetary policy is to combat deflation. During times of recent recessions and deflation, the Federal Reserve has increased its balance sheet through LSAPs, in hopes of increasing inflation. Looking at figure 5 and figure 8, we can see that times with deflation is accompanied by QE-programs and subsequent increases in the Federal Reserve's balance sheet. As discussed in chapter 2, this also corresponds to the Fed Funds Rate approaching its zero lower bound.

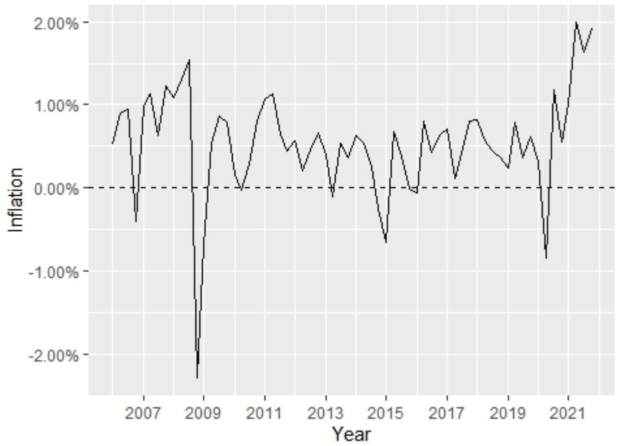

Figure 5: Inflation level in the US from 2006-2022

Unemployment

As well as inflation, unemployment is often a good indicator for the state of the economy. When the central bank bid up the price of financial assets, then the financial assets will be expensive relative to non-financial assets like labour(Watkins, 2014). By increasing their balance sheet with long term government bonds or debt, the price increase in financial assets may trickle down to the labour. Friedman (1961) explains that the employment will raise because businesses will substitute labour for capital.

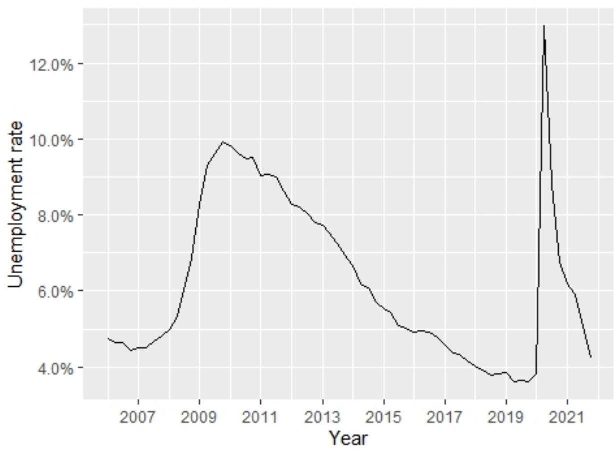

Figure 6: Unemployment in the US, quarterly data from 2006 to 2022

Index for industrial production

The index for industrial production is an index for the US which details out the growth of various sectors in the American economy. This index is meant to give a good indication on the economic state of the US during periods of unconventional monetary policy. Furthermore, we wish to see how this variable will be affected to changes in the Fed's balance sheet. A straightforward definition of the variable is: Industrial Production Index, is an economic indicator that measures real output for all facilities located in the US manufacturing, mining, electric and gas utilities (Board of Governors of the Federal Reserve System, 2013). This is also meant to account for structural developments in the economy.

The level of the Index of Industrial Production (INDPRO) is an abstract number, the magnitude of which represents the status of production in the industrial sector for a given period of time as compared to a reference period of time. The base year was at one time fixed at 1993–94 so that year was assigned an index level of 100. The current base year is 2011-2012.

Figure 7: Index for industrial production, quarterly data from 2006 to 2022

QE-related assets

To illustrate the behavior of the Federal Reserve during the deployment of Quantitative Easing, we have decided to combine the Fed's balance of mortgage backed securities and Treasury securities, as these are the biggest assets classes the Fed purchases during LSAPs as per chapter 2, and are highly correlated with the use of the unconventional monetary policy. Looking at the figure below we see a big increases on the balance of these assets in periods where QE has been deployed in the US.

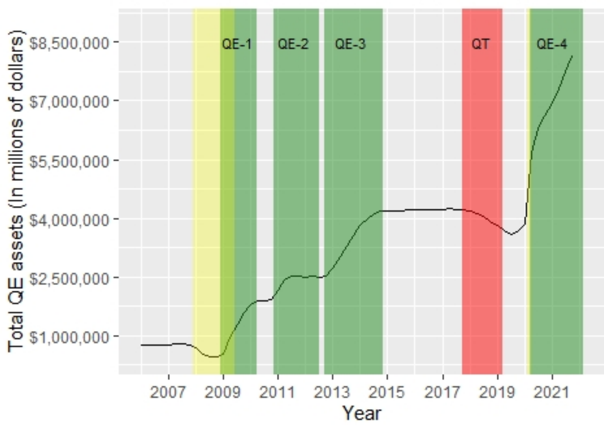

Figure 8: Federal Reserve's balance of MBS and 10-Y Treasuries from 2006 to 2022

4.1.1. Transmission channels of QE

To see the effectiveness of QE, and through which channels the effects have been most significant, we have chosen to mainly look at four channels: *The portfolio balance channel, the balance sheet channel, the risk taking channel* and *the signalling channel*. Although there are other channels we have talked about in which the effects of QE may transmit, we have chosen these four channels, as the data available as well as their relevance to the literature on QE are more significant than others.

The *portfolio balance channel* is captured by the ten-year Treasury term premiums, as well as Moody's BAA corporate bond yield relative to the ten-year Treasury constant maturity rate. Moody's seasoned Bond yield measures the yield on corporate bonds that are rated BAA. While the ten-year marked yield on U.S. Treasury securities with constant maturity, measures the market yield on long term government bonds. This will capture the re-balancing of portfolios, and more specifically, the substitution effect decreased yield on government bonds has on yield on corporate bonds rated BAA. Bonds rated BAA and above are considered investment grade. These grades are given by Moody's Investors Service, which is identified as a Nationally Recognized Statistical Ration Organization by the U.S. Securities and Exchange Commission.

The *risk taking channel* is captured by the growth rates of St. Louis stress and CBOE volatility indexes(VIX). VIX measures market expectation of near term volatility conveyed by stock index option prices, and the St. Louis stress index (SLSI) measures the degree of financial stress in the markets. SLSI is constructed from 18 weekly data series: seven interest rate series, six yield spreads and five other indicators. Each of these variables captures some aspect of financial stress. Accordingly, as the level of financial stress in the economy changes, the data series are likely to move together.

For *the balance sheet channel*, we have chosen to include variables consisting of net worth series for both households, and non-financial corporate businesses. We test for stationarity, and for both series we conclude that they are non-stationary $I(1)$ variables, which we take the first-difference of to make them stationary. However, for the sake of interpretation of our model, we also transform both series into growth rates.

For the bank lending channel, we see how banks could ease their conditions for conforming loans by having an increased amount of deposits on their balance sheet. We therefore use the bank credit ratio as a measure of available liquidity, and housing starts (HOUST), as a proxy for aggregate demand for loans.

The *signalling channel* is proxied with the 3-Month Treasury Bill Secondary Market Rate and the ten-year breakeven inflation rate. As we want to look at the dynamic structure between expectations about the future inflation and actual inflation, we look into how the announcements and purchases of QE may alter the short term rates, which are often highly inter-linked with the short term Treasury yields, meaning that when interest rates go up, yields tend to be higher. Conversely, when interest rates go down, then the price of bonds tend to decrease, causing the yield to go up (Carr and Smith, 1972). The model aims to capture the signal induced effect trough changes in the short term yield for government bonds. From a theoretical point of view, we include the ten-year break-even inflation rate as a measure of the expected rate of inflation, and exploit Fisher's equation, as mentioned in chapter 3.

5. Method baseline model and extended model

In this chapter we will present two models, where we first will explain the choice of methods to formulate and interpret our data-set. Furthermore, we will explain our choice of variables and how they are related to the theory presented in chapter 3. We also discuss solutions to problems we have encountered with the series of data which are available to us.

Description and variable names	Units	Sources
Unemployment	Rate	Federal Reserve St. Louis
Index for industrial production	Index	Federal Reserve St. Louis
Bank credit ratio of GDP	Rate	FRED/own calculations
QE-related assets	Millions	FRED/own calculations
Inflation	Rate	Federal Reserve St. Louis
Ten-year Treasury Term Yield (10Y)	Rates	FRED
Moody's Seasoned Baa Corporate Bond Yield (BAA)	Rates	Moody's
3-Month Treasury Bill Secondary Market Rate	Rates	Federal Reserve St. Louis
10-Year Breakeven Inflation Rate (10Y infl)	Rates	Federal Reserve St. Louis
Market Yield on U.S. Treasury Securities at 10-Year (CM)	Rates	Federal Reserve St. Louis
Households Net Worth series	Billions	Federal Reserve St. Louis
Non-financial businesses net worth series	Billions	Federal Reserve St. Louis
St. Louis Fed Financial Stress Index (STL stress)	Index	Federal Reserve St. Louis
CBOE Volatility Index: VIX (CBOE VIX)	Index	CBOE Market Statistics
Housing starts	Millions	Federal Reserve St. Louis
Period of QE	Binary	Federal Reserve St. Louis

Table 6: Description of variable names, specification of units, and source of extraction

5.1. Methodical approach

To analyze the effect of quantitative easing on the real economy in the USA, we use time-series data to approach our research question. In order to do an analysis of the problem at hand, we decided to apply a VAR-model. This is simply because there are inter-temporal relationships between real-economy variables and our variables for quantitative easing, meaning that purchases of long-term government bonds have an effect on inflation and unemployment, as well as changes in inflation and unemployment will have effects on the balance sheet of the central banks (Bhattarai et al., 2015).

It is natural to use a time-series of data, due the economy being "slow to react". What this is saying is that a policy imposed by the Federal Reserve will likely have a contemporaneous effect on the economy, but also that there is a lag in effect of monetary policy. Friedman (1961), studied the relationship between stock of money and economic activity. Since Friedman's pioneering work, most studies include lagged effects when calculating the results of monetary and fiscal policy (Tanner, 1969).

In former research on our topic, we find that former studies variate between monthly and quarterly observations. Although there is no direct comparison to our analysis, we have been inspired by Watzka and Schenkelberg (2011) and Kapetanios et al. (2012).

Firstly we start by explaining what a VAR-model is, and why it is a good model for our problem set. We then the explain the tests we have done on our set of variables. After our data is formulated and tested for standard assumptions of time series analysis and specifically VAR-models, we present our first four-variable VAR model, before we introduce a bigger VAR-model to further quantify the effects QE has on the real economy through the different transmission channels.

5.2. General approach to VAR-models

When we are not confident that a variable is endogenous or exogenous, a natural extension would be of a transfer function analysis in which we treat each variable symmetrically (Enders, 2014). Assuming a two-variable case, we can let the time path of y_t be affected by current and past realizations of the x_t sequence while also letting the time path of x_t be affected by current and past realizations of the y_t sequence. To express this we consider a simple bivariate system, as in Enders (2014):

$$\begin{bmatrix} 1 & b_{12} \\ b_{21} & 1 \end{bmatrix} \begin{bmatrix} y_t \\ x_t \end{bmatrix} = \begin{bmatrix} b_{10} \\ b_{20} \end{bmatrix} + \begin{bmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{bmatrix} \begin{bmatrix} y_{t-1} \\ x_{t-1} \end{bmatrix} + \begin{bmatrix} \epsilon_{y_t} \\ \epsilon_{x_t} \end{bmatrix} \tag{5.1}$$

or

$$Bz_t = \Gamma_0 + \Gamma_1 z_{t-1} + \epsilon_t \tag{5.2}$$

where

$$B = \begin{bmatrix} 1 & b_{12} \\ b_{21} & 1 \end{bmatrix}, z_t = \begin{bmatrix} y_t \\ x_t \end{bmatrix}, \Gamma_0 = \begin{bmatrix} b_{10} \\ b_{20} \end{bmatrix}, \Gamma_1 = \begin{bmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{bmatrix}, \epsilon_t = \begin{bmatrix} \epsilon_{y_t} \\ \epsilon_{x_t} \end{bmatrix} \tag{5.3}$$

Following the steps of Enders(2014), we premultiplicate the above equation by B^{-1} which gives us our VAR model in standard form:

$$z_t = A_0 + A_1 z_{t-1} + e_t \tag{5.4}$$

where $A_0 = B^{-1}\Gamma_0, A_1 = B^{-1}\Gamma_1$, and $e_t = B^{-1}\epsilon_t$

u_t and v_t are white noise disturbances. And in literature, is referred to as innovations or shock terms (Enders, 2014).

One of several reasons VAR-models are applied in macroeconomics is that it is often hard to present a one-way causal relationship, since many variables can be simultaneous, and therefore hard to identify which variables are endogenous or exogenous (Brooks, 2019).VAR-modelling treats all variables as exogenous, and the results are interpreted by OLS (Enders, 2014).

VAR models generalize univariate autoregressive models by allowing multivariate time series. A univariate regressions is a one single equation, where current values are explained by its lagged variables. Expanding to a multivariate regression, a VAR is is a n-variables n-equations model, which express each variable as a linear function of its own past values and the past values of all other variables being considered. Where the error term is serially uncorrelated.

VAR models first became popular by Christopher Sims due to his research paper from 1980: "Macroeconomics and Reality".

The main premise of using a VAR model, is that it provides a coherent and credible approach to data description, forecasting, structural inference, and policy analysis. VAR models are mainly used to forecast macroeconomic variables (GDP, inflation and unemployment) and also policy analysis (Stock & Watson, 2001). Which for our research question seems to be a good fit.

To execute a VAR model we need to satisfy a couple of assumptions. Mainly that we can only regress variables x_t and y_t as long as they are stationary. If the variables are non-stationary, we can apply logs and differences (Enders, 2014).

5.3. Stationarity

Firstly, we need to verify the assumption of stationarity. The reason being that if our variables are non-stationary and follow the same time trend, then we might obtain a spurious relationship (Brooks, 2019). According to Alexander (2008), a variable y_t, is said to be stationary if:

- $E(y_t)$ is finite and independent of time
- $var(y_t)$ is finite and independt of time

- $Cov(y_t, y_s)$ is a finite function of $|t-s|$, but not for t or s by themselves.

To test for stationarity, we conduct an Augmented Dickey-Fuller (ADF) test, which is one of the most common method used for testing for stationarity. The test-procedure is to run a regression model, store the residuals, before we test if the residuals or lagged values of the residuals explain variation in our stored residuals.

The ADF test is an extended version of the DF-test, which also test for stationarity, but does not take serial correlation into account. The standard DF is presented as:

$$y_t = \psi y_{t-1} + u_t \tag{5.5}$$

Continuing by subtracting y_{t-1} from both sides:

$$\Delta y_t = (\psi - 1)y_{t-1} + u_t = \Psi y_{t-1} + u_t \tag{5.6}$$

Where the null-hypothesis is that $\Psi = 0$, or $\psi - 1 = \Psi$, while the alternative hypothesis is that $Psi < 0$.

If we extend this to include p lags, the model is formulated as:

$$\Delta y_t = \Psi y_{t-1} + \sum_{t=1}^{p} \alpha_p \Delta y_{t-p} + u_t \tag{5.7}$$

5.4. Stability condition

To satisfy conditions for stationarity, we also check our VAR for stability conditions. Which is often referred to as stationarity conditions in time series analysis (Enders, 2014). If all our eigenvalues lie within the unit circle, the VAR is said to be stable, which is a critical assumption. A VAR-model is said to be covariance stable, when the effect of u_t disappears with time.

5.5. Normality

To check if our model has normal distributed residuals, we will use the Jarque-Bera test. We test the join null-hypothesis that there is no skewness or kurtosis, and the alternative hypothesis is that there exists skewness or kurtosis. According to Lütkepohl (2005), for a time-series to be normally distributed, the expectation of kurtosis and skewness needs to be zero. For kurtosis, this equals a value of 3.

5.6. Lag length selection

We execute several test for the VAR(p), before we determine the lag length using several different selection criterias. The general method to choose the amount of lags from a VARp model with orders $p = 0, \ldots, p_{max}$ and minimize the some model selection criterias. Model selection criteria for VAR(p) models have the form:

$$IC(p) = ln|\overline{\Sigma}(p)| + cT \cdot \varphi(n, p) \tag{5.8}$$

where $\overline{\Sigma}(p) = T^{-1}\Sigma_{t=1}^{T}\hat{\epsilon}_t\hat{\epsilon}`_t$ is the residual covariance matrix without a degrees of freedom correction form a VAR(p) model, c_T is a sequence indexed by the sample size T, and $\varphi(n,p)$ is a penalty function which penalizes large VAR(p) models. The built in VAR-functions in Stata tells us the three most common information criterion which are the Akaike (AIC), Schwarz-Bayesian (BIC) and Hannan-Quinn (HQ):

$$\begin{aligned} AIC(p) &= ln|\overline{\Sigma}(p)| + \frac{2}{T}pn^2 \\ BIC(p) &= ln|\overline{\Sigma}(p)| + \frac{ln\,T}{T}pn^2 \\ HQ(p) &= ln|\overline{\Sigma}(p)| + \frac{2\,ln\,ln\,T}{T}pn^2 \end{aligned} \tag{5.9}$$

The AIC criteria asymptotically overestimates the order with positive probability, as for the BIC and HQ criteria, they estimate the order consistently under fairly general conditions if the true order p is less than or equal to p_{max}. In our result section we adopt to this by are computed criteria-values in Stata.

5.7. Autocorrelation

Autocorrelation is when the residuals to a time series is linearly correlated to previous values of its previous residuals. Which means that:

$$E(u_t, u_{t-1}) \neq 0 \tag{5.10}$$

The consequences of autocorrelation is that our analysis can be misleading. We look for autocorrelation in our model by running the predicted residuals against the mean over 62 quarters from 2006 to 2021. This will give us the residuals plotted against mean of the residuals, which are close to zero.

To test for autocorrelation, we use a Lagrange-multiplier test. Here the null-hypothesis is that there exists no autocorrelation in lag i, where $i = 1, 2, \dots, p$, while the alternative hypothesis is that the time series is dependent on previous values of itself. We reject H_0 if our p-value is higher than our critical level.

5.8. Granger Causality test

The Granger Causality test is a test of whether the lags of one variable enters into the equation for another variable (Enders, 2014). We again illustrate with a bivariate model as previously, with ρ number of lags. In the example with the bivariate model, we say that y_t does not *Granger cause* x_t if, and only if $A_{21}L$ is equal to zero. If all the coefficients in $A_{21}(L)$ are equal to zero, then the series of y_t is not useful for forecasting the performance of x_t. If we have all stationary variables, we can test for Granger Causality by a regular F-test (Enders, 2014).

The unrestricted model is the bivariate VAR-model with ρ lags, and the restrictions applied to the unrestricted model will be:

$$a_{21}(1) = a_{21}(2) = a_{21}(3) = \dots = a_{21}(\rho) = 0. \tag{5.11}$$

The null-hypothesis is that previous and future lagged values of y_t does not Granger cause x_t, and we reject this for the alternative, that y_t does Granger cause x_t if $p > 0.05$[10]. If the nullhypothesis is rejected, then values of the series y_t helps to predict future values of x_t.

[10]With a critical value of 5%.

In time-series this can be very useful, as we are looking into the relationship on QE and macro-variables. If an increase in the balance sheet granger-causes the inflation, then we have good fundamental data to forecast the forward path of inflation, and so on with our other variables.

5.9. Innovation accounting

Two useful tools for examining the relationships between economic variables are *impulse response functions* and *variance decompositions.* If the correlations between various shocks/innovations are small, then the identification problem will less likely be as significant to our model (Enders, 2014).

5.9.1. The impulse response function

The reason we want to do an impulse-response analysis, is the see how a shock in one variable, affects another variable in the subsequent periods. We do so simply by putting the shocks in our VMA representation. And we get:

$$A_t = \mu_A + \theta_{1AA}\epsilon_{A,t-1} + \theta_{1AB} + \ldots \theta_{2AA}\epsilon_{A,t-2} + \theta_{2AB}\epsilon_{B,t-2} + \ldots + \epsilon_{A,t}, \tag{5.12}$$

which then tells us that a shock to B from one period before, $\epsilon_{B,t-1}$, will have an effect of θ_{1AB} and the shock to B from two periods before, $\epsilon_{B,t-2}$ will have an effect of θ_{2AB}, and so on.

In our first bivariate model we look at how shocks in CPI affects the balance sheet of the central bank, but also how a shock to the balance sheet affects the consumer price index.

For our multivariate model we more specifically look into the different transmission channels in which QE may stimulate the real economy.

The magnitude of the shocks are one standard deviation, while the shaded grey are are the confidence bands. On the X-axis are the period, which are quarters. And on the Y-axis are the percentage change from a unit shock in time in period t, and we estimate the impulse response functions for the standard short run restrictions, by 4 years (16 quarters).

One problem with a reduced form VAR is that is is impossible to disentangle what impact a sudden change in one variable will have on the other variables. The reason for this can be explained as in Enders (2014)

If the stability function is fulfilled we write x_t as:

$$z_t = \mu + \sum_{i=0}^{infty} A_1^i e_{t-1} \tag{5.13}$$

where $\mu = [\bar{y}\bar{x}]'$

We then use this to show the moving average representation of the sequences y_t and x_t.

$$\begin{bmatrix} y_t \\ x_t \end{bmatrix} = \begin{bmatrix} \bar{y} \\ \bar{x} \end{bmatrix} + \sum_{i=0}^{\infty} \begin{bmatrix} \phi_{11}(i) & \phi_{12}(i) \\ \phi_{21}(i) & \phi_{22}(i) \end{bmatrix} \begin{bmatrix} \epsilon_{yt-i} \\ \epsilon_{xt-i} \end{bmatrix} \tag{5.14}$$

These four sets of coefficients $\phi_{jk}(i)$ are called the impulse response functions. If we do know all the parameters in our original bivariate model, we could trace out the time paths of ϵ_{yt} and ϵ_{xt}. However, this is not available for us if the VAR is under-identified. This concept is explained later with structural VAR and the identification problem.

5.9.2. Variance decomposition

The variance decomposition, also referred to as the forecast error decomposition, displays the error made forecasting a variable over time due to a specific shock. In other words, it shows how much of the shocks in a given variable is caused by its "own shocks", and how much of the shock is explained by shocks in some other variables (Enders, 2014). Since none of our variables are exactly deterministic, it will be useful to see how much of the shocks to our macroeconomic variables are caused by themselves, and changes to the Fed's balance of QE-related assets.

To find the variance decomposition, we update our equation by one period, and take the conditional expectation for that period and subtract the actual values. We approach this method, similarly as in Enders (2014):

$$E_t x_{t+1} = A_0 + A_1 x_t \tag{5.15}$$

Then the one step ahead forecast error will be $x_t + 1 - E_t x_{t+1} = e_{t+1}$

Updating for two periods will in turn give us the equation:

$$\begin{aligned} x_{t+2} &= A_0 + A_1 x_{t+1} + e_{t+2} \\ &= A_0 + A_1(A_0 + A_1 x_t + e_{t+1}) + e_{t+2} \end{aligned}$$

which shows that this can easily be extended to n-ahead forecast as following:

$$E_t x_{t+n} = (I + A_1 + A_1^2 + \ldots + A_1^{n-1})A_0 + A_1^n x_t \tag{5.16}$$

where the associated forecast error is:

$$e_{t+n} + A_1 e_{t+n-1} + A_1^2 e_{t+n-2} + \ldots + A_1^{n-1} e_{t+1} \tag{5.17}$$

Again, as with the impulse response function, the forecast error variance decomposition contains the same problem inherent in the impulse response function as previously described.

5.10. Structural VAR and Identification problem

Lets recall that the standard reduced form VAR model, which considers each variable to be a function of its own past values, and the past values of other variables in the model. Although reduced VAR models are easily estimated by OLS and are useful for forecasting, there is and issue with disentangling the sudden impact of a sudden change in one variable will have on the other variables in the model.

So, what a structural VAR can do, is that it allows us to examine the causal relationship between variables. We can use economic theory to add structural restrictions to our VAR model, and in this way it becomes possible to examine the impact individual shocks will have on other variables (Clower, 2021).

Lets go back to our bivariate VAR model with QE and inflation. And for illustration, suppose that $y_{1,t}$ and $y_{2,t}$ can both be modeled using past observations of $y_{1,t}$ and $y_{2,t}$ going back one period, and random shocks to each variable $\epsilon_{1,t}$ and $\epsilon_{2,t}$.

Which again are mathematically represented by a two-equation system:

$$y_{1,t} = \phi_{11}y_{1,t-1} + \phi_{12}y_{2,t-1} + b_{11}\epsilon_{1,t} + b_{12}\epsilon_{1,t}$$
$$y_{2,t} = \phi_{21}y_{1,t-1} + \phi_{22}y_{2,t-1} + b_{21}\epsilon_{1,t} + b_{22}\epsilon_{2,t} \tag{5.18}$$

Here, the S-VAR includes separate contemporaneous shocks to each variable $\epsilon_{1,t}$ and $\epsilon_{2,t}$. These shocks are not observable and zero-mean white noise process, serially uncorrelated and independent of each other.

In this model the matrix B is:

$$B = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}$$

which captures the structural impacts of $\epsilon_{1,t}$ and $\epsilon_{2,t}$ have on the endogenous variables $y_{1,t}$ and $y_{2,t}$.

Although this is an easy setup, we still struggle to estimate B, since both $\epsilon_{1,t}$ and $\epsilon_{2,t}$ are unknown (Clower, 2021). This is where the reduced VAR combines the "shock" components of each equation so that:

$$u_{1,t} = b_{11}\epsilon_{1,t} + b_{12}\epsilon_{2,t}$$
$$u_{2,t} = b_{21}\epsilon_{1,t} + b_{22}\epsilon_{2,t} \tag{5.19}$$

So our now two-equation system becomes a reduced form VAR model:

$$y_{1,t} = \phi_{11}y_{1,t-1} + \phi_{12}y_{2,t-1} + u_{1,t}$$
$$y_{2,t} = \phi_{21}y_{1,t-1} + \phi_{22}y_{2,t-1} + u_{2,t} \tag{5.20}$$

By OLS we can estimate our unknown parameters in the reduced form VAR model

$$\Phi = \begin{bmatrix} \phi_{11} & \phi_{12} \\ \phi_{21} & \phi_{22} \end{bmatrix}$$

But the estimated residuals in (5.20) will not allow us to determine the impacts of the shocks $\epsilon_{1,t}$ and $\epsilon_{2,t}$ on Y_1 and Y_2

Going back to our shock components:

$$u_{1,t} = b_{11}\epsilon_{1,t} + b_{12}\epsilon_{2,t}$$
$$u_{2,t} = b_{21}\epsilon_{1,t} + b_{22}\epsilon_{2,t} \tag{5.21}$$

illustrated in matrix form

$$U_t = B\epsilon_t \tag{5.22}$$

From this relationship we can derive the covariance matrix of the reduced form residuals, using linear algebra and a few statistical relationship, to identify what is one of the most significant properties of implementing VAR relationships:

$$\Sigma_u = BB' \tag{5.23}$$

Where Σ_u is a covariance matrix of the reduced form residuals, i.e.:

$$\Sigma_u = \mathbb{E}[u_t' u_t] \tag{5.24}$$

To see why this is a problem, we can again consider our simplified two-variable VAR system: Again recalling that Σ_u is the covariance matrix of the residuals from our reduced form model:

$$\Sigma_u = \begin{bmatrix} \sigma_{11}^2 & \sigma_{12}^2 \\ \sigma_{21}^2 & \sigma_{22}^2 \end{bmatrix} \tag{5.25}$$

Which we can further expand to a system of equations:

$$\begin{aligned} \sigma_{11}^2 &= b_{11}^2 + b_{12}^2 \\ \sigma_{12}^2 &= b_{11}b_{21} + b_{12}b_{22} \\ \sigma_{21}^2 &= b_{11}b_{21} + b_{12}b_{22} \\ \sigma_{22}^2 &= b_{21}^2 + b_{22}^2 \end{aligned} \tag{5.26}$$

Since we have two parameters which are equal, $\sigma_{12}^2 = \sigma_{22}^2$, we have only 3 unique equations, but 4 unknowns. This makes our model under-identified. To solve this issue, we need more equations, which we obtain by imposing the Cholesky identification (Clower, 2021).

The long run restriction scheme is built on the theory that some shocks have no long run cumulative effects on one or more endogenous variables. In our theory section we argued that QE has no long run effects on inflation and unemployment, as suggested by Watzka and Schenkelberg (2011)

To see how we can implement zero long-run restrictions, we first look into how shocks accumulate over time.

To illustrate, we recall our bivariate model:

$$\begin{aligned} y_{1,t} &= \phi_{11}y_{1,t-1} + \phi_{12}y_{2,t-1} + b_{11}\epsilon_{1,t} + b_{12}\epsilon_{2,t} \\ y_{2,t} &= \phi_{21}y_{1,t-1} + \phi_{22}y_{2,t-1} + b_{21}\epsilon_{1,t} + b_{22}\epsilon_{2,t} \end{aligned} \tag{5.27}$$

or in compact form:

$$Y_t = \Phi Y_{t-1} + B\epsilon_t \tag{5.28}$$

Now, lets consider time period $T+1$:

$$Y_{t+1} = \Phi Y_t + B\epsilon_{t+1} \tag{5.29}$$

Substituting for Y_t, we get:

$$\begin{aligned} Y_{t+2} &= \Phi Y_{t+1} + B\epsilon_{t+2} \\ &= \Phi(\Phi^2 Y_{t-1} + \Phi B\epsilon_t + B\epsilon_{t+1}) + B\epsilon_{t+2} \\ &= \Phi^3 Y_{t-1} + \Phi^2 B\epsilon_t + \Phi B\epsilon_{t+1} + B\epsilon_{t+2} \end{aligned} \tag{5.30}$$

If we just focus on the impact of ϵ_t in each time period we find that:

The long-run cumulative impact then, is equal to the sum of all these impacts:

Time period	Impact of ϵ_t
T	$B\epsilon_t$
$T+1$	$\Phi B\epsilon_t$
$T+2$	$\Phi^2 B\epsilon_t$
$\vdots$	$\vdots$
$T+S$	$\Phi^S B\epsilon_t$
$\vdots$	$\vdots$
$T+\infty$	$\Phi^\infty B\epsilon_t$

Table 7: Long run impacts of ϵ_t

$$B\epsilon_t + \Phi B_t + \Phi\epsilon_t + \ldots 0\Phi^\infty B\epsilon_t = \sum_{i=0}^{\infty} \Phi^i B\epsilon_t \tag{5.31}$$

As we have checked or system for the stability conditions, we can simplify the expression above to:

$$\sum_{i=0}^{\infty} \Phi^i = (1-\Phi)^{-1} \tag{5.32}$$

which implies that our cumulative long-run effects of ϵ_t are given by:

$$C = (1-\Phi)^{-1}B \tag{5.33}$$

5.11. Zero short-run restrictions

In line with theory of contemporary shocks to monetary variables, we try to solve our under-identified model by imposing the Cholesky identification scheme.

Picking restrictions to identify SVAR models are often based on prior knowledge of the influence on variables. We follow Stock and Watson (2001) and assume that inflation depends only on past observations of other variables, and the contemporaneous changes in the monetary pool policy does not effect unemployment, but contemporaneous inflation does, and both contemporaneous inflation and unemployment both inform the Federal Reserve's balance sheet. Contrary to Stock and Watson, we use QE-related asset as the monetary pool, and observe the "shocks" as percentage change in the Fed's balance of said assets.

We recall our example with a bivariate model, and now alter the B matrix to fit our restrictions.

$$\begin{aligned} y_{1t} &= \phi_{11}y_{1t-1} + \phi_{12}y_{2t-1} + b_{11} + u_{1t} \\ y_{2t} &= \phi_{21}y_{1t-1} + \phi_{22}y_{2t-1} + u_{2t} \end{aligned} \tag{5.34}$$

If we believe that shocks to y_{2t} has no contemporaneous impacts on y_{1t}, then this implies that $b_{12} = 0$.

Our matrix representations of the shocks will then become:

$$B = \begin{bmatrix} b_{11} & 0 \\ b_{21} & b_{22} \end{bmatrix} \tag{5.35}$$

From our above matrix, we can see that the B matrix is lower triangular. Which allows us to use the Choleksy decomposition of Σ_u for estimation.

5.12. Long run restrictions

The long run restriction scheme is built on the theory that some shocks have no long run cumulative effects on one or more endogenous variables. In our theory section we argued that QE has no long run effects on inflation and unemployment, as suggested by Watzka and Schenkelberg (2011)

To see how we can implement zero long-run restrictions, we first look into how shocks accumulate over time.

To illustrate, we recall our bivariate model:

$$\begin{aligned} y_{1,t} &= \phi_{11}y_{1,t-1} + \phi_{12}y_{2,t-1} + b_{11}\epsilon_{1,t} + b_{12}\epsilon_{2,t} \\ y_{2,t} &= \phi_{21}y_{1,t-1} + \phi_{22}y_{2,t-1} + b_{21}\epsilon_{1,t} + b_{22}\epsilon_{2,t} \end{aligned} \tag{5.36}$$

or in compact form

$$Y_t = \Phi Y_{t-1} + B\epsilon_t \tag{5.37}$$

Now, lets consider time period $T+1$:

$$Y_{t+1} = \Phi Y_t + B\epsilon_{t+1} \tag{5.38}$$

Substituting for Y_t, we get:

$$\begin{aligned} Y_{t+2} &= \Phi Y_{t+1} + B\epsilon_{t+2} \\ &= \Phi(\Phi^2 Y_{t-1} + \Phi B\epsilon_t + B\epsilon_{t+1}) + B\epsilon_{t+2} \\ &= \Phi^3 Y_{t-1} + \Phi^2 B\epsilon_t + \Phi B\epsilon_{t+1} + B\epsilon_{t+2} \end{aligned} \tag{5.39}$$

If we just focus on the impact of ϵ_t in each time period we find that:

Time period	**Impact of ϵ_t**
T	$B\epsilon_t$
$T+1$	$\Phi B\epsilon_t$
$T+2$	$\Phi^2 B\epsilon_t$
$\vdots$	$\vdots$
$T+S$	$\Phi^S B\epsilon_t$
$\vdots$	$\vdots$
$T+\infty$	$\Phi^\infty B\epsilon_t$

Table 8: Long run impacts of ϵ_t

The long-run cumulative impact then, is equal to the sum of all these impacts:

$$B\epsilon_t + \Phi B_t + \Phi\epsilon_t + \ldots 0\Phi^\infty B\epsilon_t = \sum_{i=0}^{\infty} \Phi^i B\epsilon_t \tag{5.40}$$

As we have checked or system for the stability conditions, we can simplify the expression above to:

$$\sum_{i=0}^{\infty} \Phi^i = (1 - \Phi)^{-1} \tag{5.41}$$

which implies that our cumulative long-run effects of ϵ_t are given by:

$$C = (1 - \Phi)^{-1} B \tag{5.42}$$

In this section we use the Cholesky decomposition, and apply restrictions on the response of our variables to each impulse. We apply methods from (Sims et al., 1990) and (Blanchard and Quah, 1988), and will impose restrictions on our matrixes for the short- and long run effects.

As discussed in the above section, we impose some restrictions on our **A** and **B** matrixes, which will allow us to see more accurate estimates, since our standard VAR-model is under-identified. Again, the **A** matrix is composed of the contemporaneous effects, and by restricting our **A** matrix we will find out the impulse response functions, where the model is now accounting for the short-run relationships for the restrictions imposed. Given that our identification strategy is straight-forward zero-restrictions, this may leave out some form of relationships between our variables, but this problem is addressed later in the discussion section.

As we have issues with compiling all the matrices with the correct restrictions, we focus on bivariate models for the effects on each of the macro-variables separately.

For the short run restrictions:

$$A = \begin{bmatrix} 1 & \cdot \\ 0 & 1 \end{bmatrix} \quad B = \begin{bmatrix} \cdot & 0 \\ 0 & \cdot \end{bmatrix} \tag{5.43}$$

While the long run restrictions on the unemployment rate is:

$$C = \begin{bmatrix} \cdot & 0 \\ 0 & \cdot \end{bmatrix} \tag{5.44}$$

Here, the dot is the unrestricted parts of our matrices, which the SVAR will estimate.

5.13. VAR representation of the baseline model

We start of by looking at the relationship between two variables, we can illustrate by assuming a bivariate model where one variable is the inflation, and the other a variable we call quantitative easing. The variable quantitative easing is a component of the sum of 10-year yield Treasuries and mortgage backed securities, which are the two primary asset classes the Federal Reserve has purchased in connection to their QE-programs, as previously discussed.

$$u_{1,t} = a_1 + \sum_{m=1}^{m=2} b_{11} y^{+}_{1,t-m} \sum_{p=1}^{p=2} b_1 2 y_{2,t-p} + u_t \tag{5.45}$$

$$y_{2,t} = a_2 + \sum_{m=1}^{m=2} b_{21} y_{1,t-m} + \sum_{p=1}^{p=2} b_{22} y_{2,t-p} + v_t \tag{5.46}$$

And their matrix representation is the following:

$$\begin{bmatrix} y_{1,t} \\ y_{2,t} \end{bmatrix} = \begin{bmatrix} a_1 \\ a_2 \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \begin{bmatrix} u_{1,t-1} \\ y_{2,t-1} \end{bmatrix} + \begin{bmatrix} u_t \\ v_t \end{bmatrix}$$

This is the baseline for our analysis. Substituting y_1 for inflation, and y_2 for QE, we can consider the relationship we wish to measure. Which is straightforward investigating the effects QE can have on the inflation through a bivariate VAR-model, but also how the level of inflation affects decisions on the Federal Reserve's balance sheet.

The equations for each variable can then be expressed by the following system of equations:

$$y_{1,t} = a_1 + \sum_{k=1}^{k=2} b_{11}\pi_{t-k}^{infl} + \sum_{m=1}^{m=2} b_{12}u_{t-m}^{Une} + \sum_{p=1}^{p=2} b_{13}q_{t-p}^{QE} + \sum_{s=2}^{s=2} b_{14}x_{t-s}^{IND} + u_t \tag{5.47}$$

$$u_t^{Une} = a_2 + \sum_{k=1}^{k=2} b_{21}\pi_{t-k}^{infl} + \sum_{m=1}^{m=2} b_{22}u_{t-m}^{Une} + \sum_{p=1}^{p=2} b_{23}q_{t-p}^{QE} + \sum_{s=2}^{s=2} b_{24}x_{t-s}^{IND} + u_t \tag{5.48}$$

$$q_t^{QE} = a_3 + \sum_{k=1}^{k=2} b_{31}\pi_{t-k}^{infl} + \sum_{m=1}^{m=2} b_{32}u_{t-m}^{Une} + \sum_{p=1}^{p=2} b_{33}q_{t-p}^{QE} + \sum_{s=2}^{s=2} b_{34}x_{t-s}^{IND} + u_t \tag{5.49}$$

$$x_t^{IND} = a_4 + \sum_{k=1}^{k=2} b_{41}\pi_{t-k}^{infl} + \sum_{m=1}^{m=2} b_{42}u_{t-m}^{Une} + \sum_{p=1}^{p=2} b_{43}q_{t-p}^{QE} + \sum_{s=2}^{s=2} b_{44}x_{t-s}^{IND} + u_t \tag{5.50}$$

which in the result-section will be interpreted by use of OLS.

5.14. Multi-variate VAR model for transmission channels

In our multivariate model with the included variables for the transmission channels discussed in chapter 3, we want to see how significant the effects of each transmission channel can be, and how much an increase on the balance sheet of QE-related assets will affect variables in the transmission channels.

Our procedure is straight up the same as in the basic VAR model for Model 1, and we will evaluate the effectiveness of QE in the following reduced-form VAR model:

$$Y_t = c + A(L)Y_{t-1} + u_t \tag{5.51}$$

where Y_t is a vector of endogenous variables, c is a vector of intercepts and $A(L)$ is a matrix of auto-regressive coefficients with a one period lag. For our bigger VAR-system, the vector Y_t consists of all the variables we have included for the transmission channels and the real economy.

$$\begin{aligned} Y_t = \{&INFL_t, UNRATE_t, QE_t, VIXCLS_t, TB3MS_t, T10YIE_t, STLFSI3_t, \\ &INDPRO_t, HOUST_t, HHNW_t, DGS10_t, BCR_t, NFBNW_t, BAA_t\} \end{aligned} \tag{5.52}$$

We use these variables as discussed in chapter 3, to isolate the effects of the transmission channels, and see how much changes in the balance sheet of QE-related assets will affect these channels. Results are again interpreted by OLS, and we discuss our findings in the next chapter.

6. Results

The following chapter will explain the executed tests and the proceeding results. The chapter is divided into four sections: in the first part a four-variable VAR-model is presented and discussed, in the second we impose restrictions on our first model to obtain the SVAR-model, in the third we extend our original VAR-model, before we discuss implications, effectiveness and problems with our models.

6.1. Four-variable VAR-model

6.1.1. Stationarity

	t-stat	p-value	n-obs	1%	5%
UNRATE	-2.527	0.1090	63	-3.562	-2.920
INFL	-5.589	0.0000	63	-3.562	-2.920
QE	1.907	0.9985	63	-3.562	-2.920
INDPRO	-2.023	0.2767	63	-3.562	-2.920

Table 9: Augmented Dickey-Fuller test for our nominal values

There is an issue of whether we should difference the variables or not. As per Sims et al. (1990), they argued that one should not differentiate the variables even if they are not stationary. Arguing that the goal of a VAR analysis is to determine the interrelationship among the variables, and by differentiation, one "throws away" information about potential co-movements in the data. Furthermore, they state the purpose of VAR-modelling is not to determine accurate parameters, but determine the actual interrelations-ship between variables. On the contrary, we also find in Brooks (2014), that stability in the VAR-system is essential for estimation of statistical relationship. If the variables are non-stationary, we can differentiate (Brooks, 2014).

Continuing with the assumption that all variables must be stationary, we differentiate the variables which have a p-value, higher than 0.05. The variable QE is also transformed to logarithmic form, for later estimation purposes.

	t-stat	p-value	n-obs	1%	5%
ΔUNRATE	-9.257	0.0000	62	-3.562	-2.920
INFL	-5.589	0.0000	62	-3.562	-2.920
Δ l.QE	-3.987	0.0015	62	-3.562	-2.920
ΔINDPRO	-7.514	0.0000	62	-3.562	-2.920

Table 10: DF-test with differenced terms

Given our results from table 10, we can conclude that the variables which where not stationary in table 9, are stationary when differenced.

6.1.2. Stability

From table 27, we see the results of our test for stability. We can conclude that since all eigenvalues lie inside the unit circle, the stability condition is satisfied with our first VAR model.

Eigenvalue		Modulus
.741228 +	.4271666i	.855506
.741228 -	.4271666i	.855506
-.1980819 +	.5422397i	.577287
-.1980819 -	.5422397i	.577287
-.494791		.494791
.1325831 +	.4193503i	.43981
.1325831 -	.4193503i	.43981
.1031948		.103195

Table 11: Eigenvalue stability condition

An illustration of the unit circle with the eigenvalues is given in figure 9. Since we find stability in our system, we conclude that a shock in u_t will even out over time.

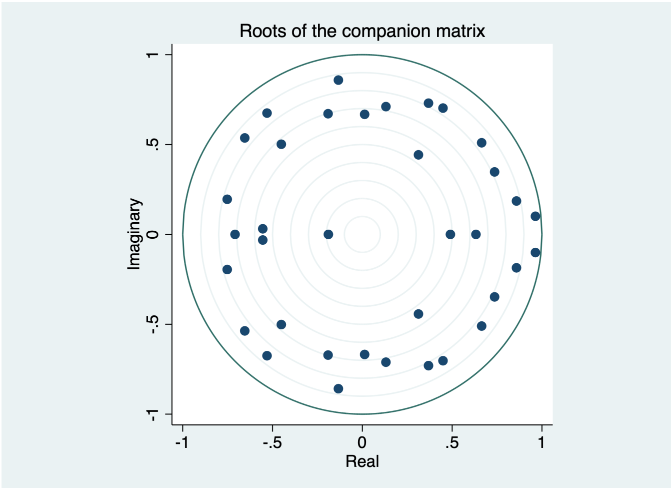

Figure 9: The unit circle with the roots of the companion matrix

6.1.3. Lag-length selection

Table 12 shows the selection criterions for our variables, the test is conducted with 4 lags, and the asterisk behind the values shows the preferred number of lags for each criterion. As argued in chapter 5, we would go with the AIC information criterion, additionally, all other criterions presented in table 12 prefers the model with two lags as well. Therefore the proceeding tests and estimations are conducted with two lags.

Selection-order criteria

Sample: **2007q3 - 2021q4** Number of obs = **58**

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-238.666				.050604	8.36778	8.42313	8.50988
1	-151.835	173.66	16	0.000	.004407	5.92534	6.2021	6.63584
2	-108.537	86.597	16	0.000	.001734*	4.98402*	5.48217*	6.26291*
3	-93.2816	30.51	16	0.016	.001817	5.00971	5.72927	6.857
4	-79.7576	27.048*	16	0.041	.002059	5.09509	6.03605	7.51078

Table 12: Lag-selection criteria for model 1

6.1.4. Autocorrelation

Firstly, we run our VAR-model, and obtain the predicted residuals. Thereafter, we plot the predicted residuals towards the residual mean to check for patterns of autocorrelation.

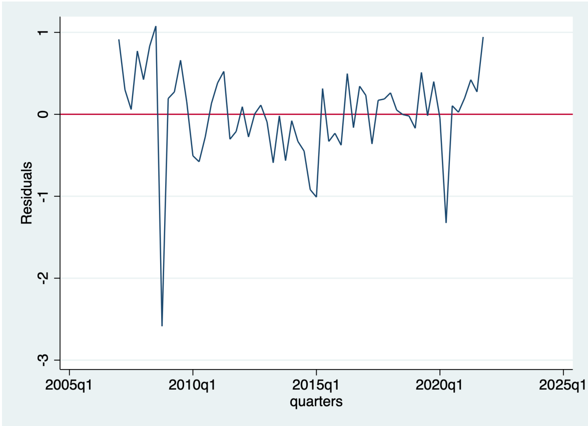

Figure 10: Plotted line of residuals to the four-variable VAR

As seen from figure 10, we see no obvious pattern, but have a few outliers from our residuals. We continue by applying the Lagrange multiplier test, and the results are reported in table 13

lag	chi2	df	Prob>chi2
1	19.8207	16	0.22841
2	29.0199	16	0.02380

Table 13: Lagrange multiplier test

The null-hyptesis is that the residuals are not autocorrelated given the selected lag length. We reject the null when $p < 0.05$. Given our results we reject that there is correlation within the first lag, but not the second. We need to keep this in mind when discussing results our VAR equations.

6.1.5. Granger causality test

From table 14 we can see the results from our estimated VAR-model. The null hypothesis is that lagged values of x_t does not Granger cause y_t. In table 14 the results are presented as $equation = y_t$ and $excluded = x_t$, meaning that in our null-hypothesis, the x_t variable is excluded, and we reject the null that x_t can be omitted if $p < 0.05$.

Equation	Excluded	chi2	df	Prob>chi2
Infl	QEprc	7.6777	2	0.022
Infl	INDPROperc	2.0371	2	0.361
Infl	dUNRATE	3.0946	2	0.213
QEperc	Infl	8.4714	2	0.014
QEperc	INDPROperc	4.9277	2	0.085
QEperc	dUNRATE	5.1991	2	0.074
QEperc	ALL	21.043	6	0.002
INDPROperc	Infl	8.2852	2	0.016
INDPROperc	QEperc	47.095	2	0.000
INDPROperc	dUNRATE	399.05	2	0.000
INDPROperc	ALL	999.42	6	0.000
dUNRATE	Infl	.93382	2	0.627
dUNRATE	QEperc	.57881	2	0.749
dUNRATE	INDPROperc	4.0727	2	0.131
dUNRATE	ALL	7.1777	6	0.305

Table 14: Granger causality Wald test for Model 1

We can conclude that changes in QE-related assets, inflation, and industrial production, does not Granger cause changes in the unemployment rate. A part from this, our vector of variables seem to Granger cause each other quite well. Which means that our data can be useful for predicting future values of our variables.

6.1.6. Impulse response functions

In figure 11 we see the impulse responses for all four of the variables in model 1. The impulse response function applies the Cholesky Decompositions for identification purposes, which could give us problematic results, as discussed in chapter 5.

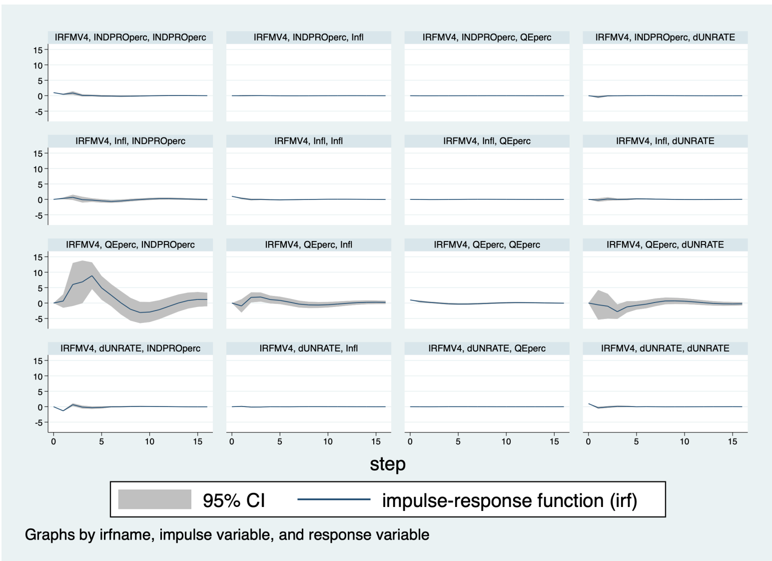

Figure 11: Impulse response functions for Model 1

After $IRMFV4$, we first see the impulse, and then the response. The y-axis shows the response-variable's response to a one standard deviation shock in the impulse variable. As we are mostly interested in the response of the macroeconomic variables due to an increase in the Fed's balance of QE-related assets, we can observe these response on line 3. We see that a one standard deviation, i.e., one percentage increase in the Fed's balance of QE related assets will give a positive response up until about 8.5%[11]. Furthermore we see an one standard deviation shock to QE will in the first periods have a negative impact on the unemployment rate, possibly due to the economy being slow to react, but this effect becomes positive after 7 periods. Lastly we see that is has a negative impact in the following period for inflation, then becomes positive for about five periods, before again switching from positive to negative.

6.1.7. Variance decomposition

In figures 15 to 17 we have put the forward error variance decompositions of changes to QE-related assets side by side with the variables of interest. The FEVD indicates the amount of the information each variable contributes to the other variables forecast errors in the VAR model.

Lags	Unemployment		QE assets	
	Unemployment	QE assets	Unemployment	QE assets
0	0	0	0	0
1	.775721	0	.30127	.595248
2	.787406	2.9e-06	.21326	.650921
3	.783587	.000028	.192103	.592755
4	.763317	.025106	.183697	.565364
5	.760483	.030332	.169463	.543445
6	.750528	.032263	.159234	.530659
7	.747226	.033768	.148732	.514143
8	.744913	.033684	.144401	.517055
9	.743815	.033767	.142817	.514865
10	.742479	.03408	.141522	.511783
...	...	...	...	...
16	.740277	.035427	.138425	.506675

Table 15: Variance decomposition, Unemployment rate and QE related assetts

The second row shows how much of the forecast error in unemployment is explained by shocks in unemployment, while the third row shows how shocks in QE-related assets will impact the forecast error in unemployment, meaning that after 16 periods, shocks in unemployment will account for approximately 74% of the forecast error, while changes in the Fed's balance of QE-related assets will account for about 3.5% after 16 periods (four years). Similarly, a one standard deviation shock to unemployment will account for about 30% of the forecast error variance to QE-related assets in period $t + 1$, while the effect of the shock is reduced to 13% after four years. A one standard deviation shock to QE-related assets will account for about 60% of the forecast error variance in the first coming period, it peaks at 65% in the next period, before it is reduced to approximately 50% after four years.

[11]The results of the impulse response functions for impulses of QE is reported in table 23 and 24.

Lags	Inflation		QE assets	
	Inflation	QE assets	Inflation	QE assets
0	0	0	0	0
1	1	0	.032794	.595248
2	.949539	.007365	.023528	.650921
3	.858104	.082659	.082057	.592755
4	.823136	.109779	.0766	.565364
5	.827067	.108557	.089089	.543445
6	.815567	.118695	.116852	.530659
7	.812797	.117976	.156776	.514143
8	.81062	.118098	.158773	.517055
9	.809903	.118235	.15661	.514865
10	.809558	.118347	.155423	.511783
...	...	...	...	...
16	.808013	.11943	.161337	.506675

Table 16: Variance decomposition, inflation rate and QE related assets

Table 16 is interpreted in the same was as previously. As one can tell from the table, a shock due to inflation in time t will account for about 95% of its forecast error variance after two periods, while it decreases to about 81% after four years. While a one standard deviation shock in QE-related assets will have a small effect at first, but increase up until about 12% after four years.

A one standard deviation shock in inflation at time t, will account for about 7% of the forecast error variance at time $t + 1$, increasing to roughly 19% after four years. The interpretation of forecast error variance of a QE-related asset shock to itself is the same as in table 15

Lags	Industrial production		QE assets	
	Industrial production	QE assets	Industrial production	QE assets
0	0	0	0	0
1	.999281	0	.070689	.595248
2	.21862	.00027	.112291	.650921
3	.174346	.012862	.133085	.592755
4	.168447	.040962	.174339	.565364
5	.150554	.13088	.198002	.543445
6	.148388	.15283	.193255	.530659
7	.15721	.156455	.180348	.514143
8	.165921	.156612	.179772	.517055
9	.168992	.154625	.185709	.514865
10	.169137	.154723	.191272	.511783
...	...	...	...	...
16	.1699	.159538	.193563	.506675

Table 17: Variance decomposition, Industrial production and QE related assets

6.1.8. Formal presentation and estimation results

Below we first formally present our equations in the VAR-system, then we will discuss our estimated results. The estimated results for the model is reported in table 25 in the appendix.

From table 25, we can see that the equation for each variable will have 9 parameters, and the R^2 is very high for industrial production, but not so high for other variables of interest. We also see other values of postestimation evaluation reported in table 25.

$$y_{1,t} = a_1 + \sum_{k=1}^{k=2} b_{11}\pi_{t-k}^{infl} + \sum_{m=1}^{m=2} b_{12}u_{t-m}^{Une} + \sum_{p=1}^{p=2} b_{13}q_{t-p}^{QE} + \sum_{s=2}^{s=2} b_{14}x_{t-s}^{IND} + u_t \tag{6.1}$$

$$u_t^{Une} = a_2 + \sum_{k=1}^{k=2} b_{21}\pi_{t-k}^{infl} + \sum_{m=1}^{m=2} b_{22}u_{t-m}^{Une} + \sum_{p=1}^{p=2} b_{23}q_{t-p}^{QE} + \sum_{s=2}^{s=2} b_{24}x_{t-s}^{IND} + u_t \tag{6.2}$$

$$q_t^{QE} = a_4 + \sum_{k=1}^{k=2} b_{31}\pi_{t-k}^{infl} + \sum_{m=1}^{m=2} b_{32}u_{t-m}^{Une} + \sum_{p=1}^{p=2} b_{33}q_{t-p}^{QE} + \sum_{s=2}^{s=2} b_{34}x_{t-s}^{IND} + u_t \tag{6.3}$$

$$x_t^{IND} = a_4 + \sum_{k=1}^{k=2} b_{41}\pi_{t-k}^{infl} + \sum_{m=1}^{m=2} b_{42}u_{t-m}^{Une} + \sum_{p=1}^{p=2} b_{43}q_{t-p}^{QE} + \sum_{s=2}^{s=2} b_{44}x_{t-s}^{IND} + u_t \tag{6.4}$$

We find from the results of our VAR-model in table 25, that QE has a significant effect on inflation and industrial production, in either one or two lags, but find that it has no significant effects on the unemployment rate. However, since these variables have inter-temporal relationship, we could potentially have an effect of changes in the Fed's balance of QE-related assets on the unemployment rate through changes in the other variables. As we can see from table 25, the industrial production has a significant effect on the unemployment rate in the first lag, meaning that if we increase the Fed's balance of QE-related assets, this will indirectly change the unemployment rate through changes in the industrial production.

The reported effects of QE on inflation is negative in the first lag, and this could intuitively make sense, as when the Federal Reserve decided to deploy quantitative easing as a policy tool, the inflation was already falling, and it could take some time before it stabilises at the target level of the Fed.

We find that a one percent increase in the Fed's balance of QE-related assets will increase the industrial production index by about 0.65 percent in the first lag, and 5.92 % in the second lag. The second lag being significant at a 5% level. A one percent increase in QE-related assets will in the first period decrease inflation by .936 %, but increases the inflation by 2.68% the following period, which is significant at a 5% level. While a one percent increase in the QE-related assets will decrease unemployment rate by .342 percent in the first lag, and it decreases by .872 percent in the second lag.

The R^2 of the equations are also reported in table 25, and we see that there are a lot of significant variables omitted from our first model. However, since we have stationary variables, we can still obtain useful information about the relevance of the relationship of the variables, although it is hard to say much about the variability each variable has on each other.

6.2. Structural VAR

Imposing the restrictions we describe in section (5.10-5.12), we find the following responses to a shock in QE-related assets:

As expected, since we find small correlation in our innovations, our SVAR models is quite similar to our VAR model. The order of the variables are decided by the degree of exogeneity, for which we use the Granger Causality test to help guide us.

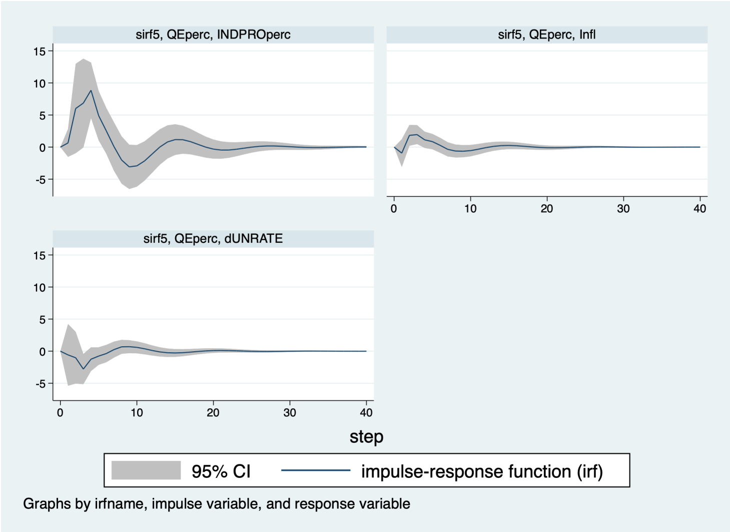

Figure 12: SVAR model with short- and long run restrictions

6.3. Model 2

Similarly for model 2, we use the DF-test to check for stationarity. And as seen in table 18, most variables are non-stationary in level terms.

6.3.1. Stationarity

	t-stat	p-value	n-obs	1%	5%
UNRATE	-2.527	0.1090	63	-3.562	-2.920
INFL	-5.589	0.0000	63	-3.562	-2.920
QE	-9.580	0.9985	63	-3.562	-2.920
VIXCLS	-3.476	0.0086	63	-3.562	-2.920
TB3MS	-2.254	0.1874	63	-3.562	-2.920
T10YIE	-2.971	0.0377	63	-3.562	-2.920
STLFSI3	-3.131	0.0243	63	-3.562	-2.920
INDPRO	-2.023	0.2767	63	-3.562	-2.920
HOUST	-2.441	0.1306	63	-3.562	-2.920
HHNW	4.166	1.0000	63	-3.562	-2.920
NFBNW	3.506	1.0000	63	-3.562	-2.920
DGS10	-1.674	0.4443	63	-3.562	-2.920
BCR	-0.339	0.9199	63	-3.562	-2.920
BAA	-0.832	0.8097	63	-3.562	-2.920

Table 18: DF-test with level values

We solve this as with model 1, by differencing all our terms. We also difference the terms that are stationary, for easier interpretation. We do not transform these variables into growth-rates, as this would cause collinearity in our VAR-model, and omit most of our variables due to this issue. In table 19, we see that our variables all our variables are stationary after being first-differenced.

	t-stat	p-value	n-obs	1%	5%
ΔUNRATE	-9.257	0.0000	63	-3.562	-2.920
INFL	-5.589	0.0000	63	-3.562	-2.920
QEperc	-3.987	0.0015	63	-3.562	-2.920
ΔVIXCLS	-8.458	0.0000	63	-3.562	-2.920
ΔTB3MS	-4.155	0.0008	63	-3.562	-2.920
ΔT10YIE	-6.911	0.0000	63	-3.562	-2.920
ΔSTLFSI3	-8.033	0.0000	63	-3.562	-2.920
INDPROperc	-7.468	0.0000	63	-3.562	-2.920
ΔHOUST	-7.402	0.0000	63	-3.562	-2.920
ΔHHNW	-6.390	0.0000	63	-3.562	-2.920
ΔNFBNW	-4.979	0.0000	63	-3.562	-2.920
ΔDGS10	-6.288	0.0000	63	-3.562	-2.920
ΔBCR	-9.153	0.0000	63	-3.562	-2.920
ΔBAA	-6.954	0.0000	63	-3.562	-2.920

Table 19: DF-test with difference terms

6.3.2. Stability

From figure 13, we see the results of our test for stability for our extended VAR model. We can conclude that since all eigenvalues lie inside the unit circle, the stability condition is satisfied with our first VAR model.

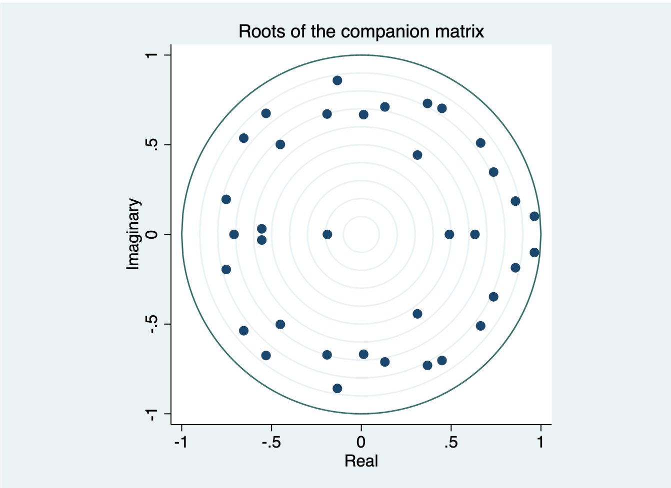

Figure 13: The unit circle with the roots of the companion matrix, model 2

The table for eigenvalues is reported in figure 27 in the Appendix B. We should note that this system is stable, however, by including more than two lags as suggested by the AIC when applying the selection criterion to a system with lags higher than two, we obtain unstable systems. That is why the results reported in table 20 is only estimated with two lags.

6.3.3. Lag length selection

Below in figure 20, we see our preferred lag selection based on the asterisk. As previously we continue with two lags. If we include more lags in the test it would tell us to use four lags, but including three or more lags in the model leads to an unstable system, as the eigenvalues exceed an absolute value of one.

Selection-order criteria

Sample: **2007q3 - 2021q4** Number of obs = **58**

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-1894.37			2.4e+10	63.6122	63.8033	64.1009*	
1	-1577	634.72	196	0.000	4.8e+08	59.5668	62.434*	66.897
2	-1307.75	538.51*	196	0.000	1.2e+08*	57.125*	62.6683	71.2967

Table 20: Lag-selection criteria for model 2

Continuing we will use only two lags for the second VAR model.

6.3.4. Autocorrelation

In figure 14, we find that the residuals are quite random and moves toward a zero mean. The residuals are about as evenly distributed as in figure 10, however the deviations from the mean are smaller from period 2006q1 to 2015q1 than in our four-variable VAR.

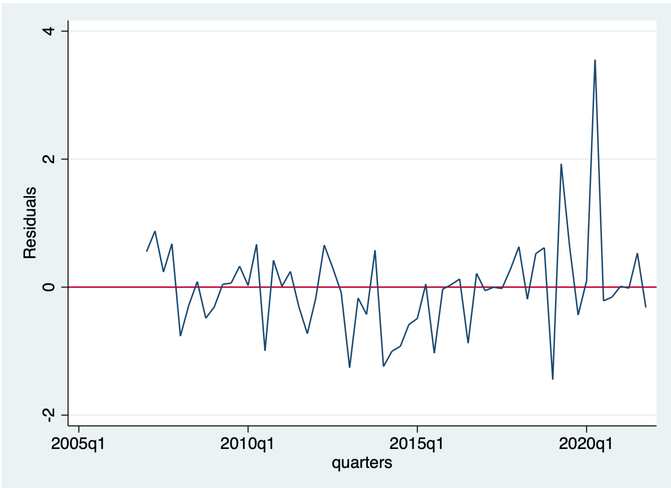

Figure 14: Plotted line of residuals to the mean, model 2

We also run the Lagrange Multiplier test on our model, where we find in table 21 that we now reject the null hypothesis that we do not have autocorrelation in the model with two lags. This is something we need to keep in mind when interpreting our estimation results.

lag	chi2	df	Prob>chi2
1	232.3113	196	0.03880
2	229.0257	196	0.05306

Table 21: Lagrange multiplier test

6.3.5. Granger Causality

The results for the Granger Causality test is reported in table 31 in appendix B. We see that our variable for QE Granger causes all variables in the VAR model except the market yield on 10-year Treasuries and the net worth series for households.

We see that generally we can reject most of the null-hypothesises that all coefficients on the lags of variable x are jointly zero in the equation for variable y. Which does not tell us anything about the causal-relationship between the variables, but that their time series are dependent on each other in one form or another.

6.3.6. Impulse response functions model 2

In figure 15 we find impulse response functions for the risk taking channel's response to a shock in the balance sheet of the Fed. We find that after a shock to the balance of QE-related assets for the Fed, we have that both the St. Louis stress index and the CBOE volatility index will after some periods increase, meaning that after about 4 periods the effect of QE will have increased the volatility and stress in the financial market. This could be because of the interest rates remaining low for a sufficient period of time, causing the financial agents to take higher risks, as suggested by Boivin(2011).

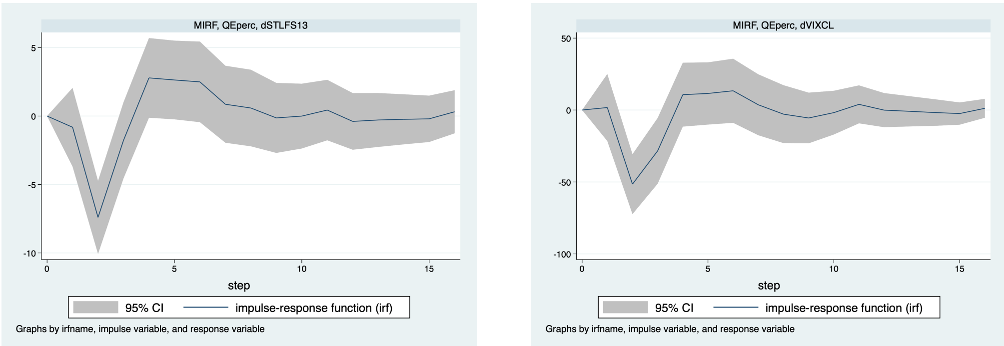

Figure 15: IRFs for the risk taking channel

In figure 16, the IRFs for the bank lending channel is reported. And we find that a one standard deviation shock to QE will have a positive effects for both the bank credit ratio, and the newly built privately owned houses. While we see a negative effect for the first two periods for the housing variables, we see a positive effect after about three periods. Which indicates that QE could be positively related to a growth in private loans.

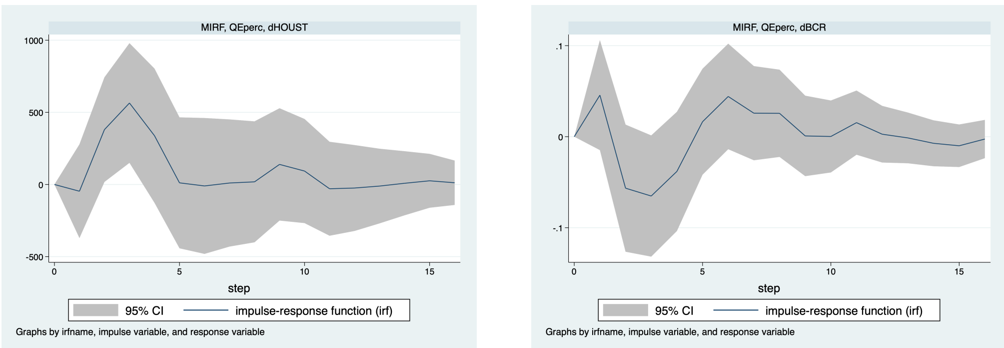

Figure 16: IRFs for the bank lending channel

In figure 17, we see the response of the two net worth series to a one standard deviation shock to QE-related assets. While we see that the initial effects are significantly positive, the shock is reduced to nearly nothing after about six periods ahead.

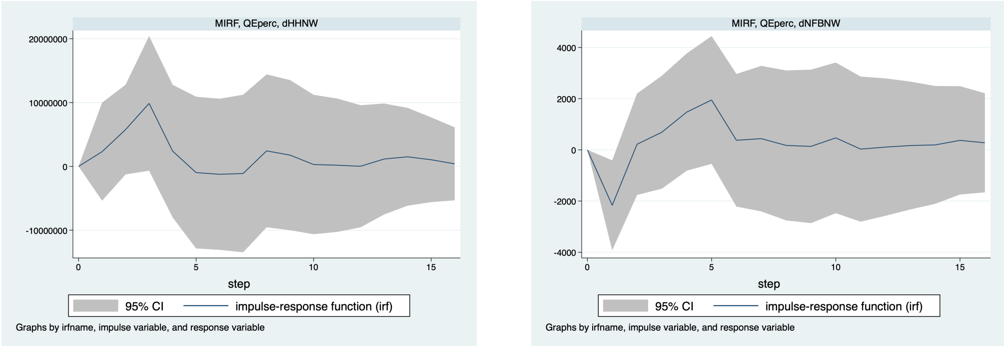

Figure 17: IRFs for the balance sheet channel

From figure 18 we see the responses of the portfolio balance channel to a one standard deviation shock to QE-related assets. From our model it seems like initially that QE is efficient at decreasing both the Moody's seasoned BAA-rated corporate yield as well as the 10-year Treasury term yield. However, this effect vanishes after a few periods. So the effect is positively correlated with decrease in the yield for bonds, which suggests that the Fed's LSAPs has decreased the yield of long term bonds.

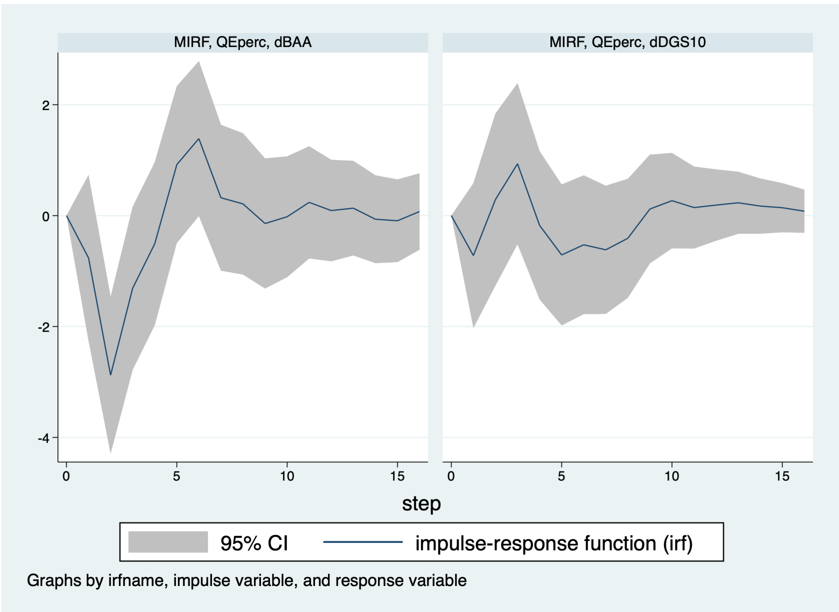

Figure 18: Impulses in QE with the response in the portfolio balance channel

Lastly, we see the signalling channel in figure 19. The signalling channel shows that an increase in QE will decrease the 3-month Treasury bill secondary market, as well as an increase in the 10-year break-even inflation rate. The signalling channel would generally be better suited for event-study type methods since the movements in the expected inflation and short term Treasuries are more affected by announcements from FOMC about future market operations. However, our model still finds similar results to previous empirical studies.

Figure 19: Impulses in QE with the response in the signalling channel

6.3.7. Variance decompositions

We again estimate the forward error variance decompositions, to see how much of a shock in variable y is explained by shocks to variable x. The FEVD are reported in tables 43 to 52

In our findings we find that the forward error variance explained by shocks to QE-related assets are very low, with respect to our variables for each of our transmission channels. However, in tables 37 to 52 we find explained variance to be much higher. This means that shocks to the real economy, to some extent, could be explained by changes in our variables for each transmission channel. We find that especially the balance sheet channel has some explanatory power over the variables for the real economy.

6.3.8. IRF's to the the real economy and estimation results by OLS

We report the graphs with IRF's for each of the transmission channel variables in figures 17 to 26 in Appendix B. We find that for most impulses to the transmission channels, the response is as expected for an expansive monetary pool. However, there are some interesting findings.

For the balance sheet channel we find that the effects on the real economy to the net worth series are substantially lower than to the net worth series of non-financial businesses.

For the risk taking channel we observe a positive effect but only after a while. This could be because of increased volatility could first lead to panic in the financial markets, where investors will get rid of assets, before re-investing when the market is down.

The portfolio balance channel is especially an interesting find. As a decrease in the long term yield for Treasury securities will have, as theory would suggest, an expansionary effect on the real economy. However, a decrease in Moody's yield for corporate bonds displays the opposite.

The signalling channel shows how Fisher's equation of expected inflation would affect the actual level of inflation and interest rates. Since many economists suggest that QE is inflationary, the 10-year breakeven inflation rate will naturally rise as the FOMC announces LSAP. Our findings are consensual with previous analysis, although there are some limitations to our assessment of the signalling channel, since quarterly observations will not efficiently capture the effects of announced purchases of MBS and Treasury securities.

For the bank lending channel we find that the immediate response to impulses in the bank-lending variables are contrary to what theory would suggest, however, after about a year this response is positive, and in line with effects of expansionary theory.

From the estimation results for Model 2, reported in table 42 in appendix B, we see that in the equation for the unemployment rate, changes in bank credit ratio, the volatility index, the 10-year breakeven inflation rate, the housing starts, the household net worth series, the market yield on 10-year Treasuries, Moody's seasoned BAA corporate bond yield, changes in QE-related assets and the non-financial businesses net worth series are all significant for the estimation of unemployment at a 5% significance level. Either in their first lag, second lag or both lags.

A one percent increase in the bank credit rate from the previous period, will by $t+1$ have increased the unemployment rate by 0.5%, which is significant at a 5% level, which seems odd, but could make sense at building up too much debt could cause the economy to collapse.

Increasing the 10-year breakeven inflation rate will decrease the change in unemployment by 2.3% which is also highly significant. Increasing new privately owned houses started by 100.000 will increase the unemployment rate by 0.5%, while in the second lag it would increase it by 0.06%.

The variable for net worth series for households are significant and negative in the first lag, but the decrease is too small to measure a significant effect on the unemployment. However, a 100 million dollar increase in the net worth series decrease the unemployment rate by 0.1% and is significant at a 1% level.

Changes in QE-related assets is only significant in the second lag, meaning that it takes up to 6 months for the effects of QE to transmit to the unemployment rate.

For inflation, previous values of inflation, 10-year breakeven inflation, housing starts, the market yield on 10-year Treasuries, Moody's seasoned BAA corporate bond yield and QE-related assets are all significant at a 5% level. Either in their first lag, second lag or both lags.

A one percent increase in the 10-year breakeven inflation rate will increase the actual inflation rate by roughly 1.9 %, which is significant at a 1% level.

A 10.000 increase in new privately owned houses decreases the inflation by 0.26% in the first lag, and 0.29%, both significant at a 5% level.

A one percentage point decrease in the 10-year Treasury yield, gives a 1.4% increase in inflation in the second lag, which is significant at a 1% level. While a one percent decrease in Moody's corporate bond yield decreases the inflation rate by about 1% in the second lag, which is also significant at a 1% level.

A percentage change in QE-related assets decreases the inflation in the first lag by 1.25%. However, in the second lag, inflation increases by roughly 5.3%, which is significant at a 5% level.

For the index for industrial production, we see that 10-year breakeven inflation rate, housing starts, and changes in QE-related assets are significant for estimation at 5% level in either their first or second lag.

The 10-year breakeven inflation rate increases the industrial production index by roughly 2.5% in the second lag, which is significant at a 5%.

6.3.9. Difference in effects in periods of QE

In this last section we have included dummy variables for each period of QE in the US up until q4 2021. Our results tells us that QE1 and QE4 has had the most impact in magnitude. QE4 has the most variability in its responses to a shock in QE. This is both positive and. negative, making QE4 the most volatile period of QE, and its responses are looking like an AR(1) model. Since this is a dummy it is difficult to measure the actual effects, however, this can give us insight into which of the four periods of QE who has had the highest impact on the economy.

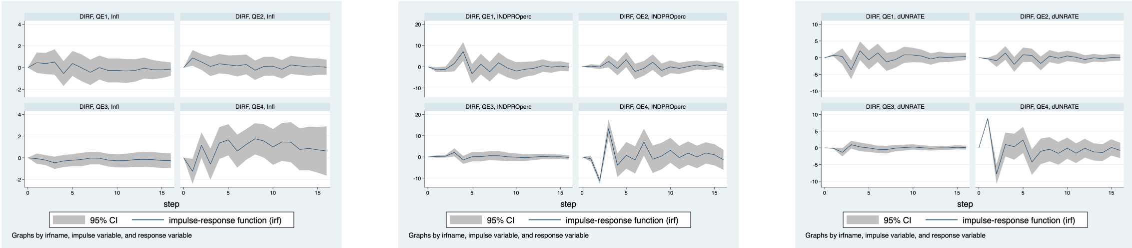

Figure 20: IRF for each period of QE in the US, responses to Inflation, index for industrial production and unemployment rate, respectively.

6.3.10. Forecasts

Below in figure 21 we have provided some forecasts for the macro-variables. VAR models are generally good for forecasting, but as we see from the graphs, we have very large 95% confidence intervals, meaning that the forecasts has big standard deviations.

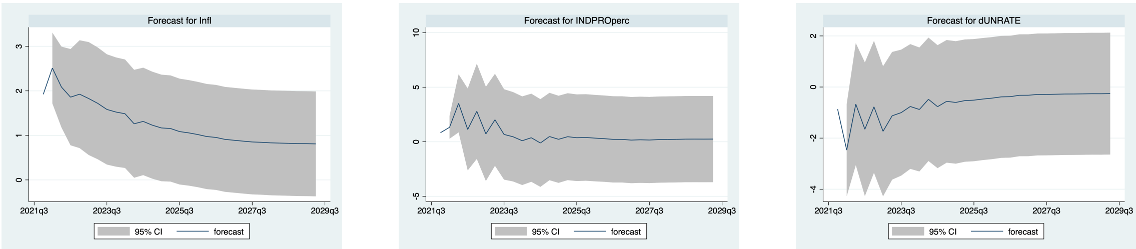

Figure 21: Forecasts for macro-variables with 30 periods ahead.

6.4. Summary

Our intention for this paper has been to try to give a credible approach to analysing and understanding the transmission channels of QE, and its effects on the real economy. We use a small VAR model, where we try to impose restrictions on the relationships between our variables to solve the identification problems as described in chapter 5. We then include several more variables to illustrate the transmission channels of QE, as we described in chapter 3.

Our analysis has a point of departure in quarterly observations from q1 2006 to q4 2021. While previous literature has focused more heavily on quantitative easing and its effects on financial markets, we try to investigate how fluctuations in the financial markets caused by quantitative easing will transmit to the real economy.

To conclude our paper, we do find that some transmission channels will affect the real economy, as to what extent and the time the transmission takes place, our results are more dubious. The increase on the balance sheet will generally lead to higher inflation, and there are positive short term effects of QE to industrial production, while unemployment is decreased following an increase in the balance sheet. However, we find that these are not sustained effects, which dies out after roughly a year. We see that for the forward error variance decompositions, that QE has the highest impact on industrial production and inflation, but the variability in unemployment related to shocks in QE-related assets is only about 3.5%.

Comparing our models, the full VAR model with transmission channels is very complex and ambiguous. The impulse response functions are mostly in line with what we have found in previous literature, but we have some issues of estimation. Especially when including more than two lags, we face issues of stability, and we also find autocorrelation in all lags with model 2.

We investigate first the transmission channels on a general level, before we include dummy variables for each period of QE as an extension to model 2. We see that each period has highly different effects on the real economy. While QE1 and QE4 has the highest impacts, these have also had the most volatile effects, especially QE4.

7. Discussion and further research

The primary objective of this paper has been to asses the real effects of QE-measures adopted by the Federal Reserve through several rounds of QE. We first use a four-variable VAR-model, where we are checking for inter-temporal relationships between changes to the balance sheet of the Federal Reserve to changes in unemployment rate, industrial production and inflation. Our secondary objective for this paper is to identify the transmission channels, the significance and if the effects have worked as intended.

Most of the empirical studies on central bank asset purchases have used event studies as a key part of their analysis. This due to the critical issue of the short time window the market is given to react. So to isolate the effects of the LSAP, one would ideally measure the effects trough one- or two-day windows. This reduces the risk that other factors may be driving the response of the financial markets. This issue is very problematic with our model, as our variables are measured by quarterly data, as most macroeconomic variables are. However, if we want to try and measure the effects of QE on the real economy, then the accessible data is mainly monthly or quarterly, which leaves uncertainty as to how much of the measured effect is caused by omitted factors.

In our first model we see relationships that we would expect on industrial production and inflation, however, as our impulse response functions shows, the effects are more unclear to unemployment. We believe the Federal Reserve would not pursue quantitative easing several times if it was completely insignificant, due to its high cost and possible implications to the wider economy, however we do not know the complete cost of zero lower bound without having an accurate measure for the counterfactual situation. Because we do not know the counterfactual[12], our estimated effects do not measure the complete effectiveness, rather explains how the market responded to the measure given the current state of the economy at the time. But since we don not know the true cost of zero-lower bound, we do not know the true cost of exercising QE.

Many of our estimates seem to convey the theory of output and inflation well, however, the effects on unemployment are still very ambiguous and not completely in line with theory. We also find that the portfolio balance channel is effectively stimulated by QE, however, the effects does not transmit to the real economy as we would have expected. If the FED is successful in lowering the ten year yield on Treasury securities, then one would think the yield on corporate bonds would be lowered at the same time[13], meaning that this would simulate the inflation and output in the same way as the 10-year security Treasuries. But a lowering in the Moody's corporate bond yield is associated with a negative inflation. Nonetheless, this seems to be an efficient channel, and conversely to other transmission channels, this channel transmits quite well to the unemployment.

The signalling channel in our model is not measured as classical models for quantitative easing. Where as the researchers for the central bank would have really small windows of data, like minutes, our hours, to capture how announcements to QE would effect the financial markets, we have quarterly data. Quarterly data does not capture the effect from announcements, rather the purchases. The effects are not as clear in the signalling channel when the purchases are being made, since they are signalled in advance, and therefore the market reaction has already taken place.

We have issues with restricting the B matrix for both model 1 and model 2, given that our attempt for model 1 does not hold as much ground, as for example the extensive research of Stock and Watson (2001). However, when correlation between the various innovations are small, the identification problem is not likely to be especially important (Enders, 2014). And thus our alternate orderings should yield similar impulse responses and variance decompositions. Therefore,

[12] A situation where the Fed does not use quantitative easing as a policy tool.

[13] Albeit, not as much, as these are not perfect substitutes

our analysis cannot be accepted as clear evidence as to if quantitative easing works, or more specifically, how well it works. Our research shows that the transmission channels targeted by the Federal Reserve in recent times as a response to the Covid-19 recession can be effective channels, if the size of the LSAP and timing of purchases are correct. If so, this will increase output, increase inflation and reduce unemployment.

To further research we would look more into changes in the classical transmission channels as *the balance sheet channel* and *the risk-taking channel*, since these are not exclusively restricted to periods of QE. We then want to look more into how these channels will be effected when interest rates are at ZLB, and if QE will also transmit through these channels as conventional monetary tools would.

We also should comment that for most transmission channels, the transmitted effect is larger in the second lag, meaning that the effects are at first more muted, meaning that the long-term effects potentially could be much broader. In our analysis we do not investigate spillover effects of QE to other economies and the import and export market. Increasing the money supply could cause a depreciation in the exchange rate for dollars (Levin, 1997), meaning that some of the inflationary effects comes from imported goods, which we do not account for in our model.

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Appendix A

Variable name	Description
UNRATE	Unemployment rate
Infl	The log of consumer price transformed into first difference
BCR	The bank credit ratio of real GDP
VIXCL	The CBOE index for volatility
TB3MS	3-Month Treasury Bill Secondary Market Rate
T10YIE	10-year brekeven inflation rate
STLFS13	The St. Louis Stress index
HOUST	Housing starts
HHNW	Household net worth series
DGS10	10-Y treasury constant maturity rate
BAA	Moody's Seasoned Baa Corporate Bond Yield (BAA)
QEperc	The log of MBS and TREAST tansformed into first difference
INDPROperc	The log of index for industrial production transformed into first difference
NFBNW	Nonfinancial buisness net worth series
QE1	Dummy for period QE1
QE2	Dummy for period QE2
QE3	Dummy for period QE3
QE4	Dummy for period QE4

Table 22: Variable names in Stata

step	Infl irf	Infl Lower	Infl Upper	INDPROperc irf	INDPROperc Lower	INDPROperc Upper
0	0 0	0	0	0	0	
1	-.93563	-3.0938	1.22254	.651504	-1.5188	2.82181
2	1.83072	.205459	3.45597	6.01612	-.948285	12.9805
3	1.94702	.475792	3.41825	6.85823	-.064247	13.7807
4	1.13239	-.134312	2.3991	8.86069	4.54299	13.1784
5	.857858	-.339941	2.05566	4.90559	1.05892	8.75226
6	.287794	-.877802	1.45339	2.53321	-1.03525	6.10167
7	-.344846	-1.45103	.761334	.08514	-3.68769	3.85797
8	-.605972	-1.6184	.406457	-2.01289	-5.70187	1.6761
9	-.64038	-1.58944	.308684	-3.08192	-6.53121	.367373
10	-.547581	-1.43485	.339683	-2.91879	-6.1602	.322626
11	-.329097	-1.15119	.492997	-2.15954	-5.2183	.899218
12	-.078851	-.83501	.677309	-1.06974	-3.98026	1.84079
13	.116204	-.572939	.805346	.016825	-2.74103	2.77468
14	.230342	-.39832	.859004	.804372	-1.77796	3.38671
15	.25886	-.314821	.832541	1.17199	-1.21443	3.55841
16	.21406	-.308734	.736855	1.15424	-1.02496	3.33344

Table 23: IRF:Impulse(QE) Response(inflation and index for industrial production)

step	Δ UNRATE irf	Δ UNRATE Lower	Δ UNRATE Upper	QE irf	QE Lower	QE Upper
0	0	0	0	1	1	1
1	-.576795	-5.38319	4.2296	.504112	.207454	.800771
2	-1.02346	-5.04843	3.0015	.221049	-.024317	.466415
3	-2.79172	-5.14479	-.438646	-.014008	-.275193	.247177
4	-1.24981	-3.0916	.591968	-.247191	-.503066	.008685
5	-.763453	-2.1307	.603793	-.338441	-.586276	-.090605
6	-.370673	-1.71903	.977686	-.318695	-.556555	-.080835
7	.245593	-.998844	1.49003	-.233442	-.464857	-.002027
8	.677856	-.408938	1.76465	-.10932	-.341071	.122432
9	.701459	-.306722	1.70964	.011401	-.218951	.241752
10	.593396	-.341152	1.52795	.094595	-.12804	.317229
11	.378075	-.485971	1.24212	.131822	-.077231	.340875
12	.108984	-.678527	.896496	.126915	-.065483	.319312
13	-.113988	-.830346	.602369	.091435	-.084704	.267573
14	-.242392	-.90042	.415636	.042517	-.119644	.204678
15	-.279337	-.882946	.324271	-.003754	-.153948	.146441
16	-.237242	-.785365	.310882	-.036693	-.175745	.102358

Table 24: IRF: Impulse(QE) Response (Unemployment rate and QE)

Sample: **2007q1 - 2021q4**			Number of obs	=	**60**
Log likelihood	=	-112.9511	AIC	=	**4.965036**
FPE	=	.0016996	HQIC	=	**5.456564**
Det(Sigma_ml)	=	.0005073	SBIC	=	**6.221642**

Equation	Parms	RMSE	R-sq	chi2	P>chi2
Infl	9	.616321	0.2482	19.80701	0.0111
INDPROperc	9	.619787	0.9437	1005.535	0.0000
dUNRATE	9	1.37259	0.1543	10.94307	0.2049
QEperc	9	.084718	0.5174	64.32848	0.0000

	Indproprc	QEprc	Infl	ΔUNRATE
Indproprc (L.1)	.458373(**)	-.02380	.0059664	-.3949756(**)
	(.0891291)	(.012183)	(.0886308)	(.1973866)
	[5.14]	[-1.95]	[0.07]	[-2.00]
Indproprc (L.2)	.1420571(**)	-.0042241	.0473077	-.0094954
	(.0335497)	(.0045859)	(.0333621)	(.0742997)
	[4.23]	[-0.92]	[1.42]	[-0.13]
QEprc (L.1)	.651504	.5041124(**)	-.9356301	-.5767947
	(1.107319)	(.1513592)	(1.101128)	(2.452286)
	[0.59]	[3.33]	[-0.85]	[-0.24]
QEprc (L.2)	4.922373(**)	-.0449671	2.675556(**)	-.871863
	(1.074428)	(.1468633)	(1.068421)	(2.379444)
	[4.58]	[-0.31]	[2.50]	[-0.37]
Infl (L.1)	.3225066(**)	-.0208629	.3392019(**)	-.2130479
	(.1293074)	(.017675)	(.1285845)	(.2863662)
	[2.49]	[-1.18]	[2.64]	[-0.74]
Infl (L.2)	.1289106	-.0454372(**)	-.1619536	.232085
	(.139726)	(.0190991)	(.1389447)	(.3094392)
	[0.92]	[-2.38]	[-1.17]	[0.75]
Δ UNRATE (L.1)	-1.33225(**)	-.0136515	.1034984	-.3418252(**)
	(.0722602)	(.0098772)	(.0718562)	(.1600286)
	[-18.44]	[-1.38]	[1.44]	[-2.14]
Δ UNRATE (L.2)	.7813943(**)	-.0431433(**)	-.1244089	-.719555
	(.1582419)	(.02163)	(.1573571)	(.3504449)
	[4.94]	[-1.99]	[-0.79]	[-2.05]
Constant	-.4239959(**)	.0552626(**)	.3826116(**)	.0686178
	(.1172973)	(.0160333)	(.1166415)	(.2597684)
	[-3.61]	[3.45]	[3.28]	[0.26]

Table 25: VAR model 1 with 2 lags, standard errors in (·) and t-values in [·]. (**) indicates that a variable is statistically significant at a 95% confidence level

Appendix B

Sample: **2007q2 - 2021q4**			Number of obs	=	**69**
Log likelihood	=	-1307.75	AIC	=	57.12499
FPE	=	1.23e+08	HQIC	=	62.66833
Det(Sigma_ml)	=	47.53058	SBIC	=	71.29672

Equation	Parms	RMSE	R-sq	chi2	P>chi2
dUNRATE	29	1.05078	0.6987	139.1497	0.0000
Infl	29	.462862	0.7423	172.788	0.0000
dBCR	29	.014166	0.6884	132.5537	0.0000
dVIXCL	29	5.4573	0.6631	118.0855	0.0000
dTB3MS	29	.221351	0.7528	182.7636	0.0000
dT10YIE	29	.225368	0.6773	125.9079	0.0000
dSTLFS13	29	.673665	0.7005	140.3162	0.0000
dHOUST	29	76.2013	0.7057	143.8534	0.0000
dHHNW	29	1.8e+06	0.7102	147.0359	0.0000
dDGS10	29	.306379	0.5620	76.99134	0.0000
dBAA	29	.35115	0.5573	75.52253	0.0000
QEperc	29	.061411	0.8459	329.2657	0.0000
INDPROperc	29	.608738	0.9670	1757.191	0.0000
dNFBNW	29	411.669	0.6487	110.8118	0.0000

Table 26: VAR model 2 with 2 lags

Eigenvalue		Modulus
.8712312 +	.08193947i	.875076
.8712312 -	.08193947i	.875076
.7453492 +	.4121764i	.851725
.7453492 -	.4121764i	.851725
-.6381844 +	.5088547i	.816218
-.6381844 -	.5088547i	.816218
.4165905 +	.698065i	.812922
.4165905 -	.698065i	.812922
-.3932033 +	.6677211i	.774894
-.3932033 -	.6677211i	.774894
-.7613633		.761363
.1437825 +	.7459731i	.759703
.1437825 -	.7459731i	.759703
.7453635 +	.1333412i	.757197
.7453635 -	.1333412i	.757197
-.1761888 +	.7350345i	.755856
-.1761888 -	.7350345i	.755856
.468217 +	.5107461i	.692884
.468217 -	.5107461i	.692884
-.03983799 +	.6115243i	.612821
-.03983799 -	.6115243i	.612821
-.5230179 +	.1982667i	.559337
-.5230179 -	.1982667i	.559337
-.1444743 +	.4051229i	.430113
-.1444743 -	.4051229i	.430113
.173049 +	.3896164i	.426318
.173049 -	.3896164i	.426318
-.2873225		.287323

Table 27: Eigenvalue stability condition

Skewness test

Equation	Skewness	chi2	df	Prob > chi2
dUNRATE	1.6324	26.646	1	0.00000
Infl	-.77627	6.026	1	0.01410
dBCR	.41039	1.684	1	0.19436
dVIXCL	.79406	6.305	1	0.01204
dTB3MS	.28023	0.785	1	0.37552
dT10YIE	.4281	1.833	1	0.17581
dSTLFS13	-.14718	0.217	1	0.64164
dHOUST	.04176	0.017	1	0.89494
dHHNW	-.80731	6.517	1	0.01068
dDGS10	.33872	1.147	1	0.28411
dBAA	-.40682	1.655	1	0.19828
QEperc	-.00924	0.001	1	0.97668
INDPROperc	-.19496	0.380	1	0.53754
dNFBNW	.18405	0.339	1	0.56056
ALL		53.553	14	0.00000

Table 28: Skewness test Model 2

Jarque-Bera test

Equation	chi2	df	Prob > chi2
dUNRATE	140.264	2	0.00000
Infl	7.356	2	0.02527
dBCR	2.040	2	0.36062
dVIXCL	19.022	2	0.00007
dTB3MS	0.792	2	0.67295
dT10YIE	3.456	2	0.17765
dSTLFS13	1.443	2	0.48597
dHOUST	0.018	2	0.99085
dHHNW	8.818	2	0.01217
dDGS10	2.838	2	0.24195
dBAA	1.659	2	0.43631
QEperc	0.018	2	0.99121
INDPROperc	0.391	2	0.82262
dNFBNW	3.166	2	0.20539
ALL	191.281	28	0.00000

Table 29: Jarque-Bera test for Model 2

Kurtosis test

Equation	Kurtosis	chi2	df	Prob > chi2
dUNRATE	9.7415	113.618	1	0.00000
Infl	3.7294	1.330	1	0.24878
dBCR	3.3772	0.356	1	0.55094
dVIXCL	5.2554	12.717	1	0.00036
dTB3MS	3.0524	0.007	1	0.93400
dT10YIE	3.8058	1.623	1	0.20264
dSTLFS13	2.2995	1.227	1	0.26807
dHOUST	3.0194	0.001	1	0.97549
dHHNW	3.9593	2.300	1	0.12934
dDGS10	3.8224	1.691	1	0.19351
dBAA	3.0391	0.004	1	0.95071
QEperc	2.918	0.017	1	0.89688
INDPROperc	2.9354	0.010	1	0.91870
dNFBNW	4.0634	2.827	1	0.09269
ALL		137.728	14	0.00000

Table 30: Kurtosis test Model 2

Granger causality Wald test

Equation	Excluded	chi2	df	Prob > chi2
dUNRATE	Infl	1.2618	2	0.532
dUNRATE	dBCR	4.3868	2	0.112
dUNRATE	dVIXCL	9.4809	2	0.009
dUNRATE	dTB3MS	11.942	2	0.003
dUNRATE	dT10YIE	4.4713	2	0.107
dUNRATE	dSTLFS13	2.318	2	0.314
dUNRATE	dHOUST	8.6264	2	0.013
dUNRATE	dHHNW	29.528	2	0.000
dUNRATE	dDGS10	14.699	2	0.001
dUNRATE	dBAA	11.562	2	0.003
dUNRATE	QEperc	11.934	2	0.003
dUNRATE	INDPROperc	1.3481	2	0.510
dUNRATE	dNFBNW	8.1447	2	0.017
dUNRATE	ALL	128.58	26	0.000
Infl	dUNRATE	18.765	2	0.000
Infl	dBCR	1.7119	2	0.425
Infl	dVIXCL	.75138	2	0.687
Infl	dTB3MS	.94852	2	0.622
Infl	dT10YIE	15.027	2	0.001
Infl	dSTLFS13	1.2189	2	0.544
Infl	dHOUST	27.179	2	0.000
Infl	dHHNW	7.6591	2	0.022
Infl	dDGS10	21.67	2	0.000
Infl	dBAA	13.549	2	0.001
Infl	QEperc	30.945	2	0.000
Infl	INDPROperc	3.3509	2	0.187
Infl	dNFBNW	6.3799	2	0.041
Infl	ALL	151.76	26	0.000
dBCR	dUNRATE	7.9805	2	0.018
dBCR	Infl	1.1018	2	0.576
dBCR	dVIXCL	7.1816	2	0.028
dBCR	dTB3MS	11.804	2	0.003
dBCR	dT10YIE	5.5175	2	0.063
dBCR	dSTLFS13	2.2288	2	0.328
dBCR	dHOUST	12.23	2	0.002
dBCR	dHHNW	21.302	2	0.000
dBCR	dDGS10	15.44	2	0.000
dBCR	dBAA	10.864	2	0.004
dBCR	QEperc	19.598	2	0.000
dBCR	INDPROperc	3.0341	2	0.219
dBCR	dNFBNW	4.5307	2	0.104
dBCR	ALL	125.2	26	0.000
dVIXCL	dUNRATE	17.02	2	0.000
dVIXCL	Infl	10.553	2	0.005
dVIXCL	dBCR	7.4766	2	0.024
dVIXCL	dTB3MS	8.5549	2	0.014
dVIXCL	dT10YIE	10.106	2	0.006
dVIXCL	dSTLFS13	2.5116	2	0.285
dVIXCL	dHOUST	2.7064	2	0.258
dVIXCL	dHHNW	.03839	2	0.981
dVIXCL	dDGS10	19.959	2	0.000
dVIXCL	dBAA	10.969	2	0.004
dVIXCL	QEperc	23.542	2	0.000
dVIXCL	INDPROperc	2.0342	2	0.362
dVIXCL	dNFBNW	3.0149	2	0.221

Table 31 – continued from previous page				
dVIXCL	ALL	103.84	26	0.000
dTB3MS	dUNRATE	5.6528	2	0.059
dTB3MS	Infl	12.352	2	0.002
dTB3MS	dBCR	.29335	2	0.864
dTB3MS	dVIXCL	1.0972	2	0.578
dTB3MS	dT10YIE	.63986	2	0.726
dTB3MS	dSTLFS13	10.198	2	0.006
dTB3MS	dHOUST	.02464	2	0.988
dTB3MS	dHHNW	3.0121	2	0.222
dTB3MS	dDGS10	6.3079	2	0.043
dTB3MS	dBAA	19.387	2	0.000
dTB3MS	QEperc	21.801	2	0.000
dTB3MS	INDPROperc	7.1142	2	0.029
dTB3MS	dNFBNW	.07313	2	0.964
dTB3MS	ALL	103.05	26	0.000
dT10YIE	dUNRATE	15.802	2	0.000
dT10YIE	Infl	9.1647	2	0.010
dT10YIE	dBCR	7.5874	2	0.023
dT10YIE	dVIXCL	.50048	2	0.779
dT10YIE	dTB3MS	5.959	2	0.051
dT10YIE	dSTLFS13	.32953	2	0.848
dT10YIE	dHOUST	5.3027	2	0.071
dT10YIE	dHHNW	2.358	2	0.308
dT10YIE	dDGS10	8.8333	2	0.012
dT10YIE	dBAA	1.9188	2	0.383
dT10YIE	QEperc	24.898	2	0.000
dT10YIE	INDPROperc	3.592	2	0.166
dT10YIE	dNFBNW	.38123	2	0.826
dT10YIE	ALL	109.57	26	0.000
dSTLFS13	dUNRATE	11.349	2	0.003
dSTLFS13	Infl	13.763	2	0.001
dSTLFS13	dBCR	2.9515	2	0.229
dSTLFS13	dVIXCL	1.8395	2	0.399
dSTLFS13	dTB3MS	5.9996	2	0.050
dSTLFS13	dT10YIE	5.7173	2	0.057
dSTLFS13	dHOUST	1.8526	2	0.396
dSTLFS13	dHHNW	1.678	2	0.432
dSTLFS13	dDGS10	7.2162	2	0.027
dSTLFS13	dBAA	6.8438	2	0.033
dSTLFS13	QEperc	21.017	2	0.000
dSTLFS13	INDPROperc	5.6854	2	0.058
dSTLFS13	dNFBNW	.29606	2	0.862
dSTLFS13	ALL	134.33	26	0.000
dHOUST	dUNRATE	3.1674	2	0.205
dHOUST	Infl	1.9815	2	0.371
dHOUST	dBCR	1.2685	2	0.530
dHOUST	dVIXCL	10.419	2	0.005
dHOUST	dTB3MS	6.6554	2	0.036
dHOUST	dT10YIE	10.574	2	0.005
dHOUST	dSTLFS13	.03483	2	0.983
dHOUST	dHHNW	23.936	2	0.000
dHOUST	dDGS10	15.298	2	0.000
dHOUST	dBAA	4.8934	2	0.087
dHOUST	QEperc	15.813	2	0.000
dHOUST	INDPROperc	8.3174	2	0.016
dHOUST	dNFBNW	15.228	2	0.000

Table 31 – continued from previous page				
dHOUST	ALL	143.51	26	0.000
dHHNW	dUNRATE	1.6618	2	0.436
dHHNW	Infl	3.2974	2	0.192
dHHNW	dBCR	8.4776	2	0.014
dHHNW	dVIXCL	15.776	2	0.000
dHHNW	dTB3MS	.47266	2	0.790
dHHNW	dT10YIE	5.7576	2	0.056
dHHNW	dSTLFS13	28.921	2	0.000
dHHNW	dHOUST	3.1057	2	0.212
dHHNW	dDGS10	3.2092	2	0.201
dHHNW	dBAA	4.4931	2	0.106
dHHNW	QEperc	2.055	2	0.358
dHHNW	INDPROperc	.57378	2	0.751
dHHNW	dNFBNW	3.6943	2	0.158
dHHNW	ALL	105.32	26	0.000
dDGS10	dUNRATE	3.1795	2	0.204
dDGS10	Infl	5.5488	2	0.062
dDGS10	dBCR	2.7948	2	0.247
dDGS10	dVIXCL	2.4171	2	0.299
dDGS10	dTB3MS	.75326	2	0.686
dDGS10	dT10YIE	.79882	2	0.671
dDGS10	dSTLFS13	6.8886	2	0.032
dDGS10	dHOUST	4.6633	2	0.097
dDGS10	dHHNW	4.3036	2	0.116
dDGS10	dBAA	1.8388	2	0.399
dDGS10	QEperc	1.6669	2	0.435
dDGS10	INDPROperc	2.082	2	0.353
dDGS10	dNFBNW	1.077	2	0.584
dDGS10	ALL	55.011	26	0.001
dBAA	dUNRATE	3.2475	2	0.197
dBAA	Infl	2.6736	2	0.263
dBAA	dBCR	.17393	2	0.917
dBAA	dVIXCL	.62485	2	0.732
dBAA	dTB3MS	2.8863	2	0.236
dBAA	dT10YIE	5.1413	2	0.076
dBAA	dSTLFS13	3.5253	2	0.172
dBAA	dHOUST	1.7252	2	0.422
dBAA	dHHNW	.15246	2	0.927
dBAA	dDGS10	9.5898	2	0.008
dBAA	QEperc	10.561	2	0.005
dBAA	INDPROperc	2.958	2	0.228
dBAA	dNFBNW	1.2608	2	0.532
dBAA	ALL	73.379	26	0.000
QEperc	dUNRATE	.20548	2	0.902
QEperc	Infl	.45588	2	0.796
QEperc	dBCR	1.1163	2	0.572
QEperc	dVIXCL	5.6413	2	0.060
QEperc	dTB3MS	14.78	2	0.001
QEperc	dT10YIE	12.375	2	0.002
QEperc	dSTLFS13	1.3457	2	0.510
QEperc	dHOUST	7.8981	2	0.019
QEperc	dHHNW	18.466	2	0.000
QEperc	dDGS10	16.93	2	0.000
QEperc	dBAA	11.297	2	0.004
QEperc	INDPROperc	2.5213	2	0.283
QEperc	dNFBNW	16.542	2	0.000

Table 31 – continued from previous page

QEperc	ALL	193.74	26	0.000
INDPROperc	dUNRATE	47.551	2	0.000
INDPROperc	Infl	1.9781	2	0.372
INDPROperc	dBCR	1.2269	2	0.541
INDPROperc	dVIXCL	.66685	2	0.716
INDPROperc	dTB3MS	9.8428	2	0.007
INDPROperc	dT10YIE	13.164	2	0.001
INDPROperc	dSTLFS13	5.5535	2	0.062
INDPROperc	dHOUST	4.4256	2	0.109
INDPROperc	dHHNW	.14831	2	0.929
INDPROperc	dDGS10	1.2155	2	0.545
INDPROperc	dBAA	3.0624	2	0.216
INDPROperc	QEperc	15.154	2	0.001
INDPROperc	dNFBNW	2.8314	2	0.243
INDPROperc	ALL	1746.8	26	0.000
dNFBNW	dUNRATE	1.1174	2	0.572
dNFBNW	Infl	4.3689	2	0.113
dNFBNW	dBCR	5.8388	2	0.054
dNFBNW	dVIXCL	3.2649	2	0.195
dNFBNW	dTB3MS	3.1419	2	0.208
dNFBNW	dT10YIE	2.0362	2	0.361
dNFBNW	dSTLFS13	3.0241	2	0.220
dNFBNW	dHOUST	.58618	2	0.746
dNFBNW	dHHNW	12.699	2	0.002
dNFBNW	dDGS10	3.5629	2	0.168
dNFBNW	dBAA	1.814	2	0.404
dNFBNW	QEperc	7.6084	2	0.022
dNFBNW	INDPROperc	2.7306	2	0.255
dNFBNW	ALL	85.604	26	0.000

Table 31: Granger Causality test for model 2

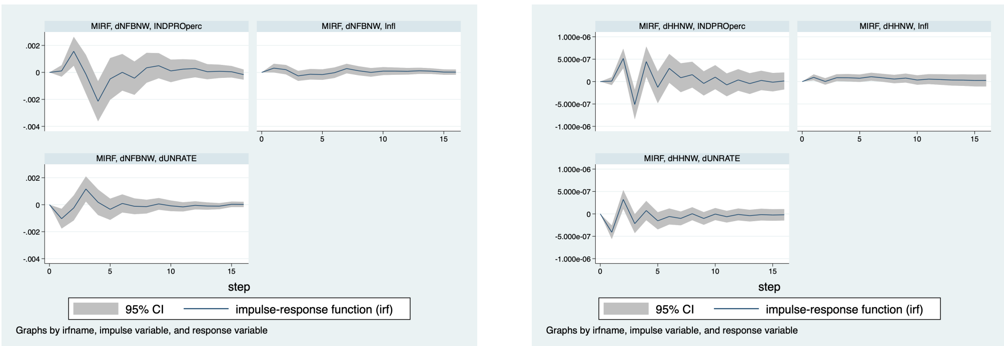
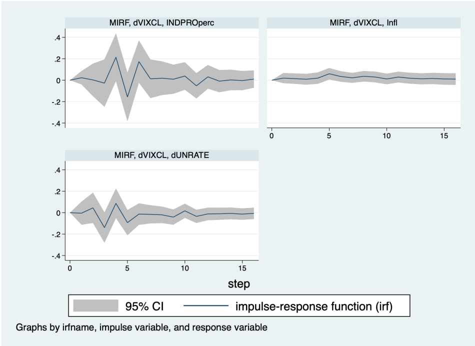


Figure 22: IRFs for the balance sheet channel on the real economy



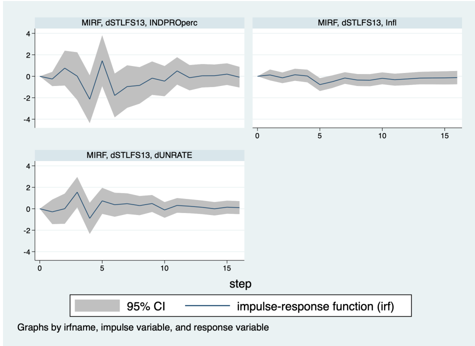


Figure 23: IRFs for the risk-taking channel on the real economy

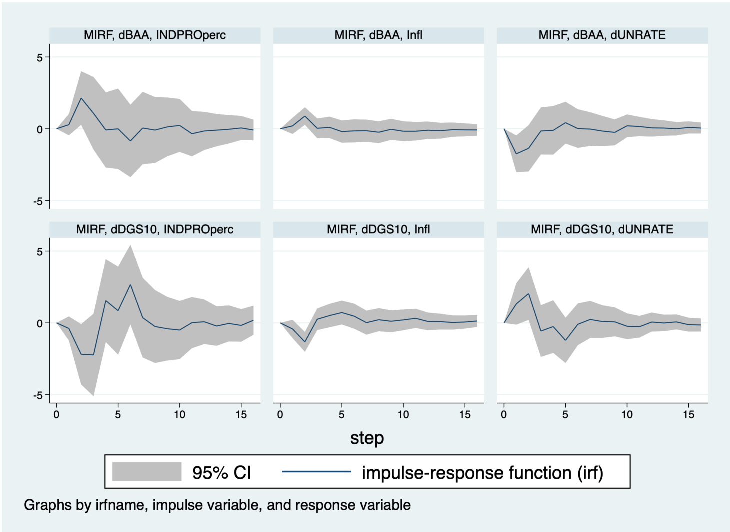


Figure 24: IRF for the portfolio rebalancing channel to the real economy

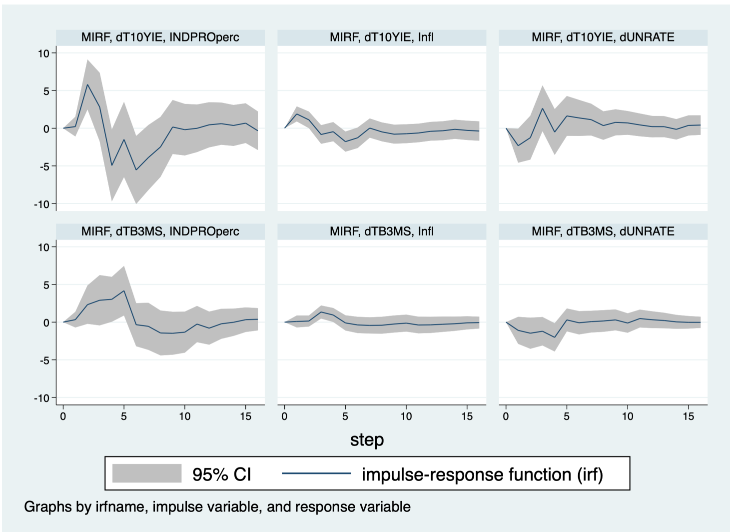


Figure 25: IRF for the signalling channel to the real economy

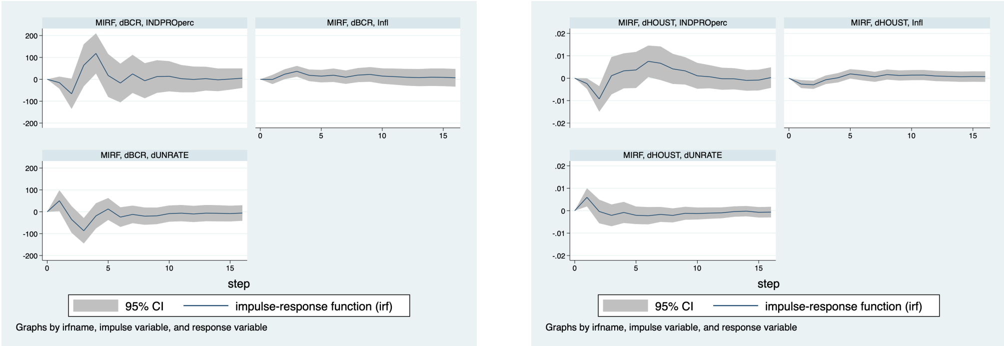


Figure 26: IRFs for the bank-lending channel on the real economy

Lags	dDGS10		dBAA	
	QE assets	dDGS10	QE assets	dBAA
0	0	0	0	0
1	.001068	.509717	.004042	.198314
2	.0037	.40891	.010719	.161098
3	.003581	.372727	.075874	.145813
4	.009018	.343433	.063991	.127362
5	.010304	.315708	.061158	.125348
6	.010928	.298751	.066623	.12231
7	.011862	.289946	.068441	.116501
8	.013413	.285768	.065446	.112355
9	.013556	.284008	.065316	.111161
10	.013543	.282909	.064657	.110093
...	...	...	...	...
16	.014933	.278052	.064124	.107001

Table 32: Variance decomposition, portfolio rebalance channel

Lags	dTB3MS		dT10YIE	
	QE assets	dTB3MS	QE assets	dT10YIE
0	0	0	0	0
1	.007271	.551115	.004477	.31401
2	.01614	.392489	.013047	.32482
3	.013386	.375706	.112576	.253019
4	.011322	.421952	.096689	.21551
5	.010477	.430467	.086449	.192594
6	.009566	.418705	.078505	.187315
7	.009711	.405241	.076984	.185788
8	.009582	.401305	.072786	.177605
9	.010224	.396693	.071613	.175505
10	.010171	.394641	.07211	.174809
...	...	...	...	...
16	.01177	.392495	.071957	.17252

Table 33: Variance decomposition, signalling channel

Lags	dHOUST		dBCR	
	QE assets	dHOUST	QE assets	dBCR
0	0	0	0	0
1	.007881	.452485	0	.171306
2	.032155	.292299	.001918	.184091
3	.02368	.208085	.001881	.155257
4	.051607	.184441	.01187	.132228
5	.049211	.18358	.011679	.132645
6	.047778	.18934	.011187	.133362
7	.047174	.190893	.018268	.13116
8	.046854	.18908	.018151	.1294045
9	.046854	.18908	.020624	.12923
10	.048624	.18806	.020497	.128324
...	...	...	...	...
16	.04823	.187127	.02156	.126648

Table 34: Variance decomposition, bank lending channel

Lags	dHHNW		dNFBNW	
	QE assets	dHHNW	QE assets	dNFBNW
0	0	0	0	0
1	.035322	.506626	.025278	.420184
2	.03384	.404592	.023574	.307548
3	.049469	.316401	.028403	.245326
4	.048089	.296922	.028656	.218092
5	.048727	.286062	.047005	.184436
6	.046316	.272865	.053127	.168768
7	.045462	.263661	.050185	.14934
8	.043614	.253436	.050272	.140203
9	.046333	.252426	.049345	.133624
10	.046097	.250977	.049269	.129894
...	...	...	...	...
16	.047212	.249219	.050803	.1219

Table 35: Variance decomposition, balance sheet channel

Lags	dVIXCL		dSTLFS13	
	QE assets	dVIXCL	QE assets	dSTLFS13
0	0	0	0	0
1	5.0e-06	.569187	.014513	.095836
2	.00192	.422184	.009566	.075268
3	.058377	.372075	.083839	.060733
4	.05055	.3229582	.073531	.051364
5	.047843	.302199	.071299	.055271
6	.046065	.279688	.073085	.077002
7	.045869	.276932	.073776	.076869
8	.043637	.263801	.070636	.075464
9	.043112	.262733	.07101	.074462
10	.042823	.260973	.070276	.07767
...	...	...	...	...
16	.042583	.2584	.068534	.07874

Table 36: Variance decomposition, risk taking channel

Lags	dUNRATE		Infl		INDPROperc	
	dDGS10	dBAA	dDGS10	dBAA	dDGS10	dBAA
0	0	0	0	0	0	0
1	0	0	0	0	.000376	.037935
2	.011581	.014477	.003658	.0002	.000204	.005823
3	.015171	.021392	.017052	.025963	.001164	.007773
4	.016182	.024925	.017998	.020927	.010362	.009329
5	.017307	.024575	.039158	.018373	.014504	.014406
6	.025305	.025582	.047192	.016022	.01665	.014077
7	.024844	.025196	.04882	.014914	.029417	.013379
8	.024543	.024424	.044862	.016579	.028872	.013769
9	.024266	.024052	.041774	.018569	.028403	.013497
10	.024282	.024159	.039773	.017639	.027871	.013272
...	...	...	...	...	...	...
16	.024019	.024902	.035636	.020851	.028327	.014422

Table 37: Variance decomposition, portfolio rebalance channel to real economy

Lags	dUNRATE		Infl		INDPROperc	
	dTB3MS	dT10YIE	dTB3MS	dT10YIE	dTB3MS	dT10YIE
0	0	0	0	0	0	0
1	0	0	0	0	.000376	.037935
2	.000042	.000421	.001561	.049145	.007942	.000489
3	.011937	.000399	.013779	.035839	.005081	.012981
4	.038799	.005437	.039404	.03179	.031416	.019032
5	.051056	.005698	.056919	.026645	.069937	.017847
6	.054128	.007406	.063991	.02481	.097233	.019103
7	.05622	.009104	.060593	.026295	.10205	.023117
8	.056537	.011859	.055334	.02465	.100447	.026303
9	.056746	.011721	.052594	.023279	.097658	.031443
10	.055877	.01155	.05039	.023107	.096185	.030856
...	...	...	...	...	...	...
16	.054905	.013486	.046158	.025388	.097643	.031327

Table 38: Variance decomposition, signalling channel to real economy

Lags	dUNRATE		Infl		INDPROperc	
	dHOUST	dBCR	dHOUST	dBCR	dHOUST	dBCR
0	0	0	0	0	0	0
1	0	0	0	0	.089387	.018157
2	.001995	.062632	.006618	.000464	.023709	.009574
3	.005953	.064299	.044102	.061615	.011436	.060045
4	.008275	.068795	.037127	.063258	.017052	.057583
5	.008019	.066975	.03401	.051863	.017889	.046418
6	.021439	.066027	.045306	.044085	.018862	.04796
7	.027495	.067271	.060192	.045901	.049974	.048063
8	.032069	.065321	.063369	.047218	.063689	.046949
9	.035919	.068234	.069376	.055761	.071481	.045648
10	.038141	.069065	.073633	.063373	.07339	.049213
...	...	...	...	...	...	...
16	.041367	.069656	.087438	.069949	.073064	.050946

Table 39: Variance decomposition, bank lending channel to real economy

Lags	dUNRATE		Infl		INDPROperc	
	dHHNW	dNFBNW	dHHNW	dNFBNW	dHHNW	dNFBNW
0	0	0	0	0	0	0
1	0	0	0	0	.027328	0
2	.123235	.037124	.027088	.024201	.004618	.000351
3	.174909	.030478	.02032	.023255	.075576	.034575
4	.174827	.053992	.053334	.026623	.135157	.026963
5	.170681	.05294	.076831	.023763	.155136	.058226
6	.17514	.051514	.089227	.022547	.146887	.056322
7	.172666	.050591	.109749	.020759	.150889	.049658
8	.170432	.049293	.110309	.024984	.146174	.048968
9	.16763	.048848	.108527	.024235	.144343	.048346
10	.170078	.048155	.113422	.022937	.141499	.048735
...	...	...	...	...	...	...
16	.168221	.047762	.113712	.02272	.140734	.048585

Table 40: Variance decomposition, balance sheet channel to real economy

Lags	dUNRATE		Infl		INDPROperc	
	dSTLFS13	dVIXCL	dSTLFS13	dVIXCL	dSTLFS13	dVIXCL
0	0	0	0	0	0	0
1	0	0	0	0	.011676	.010635
2	.072503	.073432	.03414	.03216	.001939	.001744
3	.062957	.073992	.023687	.026961	.059767	.073752
4	.070519	.0650342	.030568	.02156	.055795	.07815
5	.078286	.064272	.033391	.017653	.051783	.062984
6	.075242	.060044	.055791	.015072	.056416	.05921
7	.076216	.058846	.05814	.018374	.058554	.05232
8	.07789	.059792	.054531	.023384	.062879	.050343
9	.078964	.059079	.061235	.02211	.066668	.051238
10	.079455	.058182	.063763	.021373	.066661	.050197
...	...	...	...	...	...	...
16	.080549	.057556	.072352	.02264	.06672	.049417

Table 41: Variance decomposition, risk taking channel to real economy

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
dUNRATE						
dUNRATE						
L1.	-.5399812	.3291122	-1.64	0.101	-1.185029	.1050668
L2.	.1508819	.345508	0.44	0.662	-.5263014	.8280652
Infl						
L1.	-.0275586	.3223533	-0.09	0.932	-.6593595	.6042423
L2.	-.3936436	.3759166	-1.05	0.295	-1.130426	.3431393
dBCR						
L1.	50.56012	24.24201	2.09	0.037	3.046647	98.07359
L2.	-10.5128	24.65072	-0.43	0.670	-58.82734	37.80173
dVIXCL						
L1.	-.0049585	.0549211	-0.09	0.928	-.1126019	.1026849
L2.	.1535263	.0499801	3.07	0.002	.0555672	.2514855
dTB3MS						
L1.	-1.091017	.9146721	-1.19	0.233	-2.883741	.7017078
L2.	-1.22901	.7710082	-1.59	0.111	-2.740158	.2821383
dT10YIE						
L1.	-2.318461	1.150931	-2.01	0.044	-4.574245	-.0626769
L2.	-.6758783	1.181994	-0.57	0.567	-2.992544	1.640788
dSTLFS13						
L1.	-.2864234	.5815998	-0.49	0.622	-1.426338	.8534912
L2.	-.7006755	.4619702	-1.52	0.129	-1.60612	.2047694
dHOUST						
L1.	.0059579	.0020545	2.90	0.004	.001931	.0099847
L2.	-.0006562	.0019423	-0.34	0.735	-.0044629	.0031506
dHHNW						
L1.	-4.10e-07	7.80e-08	-5.26	0.000	-5.63e-07	-2.57e-07
L2.	2.76e-07	1.07e-07	2.57	0.010	6.54e-08	4.86e-07
dDGS10						
L1.	1.318455	.7333865	1.80	0.072	-.1189558	2.755866
L2.	2.506248	.7466463	3.36	0.001	1.042848	3.969648
dBAA						
L1.	-1.748112	.6508667	-2.69	0.007	-3.023788	-.472437
L2.	-1.369929	.647877	-2.11	0.034	-2.639744	-.1001131
QEperc						
L1.	2.29582	2.284388	1.01	0.315	-2.181499	6.773138
L2.	-7.487565	2.171678	-3.45	0.001	-11.74398	-3.231154
INDPROperc						
L1.	.1957537	.1748483	1.12	0.263	-.1469428	.5384502
L2.	-.0375507	.0641311	-0.59	0.558	-.1632453	.0881439
dNFBNW						
L1.	-.0010359	.0003744	-2.77	0.006	-.0017696	-.0003021
L2.	-.0002008	.0003073	-0.65	0.513	-.0008032	.0004016

Table 42 – continued from previous page						
Infl						
dUNRATE						
L1.	-.0404018	.1449726	-0.28	0.780	-.3245428	.2437391
L2.	-.653181	.1521949	-4.29	0.000	-.9514774	-.3548845
Infl						
L1.	.0034763	.1419953	0.02	0.980	-.2748294	.281782
L2.	.310177	.1655897	1.87	0.061	-.0143728	.6347268
dBCR						
L1.	-.8076547	10.67851	-0.08	0.940	-21.73714	20.12183
L2.	13.80296	10.85854	1.27	0.204	-7.479386	35.08532
dVIXCL						
L1.	.0193181	.0241925	0.80	0.425	-.0280983	.0667346
L2.	-.0067197	.022016	-0.31	0.760	-.0498703	.0364309
dTB3MS						
L1.	.0883851	.4029093	0.22	0.826	-.7013026	.8780728
L2.	.1880346	.3396259	0.55	0.580	-.47762	.8536892
dT10YIE						
L1.	1.89723	.5069805	3.74	0.000	.903567	2.890894
L2.	.4577527	.5206635	0.88	0.379	-.5627291	1.478234
dSTLFS13						
L1.	.1220237	.2561923	0.48	0.634	-.380104	.6241513
L2.	-.1735206	.2034959	-0.85	0.394	-.5723653	.2253242
dHOUST						
L1.	-.002625	.000905	-2.90	0.004	-.0043988	-.0008512
L2.	-.0028943	.0008556	-3.38	0.001	-.0045711	-.0012174
dHHNW						
L1.	9.39e-08	3.44e-08	2.73	0.006	2.65e-08	1.61e-07
L2.	-1.02e-08	4.73e-08	-0.22	0.829	-1.03e-07	8.25e-08
dDGS10						
L1.	-.4244778	.3230537	-1.31	0.189	-1.057651	.2086958
L2.	-1.461576	.3288946	-4.44	0.000	-2.106198	-.8169546
dBAA						
L1.	.2022477	.2867041	0.71	0.481	-.3596821	.7641774
L2.	1.033149	.2853871	3.62	0.000	.4738002	1.592497
QEperc						
L1.	-1.245377	1.006263	-1.24	0.216	-3.217617	.726863
L2.	5.274198	.9566152	5.51	0.000	3.399267	7.14913
INDPROperc						
L1.	-.1183824	.07702	-1.54	0.124	-.2693387	.032574
L2.	.0383181	.0282495	1.36	0.175	-.0170498	.0936861

Table 42 – continued from previous page						
dNFBNW						
L1.	.0003173	.0001649	1.92	0.054	-5.89e-06	.0006406
L2.	.0002172	.0001354	1.60	0.109	-.0000482	.0004825
cons	-.0617715	.1278132	-0.48	0.629	-.3122808	.1887378
dBCR						
dUNRATE						
L1.	-.0107052	.004437	-2.41	0.016	-.0194015	-.0020089
L2.	.0076345	.004658	1.64	0.101	-.0014951	.0167641
Infl						
L1.	.0042802	.0043459	0.98	0.325	-.0042375	.012798
L2.	-.0032077	.005068	-0.63	0.527	-.0131407	.0067254
dBCR						
L1.	.9570684	.3268229	2.93	0.003	.3165074	1.597629
L2.	-.2108248	.332333	-0.63	0.526	-.8621855	.4405359
dVIXCL						
L1.	-.0003337	.0007404	-0.45	0.652	-.0017849	.0011175
L2.	.0017665	.0006738	2.62	0.009	.0004458	.0030872
dTB3MS						
L1.	-.0056912	.0123313	-0.46	0.644	-.0298601	.0184777
L2.	-.022927	.0103945	-2.21	0.027	-.0432998	-.0025542
dT10YIE						
L1.	-.0303619	.0155165	-1.96	0.050	-.0607736	.0000498
L2.	-.0196001	.0159353	-1.23	0.219	-.0508326	.0116324
dSTLFS13						
L1.	-.001217	.0078409	-0.16	0.877	-.016585	.0141509
L2.	-.0092096	.0062281	-1.48	0.139	-.0214165	.0029973
dHOUST						
L1.	.0000892	.0000277	3.22	0.001	.0000349	.0001434
L2.	.0000116	.0000262	0.44	0.658	-.0000397	.0000629
dHHNW						
L1.	-4.73e-09	1.05e-09	-4.50	0.000	-6.79e-09	-2.67e-09
L2.	3.01e-09	1.45e-09	2.08	0.038	1.71e-10	5.84e-09
dDGS10						
L1.	.0149189	.0098873	1.51	0.131	-.0044599	.0342976
L2.	.0362698	.010066	3.60	0.000	.0165407	.0559989
dBAA						
L1.	-.0231395	.0087748	-2.64	0.008	-.0403377	-.0059413
L2.	-.0175211	.0087345	-2.01	0.045	-.0346403	-.0004018
QEperc						
L1.	.0455985	.0307974	1.48	0.139	-.0147632	.1059602
L2.	-.129594	.0292779	-4.43	0.000	-.1869775	-.0722104

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INDPROperc						
L1.	.0039452	.0023572	1.67	0.094	-.000675	.0085653
L2.	.0000308	.0008646	0.04	0.972	-.0016637	.0017254
dNFBNW						
L1.	-.0000107	5.05e-06	-2.12	0.034	-.0000206	-8.32e-07
L2.	6.62e-07	4.14e-06	0.16	0.873	-7.46e-06	8.78e-06
cons	.0064589	.0039118	1.65	0.099	-.0012081	.0141259
dVIXCL						
dUNRATE						
L1.	-.1305746	1.709273	-0.08	0.939	-3.480689	3.21954
L2.	7.392476	1.794427	4.12	0.000	3.875464	10.90949
Infl						
L1.	5.436847	1.674171	3.25	0.001	2.155533	8.718161
L2.	-1.9908	1.952356	-1.02	0.308	-5.817347	1.835748
dBCR						
L1.	148.3285	125.903	1.18	0.239	-98.43693	395.0939
L2.	-346.2128	128.0257	-2.70	0.007	-597.1386	-95.28697
dVIXCL						
L1.	-.2698962	.2852377	-0.95	0.344	-.8289518	.2891594
L2.	-.2891007	.259576	-1.11	0.265	-.7978604	.2196589
dTB3MS						
L1.	.9988594	4.750431	0.21	0.833	-8.311815	10.30953
L2.	-9.201975	4.0043	-2.30	0.022	-17.05026	-1.353691
dT10YIE						
L1.	-18.25222	5.977464	-3.05	0.002	-29.96784	-6.536608
L2.	-4.766152	6.138792	-0.78	0.438	-16.79796	7.265659
dSTLFS13						
L1.	-1.517297	3.02059	-0.50	0.615	-7.437545	4.40295
L2.	3.212007	2.399283	1.34	0.181	-1.490502	7.914515
dHOUST						
L1.	.0174725	.0106704	1.64	0.102	-.0034412	.0383861
L2.	-.0029405	.0100873	-0.29	0.771	-.0227112	.0168302
dHHNW						
L1.	6.29e-08	4.05e-07	0.16	0.877	-7.31e-07	8.57e-07
L2.	-8.53e-08	5.58e-07	-0.15	0.878	-1.18e-06	1.01e-06
dDGS10						
L1.	7.552076	3.808908	1.98	0.047	.0867537	15.0174
L2.	15.39785	3.877774	3.97	0.000	7.797556	22.99815
dBAA						
L1.	-6.610413	3.380334	-1.96	0.051	-13.23575	.0149209
L2.	-9.065386	3.364807	-2.69	0.007	-15.66029	-2.470486

Table 42 – continued from previous page						
QEperc						
L1.	1.733532	11.86417	0.15	0.884	-21.51982	24.98688
L2.	-51.81346	11.2788	-4.59	0.000	-73.91951	-29.70741
INDPROperc						
L1.	1.231378	.9080904	1.36	0.175	-.5484461	3.011203
L2.	.0260153	.3330704	0.08	0.938	-.6267908	.6788214
dNFBNW						
L1.	-.0022676	.0019444	-1.17	0.244	-.0060785	.0015433
L2.	.0020838	.0015962	1.31	0.192	-.0010447	.0052123
cons	1.092828	1.506959	0.73	0.468	-1.860758	4.046414
dTB3MS						
dUNRATE						
L1.	.0173158	.0693291	0.25	0.803	-.1185668	.1531984
L2.	-.1729493	.072783	-2.38	0.017	-.3156013	-.0302972
Infl						
L1.	-.1954698	.0679053	-2.88	0.004	-.3285618	-.0623778
L2.	.218907	.0791887	2.76	0.006	.0637	.374114
dBCR						
L1.	-.7550421	5.106702	-0.15	0.882	-10.76399	9.25391
L2.	2.811903	5.192799	0.54	0.588	-7.365797	12.9896
dVIXCL						
L1.	.0121109	.0115694	1.05	0.295	-.0105647	.0347865
L2.	.0008334	.0105286	0.08	0.937	-.0198021	.021469
dTB3MS						
L1.	.5428977	.1926803	2.82	0.005	.1652513	.9205441
L2.	.3637647	.1624168	2.24	0.025	.0454337	.6820957
dT10YIE						
L1.	-.0341177	.2424495	-0.14	0.888	-.5093099	.4410746
L2.	.1971752	.248993	0.79	0.428	-.2908422	.6851926
dSTLFS13						
L1.	-.3783101	.1225169	-3.09	0.002	-.6184388	-.1381813
L2.	.0048787	.0973163	0.05	0.960	-.1858578	.1956152
dHOUST						
L1.	8.50e-06	.0004328	0.02	0.984	-.0008398	.0008568
L2.	-.0000635	.0004091	-0.16	0.877	-.0008654	.0007384
dHHNW						
L1.	2.85e-08	1.64e-08	1.74	0.083	-3.69e-09	6.07e-08
L2.	-9.91e-09	2.26e-08	-0.44	0.661	-5.42e-08	3.44e-08
dDGS10						
L1.	-.2274392	.1544916	-1.47	0.141	-.5302371	.0753587
L2.	-.3162543	.1572848	-2.01	0.044	-.6245268	-.0079818

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dBAA						
L1.	.603683	.1371084	4.40	0.000	.3349556	.8724105
L2.	.0015958	.1364785	0.01	0.991	-.2658972	.2690889
QEperc						
L1.	-1.295088	.4812178	-2.69	0.007	-2.238258	-.3519187
L2.	2.066113	.4574749	4.52	0.000	1.169479	2.962748
INDPROperc						
L1.	-.0982302	.0368327	-2.67	0.008	-.1704209	-.0260395
L2.	.0087466	.0135095	0.65	0.517	-.0177316	.0352248
dNFBNW						
L1.	.0000207	.0000789	0.26	0.793	-.0001339	.0001753
L2.	3.93e-06	.0000647	0.06	0.952	-.000123	.0001308
cons	-.0773764	.0611232	-1.27	0.206	-.1971756	.0424228
dT10YIE						
dUNRATE						
L1.	.0112117	.0705872	0.16	0.874	-.1271368	.1495601
L2.	-.2944284	.0741038	-3.97	0.000	-.4396691	-.1491876
Infl						
L1.	-.1860426	.0691376	-2.69	0.007	-.3215499	-.0505354
L2.	.1699183	.0806257	2.11	0.035	.0118948	.3279418
dBCR						
L1.	-4.99205	5.199372	-0.96	0.337	-15.18263	5.198533
L2.	14.53781	5.287032	2.75	0.006	4.175414	24.9002
dVIXCL						
L1.	.0083108	.0117794	0.71	0.480	-.0147763	.0313979
L2.	-.0002549	.0107196	-0.02	0.981	-.021265	.0207552
dTB3MS						
L1.	.0186378	.1961768	0.10	0.924	-.3658617	.4031374
L2.	.2875773	.1653641	1.74	0.082	-.0365305	.611685
dT10YIE						
L1.	.5829426	.2468492	2.36	0.018	.0991271	1.066758
L2.	.0123641	.2535115	0.05	0.961	-.4845093	.5092374
dSTLFS13						
L1.	.0446676	.1247402	0.36	0.720	-.1998187	.289154
L2.	.051667	.0990823	0.52	0.602	-.1425307	.2458648
dHOUST						
L1.	-.0006246	.0004407	-1.42	0.156	-.0014882	.0002391
L2.	-.0005675	.0004166	-1.36	0.173	-.001384	.0002489
dHHNW						
L1.	2.47e-08	1.67e-08	1.48	0.140	-8.07e-09	5.75e-08
L2.	1.29e-09	2.30e-08	0.06	0.955	-4.38e-08	4.64e-08

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dDGS10						
L1.	-.0764673	.1572951	-0.49	0.627	-.38476	.2318254
L2.	-.4682129	.160139	-2.92	0.003	-.7820796	-.1543462
dBAA						
L1.	.088641	.1395964	0.63	0.525	-.184963	.362245
L2.	.1720223	.1389552	1.24	0.216	-.1003249	.4443695
QEperc						
L1.	.1558924	.4899504	0.32	0.750	-.8043928	1.116178
L2.	2.120648	.4657767	4.55	0.000	1.207743	3.033554
INDPROperc						
L1.	-.0337958	.0375011	-0.90	0.367	-.1072966	.0397049
L2.	-.0189687	.0137547	-1.38	0.168	-.0459274	.00799
dNFBNW						
L1.	-1.13e-07	.0000803	-0.00	0.999	-.0001575	.0001573
L2.	.0000407	.0000659	0.62	0.537	-.0000885	.0001699
cons	-.1529329	.0622324	-2.46	0.014	-.2749061	-.0309598
dSTLFS13						
dUNRATE						
L1.	.0919971	.2109978	0.44	0.663	-.3215509	.5055451
L2.	.731089	.2215093	3.30	0.001	.2969387	1.165239
Infl						
L1.	.763419	.2066646	3.69	0.000	.3583639	1.168474
L2.	-.1792131	.2410046	-0.74	0.457	-.6515734	.2931472
dBCR						
L1.	-2.099506	15.54184	-0.14	0.893	-32.56096	28.36195
L2.	-25.25752	15.80387	-1.60	0.110	-56.23254	5.717508
dVIXCL						
L1.	.0148666	.0352106	0.42	0.673	-.0541449	.0838781
L2.	-.0407287	.0320428	-1.27	0.204	-.1035315	.0220741
dTB3MS						
L1.	-.1277944	.5864072	-0.22	0.827	-1.277131	1.021543
L2.	-.8188535	.4943026	-1.66	0.098	-1.787669	.1499618
dT10YIE						
L1.	-1.245937	.7378758	-1.69	0.091	-2.692147	.2002727
L2.	-1.237194	.7577906	-1.63	0.103	-2.722436	.2480484
dSTLFS13						
L1.	-.1352942	.3728705	-0.36	0.717	-.866107	.5955187
L2.	-.1252441	.2961746	-0.42	0.672	-.7057356	.4552475
dHOUST						
L1.	.0007718	.0013172	0.59	0.558	-.0018098	.0033535
L2.	.0012745	.0012452	1.02	0.306	-.001166	.0037151

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dHHNW						
L1.	3.63e-08	5.00e-08	0.73	0.468	-6.17e-08	1.34e-07
L2.	-8.36e-08	6.88e-08	-1.21	0.225	-2.19e-07	5.13e-08
dDGS10						
L1.	.7163405	.4701828	1.52	0.128	-.2052009	1.637882
L2.	1.047119	.4786838	2.19	0.029	.1089163	1.985322
dBAA						
L1.	-1.05533	.4172784	-2.53	0.011	-1.873181	-.2374797
L2.	-.2893197	.4153617	-0.70	0.486	-1.103414	.5247742
QEperc						
L1.	-.8175364	1.464548	-0.56	0.577	-3.687998	2.052926
L2.	-5.662047	1.392289	-4.07	0.000	-8.390883	-2.933211
INDPROperc						
L1.	.1860596	.1120974	1.66	0.097	-.0336471	.4057664
L2.	.0504417	.0411152	1.23	0.220	-.0301426	.131026
dNFBNW						
L1.	.0001247	.00024	0.52	0.603	-.0003457	.0005951
L2.	.0000301	.000197	0.15	0.878	-.000356	.0004163
cons	.0657698	.1860235	0.35	0.724	-.2988295	.4303692
dHOUST						
dUNRATE						
L1.	18.58104	23.86694	0.78	0.436	-28.19729	65.35938
L2.	-41.39731	25.05595	-1.65	0.098	-90.50607	7.711441
Infl						
L1.	-9.044096	23.37679	-0.39	0.699	-54.86176	36.77357
L2.	38.36975	27.26115	1.41	0.159	-15.06112	91.80062
dBCR						
L1.	-1921.127	1758.01	-1.09	0.274	-5366.763	1524.51
L2.	1037.685	1787.65	0.58	0.562	-2466.044	4541.413
dVIXCL						
L1.	3.374331	3.982832	0.85	0.397	-4.431877	11.18054
L2.	-11.1582	3.624513	-3.08	0.002	-18.26212	-4.054286
dTB3MS						
L1.	58.53168	66.33124	0.88	0.378	-71.47518	188.5385
L2.	66.9613	55.91286	1.20	0.231	-42.62589	176.5485
dT10YIE						
L1.	209.6569	83.46456	2.51	0.012	46.06941	373.2445
L2.	-184.4481	85.71721	-2.15	0.031	-352.4508	-16.44549
dSTLFS13						
L1.	7.27598	42.17712	0.17	0.863	-75.38966	89.94162
L2.	3.702924	33.50168	0.11	0.912	-61.95917	69.36502

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dHOUST						
L1.	-.2284923	.1489935	-1.53	0.125	-.5205142	.0635296
L2.	.2629147	.1408507	1.87	0.062	-.0131476	.5389769
dHHNW						
L1.	.0000253	5.66e-06	4.48	0.000	.0000143	.0000364
L2.	-.0000231	7.79e-06	-2.97	0.003	-.0000384	-7.87e-06
dDGS10						
L1.	-120.4728	53.18456	-2.27	0.024	-224.7126	-16.23297
L2.	-170.636	54.14615	-3.15	0.002	-276.7605	-64.51147
dBAA						
L1.	80.41099	47.2003	1.70	0.088	-12.0999	172.9219
L2.	67.16691	46.98349	1.43	0.153	-24.91904	159.2529
QEperc						
L1.	-46.64717	165.6619	-0.28	0.778	-371.3385	278.0441
L2.	600.6558	157.4883	3.81	0.000	291.9845	909.3271
INDPROperc						
L1.	-28.28154	12.67985	-2.23	0.026	-53.13359	-3.429482
L2.	10.88683	4.650731	2.34	0.019	1.771566	20.0021
dNFBNW						
L1.	.1054829	.0271495	3.89	0.000	.0522708	.158695
L2.	-.0095551	.022288	-0.43	0.668	-.0532389	.0341286
cons	-47.68957	21.04198	-2.27	0.023	-88.93109	-6.44804
dHHNW						
dUNRATE						
L1.	-157860.2	563725.3	-0.28	0.779	-1262741	947021.1
L2.	-730858.8	591809.2	-1.23	0.217	-1890783	429065.9
Infl						
L1.	-625629.6	552148.2	-1.13	0.257	-1707820	456561
L2.	1085943	643894.9	1.69	0.092	-176067.5	2347954
dBCR						
L1.	3.64e+07	4.15e+07	0.88	0.381	-4.50e+07	1.18e+08
L2.	1.01e+08	4.22e+07	2.40	0.016	1.85e+07	1.84e+08
dVIXCL						
L1.	121222.8	94072.54	1.29	0.198	-63156.01	305601.6
L2.	325775.9	85609.22	3.81	0.000	157984.9	493566.9
dTB3MS						
L1.	954164.8	1566711	0.61	0.543	-2116533	4024863
L2.	-230324.5	1320634	-0.17	0.862	-2818720	2358071
dT10YIE						
L1.	3005875	1971392	1.52	0.127	-857982.1	6869732
L2.	-3857180	2024598	-1.91	0.057	-7825320	110959.8

Table 42 – continued from previous page						
dSTLFS13						
L1.	-489390.4	996202.8	-0.49	0.623	-2441912	1463131
L2.	-4207167	791293.3	-5.32	0.000	-5758073	-2656261
dHOUST						
L1.	1704.275	3519.153	0.48	0.628	-5193.139	8601.688
L2.	4988.929	3326.824	1.50	0.134	-1531.525	11509.38
dHHNW						
L1.	-.1679808	.1336117	-1.26	0.209	-.4298549	.0938932
L2.	.5750706	.1838956	3.13	0.002	.2146418	.9354994
dDGS10						
L1.	-1927108	1256193	-1.53	0.125	-4389201	534986
L2.	-1151128	1278905	-0.90	0.368	-3657737	1355481
dBAA						
L1.	683519.3	1114848	0.61	0.540	-1501543	2868581
L2.	2259041	1109727	2.04	0.042	84015.77	4434065
QEperc						
L1.	2307266	3912852	0.59	0.555	-5361783	9976315
L2.	3784645	3719795	1.02	0.309	-3506019	1.11e+07
INDPROperc						
L1.	210208.3	299491.9	0.70	0.483	-376785	797201.7
L2.	-50084.46	109848	-0.46	0.648	-265382.5	165213.6
dNFBNW						
L1.	1111.16	641.2587	1.73	0.083	-145.6836	2368.004
L2.	-452.8381	526.4324	-0.86	0.390	-1484.627	578.9504
cons	-449132.1	497001.3	-0.90	0.366	-1423237	524972.5
dDGS10						
dUNRATE						
L1.	.0228898	.0959606	0.24	0.811	-.1651896	.2109691
L2.	-.1792859	.1007412	-1.78	0.075	-.3767351	.0181633
Infl						
L1.	-.1769417	.0939899	-1.88	0.060	-.3611586	.0072751
L2.	.2083453	.1096076	1.90	0.057	-.0064816	.4231722
dBCR						
L1.	-9.569931	7.068346	-1.35	0.176	-23.42364	4.283773
L2.	9.587441	7.187516	1.33	0.182	-4.499832	23.67471
dVIXCL						
L1.	.024056	.0160136	1.50	0.133	-.0073301	.055442
L2.	-.004961	.0145729	-0.34	0.734	-.0335233	.0236014
dTB3MS						
L1.	-.095979	.2666948	-0.36	0.719	-.6186913	.4267332
L2.	.1857276	.2248061	0.83	0.409	-.2548844	.6263395

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dT10YIE						
L1.	-.0299796	.3355819	-0.09	0.929	-.6877081	.6277489
L2.	-.3052143	.3446391	-0.89	0.376	-.9806945	.3702658
dSTLFS13						
L1.	-.4264088	.1695795	-2.51	0.012	-.7587785	-.094039
L2.	.0171328	.1346986	0.13	0.899	-.2468716	.2811372
dHOUST						
L1.	-.0012745	.0005991	-2.13	0.033	-.0024487	-.0001004
L2.	.0001253	.0005663	0.22	0.825	-.0009846	.0012353
dHHNW						
L1.	4.30e-08	2.27e-08	1.89	0.059	-1.62e-09	8.75e-08
L2.	1.21e-08	3.13e-08	0.39	0.700	-4.93e-08	7.34e-08
dDGS10						
L1.	.2314392	.2138366	1.08	0.279	-.1876729	.6505512
L2.	-.2003402	.2177028	-0.92	0.357	-.6270299	.2263495
dBAA						
L1.	.1445978	.189776	0.76	0.446	-.2273562	.5165519
L2.	-.2103153	.1889042	-1.11	0.266	-.5805608	.1599302
QEperc						
L1.	-.7210161	.6660687	-1.08	0.279	-2.026487	.5844545
L2.	.6573711	.6332054	1.04	0.299	-.5836887	1.898431
INDPROperc						
L1.	-.0497882	.0509813	-0.98	0.329	-.1497097	.0501332
L2.	-.0144911	.018699	-0.77	0.438	-.0511404	.0221582
dNFBNW						
L1.	-.0000339	.0001092	-0.31	0.756	-.0002479	.00018
L2.	.0000892	.0000896	1.00	0.320	-.0000865	.0002648
cons	-.1337604	.0846025	-1.58	0.114	-.2995782	.0320574
dBAA						
dUNRATE						
L1.	.0099618	.1099832	0.09	0.928	-.2056012	.2255249
L2.	.2065211	.1154624	1.79	0.074	-.019781	.4328231
Infl						
L1.	.1756729	.1077245	1.63	0.103	-.0354632	.386809
L2.	-.045028	.1256243	-0.36	0.720	-.2912472	.2011911
dBCR						
L1.	-2.666431	8.10123	-0.33	0.742	-18.54455	13.21169
L2.	2.810801	8.237814	0.34	0.733	-13.33502	18.95662
dVIXCL						
L1.	.0114583	.0183536	0.62	0.532	-.0245141	.0474308
L2.	-.0076768	.0167024	-0.46	0.646	-.0404129	.0250593

Table 42 – continued from previous page						
dTB3MS						
L1.	-.013246	.3056664	-0.04	0.965	-.6123411	.5858492
L2.	-.315939	.2576566	-1.23	0.220	-.8209367	.1890587
dT10YIE						
L1.	-.8444558	.3846199	-2.20	0.028	-1.598297	-.0906148
L2.	-.1931616	.3950005	-0.49	0.625	-.9673484	.5810251
dSTLFS13						
L1.	-.2114064	.1943598	-1.09	0.277	-.5923447	.1695319
L2.	.1890975	.1543818	1.22	0.221	-.1134854	.4916803
dHOUST						
L1.	-.0007126	.0006866	-1.04	0.299	-.0020583	.0006331
L2.	.0006856	.0006491	1.06	0.291	-.0005865	.0019578
dHHNW						
L1.	3.53e-09	2.61e-08	0.14	0.892	-4.76e-08	5.46e-08
L2.	1.16e-08	3.59e-08	0.32	0.746	-5.87e-08	8.19e-08
dDGS10						
L1.	.5266568	.2450841	2.15	0.032	.0463007	1.007013
L2.	.5476156	.2495153	2.19	0.028	.0585746	1.036657
dBAA						
L1.	-.2295611	.2175076	-1.06	0.291	-.6558681	.1967459
L2.	-.562934	.2165084	-2.60	0.009	-.9872827	-.1385852
QEperc						
L1.	-.7631488	.7634	-1.00	0.317	-2.259385	.7330877
L2.	-1.847944	.7257345	-2.55	0.011	-3.270358	-.4255308
INDPROperc						
L1.	.1004351	.0584311	1.72	0.086	-.0140876	.2149579
L2.	-.0107113	.0214314	-0.50	0.617	-.0527161	.0312935
dNFBNW						
L1.	-.0001319	.0001251	-1.05	0.292	-.0003771	.0001133
L2.	.0000414	.0001027	0.40	0.687	-.0001599	.0002427
cons	-.0303677	.0969653	-0.31	0.754	-.2204161	.1596808
QEperc						
dUNRATE						
L1.	-.0063196	.0192344	-0.33	0.742	-.0440184	.0313791
L2.	.0067664	.0201926	0.34	0.738	-.0328105	.0463432
Infl						
L1.	-.0126934	.0188394	-0.67	0.500	-.0496179	.0242312
L2.	.0052111	.0219698	0.24	0.813	-.0378489	.0482712
dBCR						
L1.	1.419863	1.416784	1.00	0.316	-1.356982	4.196707
L2.	-.8833496	1.44067	-0.61	0.540	-3.707011	1.940312

Table 42 – continued from previous page						
dVIXCL						
L1.	-.0029225	.0032098	-0.91	0.363	-.0092135	.0033686
L2.	.0062968	.002921	2.16	0.031	.0005718	.0120219
dTB3MS						
L1.	.1216754	.0534565	2.28	0.023	.0169026	.2264481
L2.	-.1722753	.0450603	-3.82	0.000	-.2605918	-.0839588
dT10YIE						
L1.	-.2047949	.0672642	-3.04	0.002	-.3366304	-.0729594
L2.	-.1142754	.0690797	-1.65	0.098	-.249669	.0211183
dSTLFS13						
L1.	.0233502	.0339906	0.69	0.492	-.0432702	.0899706
L2.	.0289501	.0269991	1.07	0.284	-.0239671	.0818673
dHOUST						
L1.	.0003222	.0001201	2.68	0.007	.0000869	.0005576
L2.	8.61e-06	.0001135	0.08	0.940	-.0002139	.0002311
dHHNW						
L1.	-1.16e-08	4.56e-09	-2.53	0.011	-2.05e-08	-2.62e-09
L2.	2.49e-08	6.27e-09	3.97	0.000	1.26e-08	3.72e-08
dDGS10						
L1.	.1439213	.0428615	3.36	0.001	.0599142	.2279284
L2.	.1013807	.0436365	2.32	0.020	.0158547	.1869066
dBAA						
L1.	-.1161756	.0380388	-3.05	0.002	-.1907303	-.0416209
L2.	-.0543901	.0378641	-1.44	0.151	-.1286024	.0198221
QEperc						
L1.	1.019143	.1335072	7.63	0.000	.7574732	1.280812
L2.	-.444475	.1269201	-3.50	0.000	-.6932338	-.1957163
INDPROperc						
L1.	.0085296	.0102187	0.83	0.404	-.0114987	.0285579
L2.	-.0056975	.003748	-1.52	0.128	-.0130435	.0016485
dNFBNW						
L1.	-.0000763	.0000219	-3.49	0.000	-.0001192	-.0000334
L2.	-.0000365	.000018	-2.03	0.042	-.0000717	-1.31e-06
cons	.0241845	.0169578	1.43	0.154	-.0090521	.0574211
dINDPROperc						
dUNRATE						
L1.	-1.192683	.190662	-6.26	0.000	-1.566374	-.8189925
L2.	.6692738	.2001605	3.34	0.001	.2769665	1.061581
Infl						
L1.	.223066	.1867464	1.19	0.232	-.1429503	.5890823
L2.	-.230162	.2177768	-1.06	0.291	-.6569967	.1966728

Table 42 – continued from previous page						
dBCR						
L1.	-15.34836	14.04394	-1.09	0.274	-42.87396	12.17725
L2.	2.104095	14.28071	0.15	0.883	-25.88559	30.09378
dVIXCL						
L1.	.0228662	.031817	0.72	0.472	-.039494	.0852264
L2.	-.0103901	.0289546	-0.36	0.720	-.0671401	.0463598
dTB3MS						
L1.	.3305745	.5298899	0.62	0.533	-.7079906	1.36914
L2.	.8274666	.4466622	1.85	0.064	-.0479752	1.702908
dT10YIE						
L1.	.2143453	.6667601	0.32	0.748	-1.09248	1.521171
L2.	2.465449	.6847555	3.60	0.000	1.123353	3.807545
dSTLFS13						
L1.	-.2547413	.3369337	-0.76	0.450	-.9151191	.4056366
L2.	.5313845	.2676296	1.99	0.047	.0068401	1.055929
dHOUST						
L1.	-.0024101	.0011902	-2.02	0.043	-.0047429	-.0000772
L2.	-9.55e-08	.0011252	-0.00	1.000	-.0022054	.0022052
dHHNW						
L1.	1.10e-08	4.52e-08	0.24	0.808	-7.76e-08	9.95e-08
L2.	-2.16e-08	6.22e-08	-0.35	0.728	-1.44e-07	1.00e-07
dDGS10						
L1.	-.3887715	.4248671	-0.92	0.360	-1.221496	.4439527
L2.	-.2595673	.4325488	-0.60	0.548	-1.107347	.5882127
dBAA						
L1.	.2852899	.3770616	0.76	0.449	-.4537372	1.024317
L2.	-.5891151	.3753295	-1.57	0.117	-1.324748	.1465172
QEperc						
L1.	-1.342789	1.323397	-1.01	0.310	-3.936599	1.251021
L2.	4.875849	1.258101	3.88	0.000	2.410016	7.341682
INDPROperc						
L1.	.2851541	.1012935	2.82	0.005	.0866224	.4836857
L2.	.0951214	.0371526	2.56	0.010	.0223038	.1679391
dNFBNW						
L1.	.0001091	.0002169	0.50	0.615	-.000316	.0005341
L2.	.0002844	.000178	1.60	0.110	-.0000646	.0006334
cons	-.0693094	.1680947	-0.41	0.680	-.3987691	.2601502
dNFBNW						
dUNRATE						
L1.	-128.9378	128.9385	-1.00	0.317	-381.6526	123.7769
L2.	55.99215	135.362	0.41	0.679	-209.3124	321.2967

Table 42 – continued from previous page						
Infl						
L1.	-83.37893	126.2905	-0.66	0.509	-330.9037	164.1459
L2.	307.7177	147.2753	2.09	0.037	19.06343	596.3721
dBCR						
L1.	22906.93	9497.454	2.41	0.016	4292.262	41521.6
L2.	-8169.241	9657.578	-0.85	0.398	-27097.75	10759.26
dVIXCL						
L1.	36.85049	21.51681	1.71	0.087	-5.321684	79.02266
L2.	12.60512	19.58103	0.64	0.520	-25.77299	50.98323
dTB3MS						
L1.	128.6503	358.3472	0.36	0.720	-573.6972	830.9978
L2.	314.5314	302.063	1.04	0.298	-277.5012	906.5641
dT10YIE						
L1.	388.9045	450.908	0.86	0.388	-494.8589	1272.668
L2.	-540.1273	463.0777	-1.17	0.243	-1447.743	367.4884
dSTLFS13						
L1.	-199.0802	227.8572	-0.87	0.382	-645.6721	247.5117
L2.	-302.1149	180.9891	-1.67	0.095	-656.847	52.61726
dHOUST						
L1.	-.0299608	.8049208	-0.04	0.970	-1.607577	1.547655
L2.	-.552408	.7609301	-0.73	0.468	-2.043804	.9389875
dHHNW						
L1.	.0000772	.0000306	2.53	0.012	.0000173	.0001371
L2.	.0000776	.0000421	1.84	0.065	-4.89e-06	.00016
dDGS10						
L1.	397.6315	287.3237	1.38	0.166	-165.5126	960.7756
L2.	-381.9942	292.5186	-1.31	0.192	-955.32	191.3316
dBAA						
L1.	-181.822	254.9944	-0.71	0.476	-681.6018	317.9578
L2.	288.0334	253.8231	1.13	0.256	-209.4507	785.5174
QEperc						
L1.	-2166.056	894.9698	-2.42	0.016	-3920.165	-411.9477
L2.	1775.547	850.8127	2.09	0.037	107.9843	3443.109
INDPROperc						
L1.	-56.00492	68.50149	-0.82	0.414	-190.2654	78.25554
L2.	40.15212	25.12506	1.60	0.110	-9.092083	89.39633
dNFBNW						
L1.	.1977515	.1466723	1.35	0.178	-.089721	.485224
L2.	-.1653349	.1204086	-1.37	0.170	-.4013314	.0706616
cons	-118.829	113.677	-1.05	0.296	-341.6318	103.9737

Table 42: VAR estimation results for model 2

Lags	dDGS10		dBAA	
	QE assets	dDGS10	QE assets	dBAA
0	0	0	0	0
1	.001068	.509717	.004042	.198314
2	.0037	.40891	.010719	.161098
3	.003581	.372727	.075874	.145813
4	.009018	.343433	.063991	.127362
5	.010304	.315708	.061158	.125348
6	.010928	.298751	.066623	.12231
7	.011862	.289946	.068441	.116501
8	.013413	.285768	.065446	.112355
9	.013556	.284008	.065316	.111161
10	.013543	.282909	.064657	.110093
...	...	...	...	...
16	.014933	.278052	.064124	.107001

Table 43: Variance decomposition, portfolio rebalance channel

Lags	dTB3MS		dT10YIE	
	QE assets	dTB3MS	QE assets	dT10YIE
0	0	0	0	0
1	.007271	.551115	.004477	.31401
2	.01614	.392489	.013047	.32482
3	.013386	.375706	.112576	.253019
4	.011322	.421952	.096689	.21551
5	.010477	.430467	.086449	.192594
6	.009566	.418705	.078505	.187315
7	.009711	.405241	.076984	.185788
8	.009582	.401305	.072786	.177605
9	.010224	.396693	.071613	.175505
10	.010171	.394641	.07211	.174809
...	...	...	...	...
16	.01177	.392495	.071957	.17252

Table 44: Variance decomposition, signalling channel

Lags	dHOUST		dBCR	
	QE assets	dHOUST	QE assets	dBCR
0	0	0	0	0
1	.007881	.452485	0	.171306
2	.032155	.292299	.001918	.184091
3	.02368	.208085	.001881	.155257
4	.051607	.184441	.01187	.132228
5	.049211	.18358	.011679	.132645
6	.047778	.18934	.011187	.133362
7	.047174	.190893	.018268	.13116
8	.046854	.18908	.018151	.1294045
9	.046854	.18908	.020624	.12923
10	.048624	.18806	.020497	.128324
...	...	...	...	...
16	.04823	.187127	.02156	.126648

Table 45: Variance decomposition, bank lending channel

Lags	dHHNW		dNFBNW	
	QE assets	dHHNW	QE assets	dNFBNW
0	0	0	0	0
1	.035322	.506626	.025278	.420184
2	.03384	.404592	.023574	.307548
3	.049469	.316401	.028403	.245326
4	.048089	.296922	.028656	.218092
5	.048727	.286062	.047005	.184436
6	.046316	.272865	.053127	.168768
7	.045462	.263661	.050185	.14934
8	.043614	.253436	.050272	.140203
9	.046333	.252426	.049345	.133624
10	.046097	.250977	.049269	.129894
...	...	...	...	...
16	.047212	.249219	.050803	.1219

Table 46: Variance decomposition, balance sheet channel

Lags	dVIXCL		dSTLFS13	
	QE assets	dVIXCL	QE assets	dSTLFS13
0	0	0	0	0
1	5.0e-06	.569187	.014513	.095836
2	.00192	.422184	.009566	.075268
3	.058377	.372075	.083839	.060733
4	.05055	.3229582	.073531	.051364
5	.047843	.302199	.071299	.055271
6	.046065	.279688	.073085	.077002
7	.045869	.276932	.073776	.076869
8	.043637	.263801	.070636	.075464
9	.043112	.262733	.07101	.074462
10	.042823	.260973	.070276	.07767
...	...	...	...	...
16	.042583	.2584	.068534	.07874

Table 47: Variance decomposition, risk taking channel

Lags	dUNRATE		Infl		INDPROperc	
	dDGS10	dBAA	dDGS10	dBAA	dDGS10	dBAA
0	0	0	0	0	0	0
1	0	0	0	0	.000376	.037935
2	.011581	.014477	.003658	.0002	.000204	.005823
3	.015171	.021392	.017052	.025963	.001164	.007773
4	.016182	.024925	.017998	.020927	.010362	.009329
5	.017307	.024575	.039158	.018373	.014504	.014406
6	.025305	.025582	.047192	.016022	.01665	.014077
7	.024844	.025196	.04882	.014914	.029417	.013379
8	.024543	.024424	.044862	.016579	.028872	.013769
9	.024266	.024052	.041774	.018569	.028403	.013497
10	.024282	.024159	.039773	.017639	.027871	.013272
...	...	...	...	...	...	...
16	.024019	.024902	.035636	.020851	.028327	.014422

Table 48: Variance decomposition, portfolio rebalance channel to real economy

Lags	dUNRATE		Infl		INDPROperc	
	dTB3MS	dT10YIE	dTB3MS	dT10YIE	dTB3MS	dT10YIE
0	0	0	0	0	0	0
1	0	0	0	0	.000376	.037935
2	.000042	.000421	.001561	.049145	.007942	.000489
3	.011937	.000399	.013779	.035839	.005081	.012981
4	.038799	.005437	.039404	.03179	.031416	.019032
5	.051056	.005698	.056919	.026645	.069937	.017847
6	.054128	.007406	.063991	.02481	.097233	.019103
7	.05622	.009104	.060593	.026295	.10205	.023117
8	.056537	.011859	.055334	.02465	.100447	.026303
9	.056746	.011721	.052594	.023279	.097658	.031443
10	.055877	.01155	.05039	.023107	.096185	.030856
...	...	...	...	...	...	...
16	.054905	.013486	.046158	.025388	.097643	.031327

Table 49: Variance decomposition, signalling channel to real economy

Lags	dUNRATE		Infl		INDPROperc	
	dHOUST	dBCR	dHOUST	dBCR	dHOUST	dBCR
0	0	0	0	0	0	0
1	0	0	0	0	.089387	.018157
2	.001995	.062632	.006618	.000464	.023709	.009574
3	.005953	.064299	.044102	.061615	.011436	.060045
4	.008275	.068795	.037127	.063258	.017052	.057583
5	.008019	.066975	.03401	.051863	.017889	.046418
6	.021439	.066027	.045306	.044085	.018862	.04796
7	.027495	.067271	.060192	.045901	.049974	.048063
8	.032069	.065321	.063369	.047218	.063689	.046949
9	.035919	.068234	.069376	.055761	.071481	.045648
10	.038141	.069065	.073633	.063373	.07339	.049213
...	...	...	...	...	...	...
16	.041367	.069656	.087438	.069949	.073064	.050946

Table 50: Variance decomposition, bank lending channel to real economy

Lags	dUNRATE		Infl		INDPROperc	
	dHHNW	dNFBNW	dHHNW	dNFBNW	dHHNW	dNFBNW
0	0	0	0	0	0	0
1	0	0	0	0	.027328	0
2	.123235	.037124	.027088	.024201	.004618	.000351
3	.174909	.030478	.02032	.023255	.075576	.034575
4	.174827	.053992	.053334	.026623	.135157	.026963
5	.170681	.05294	.076831	.023763	.155136	.058226
6	.17514	.051514	.089227	.022547	.146887	.056322
7	.172666	.050591	.109749	.020759	.150889	.049658
8	.170432	.049293	.110309	.024984	.146174	.048968
9	.16763	.048848	.108527	.024235	.144343	.048346
10	.170078	.048155	.113422	.022937	.141499	.048735
...	...	...	...	...	...	...
16	.168221	.047762	.113712	.02272	.140734	.048585

Table 51: Variance decomposition, balance sheet channel to real economy

Lags	dUNRATE		Infl		INDPROperc	
	dSTLFS13	dVIXCL	dSTLFS13	dVIXCL	dSTLFS13	dVIXCL
0	0	0	0	0	0	0
1	0	0	0	0	.011676	.010635
2	.072503	.073432	.03414	.03216	.001939	.001744
3	.062957	.073992	.023687	.026961	.059767	.073752
4	.070519	.0650342	.030568	.02156	.055795	.07815
5	.078286	.064272	.033391	.017653	.051783	.062984
6	.075242	.060044	.055791	.015072	.056416	.05921
7	.076216	.058846	.05814	.018374	.058554	.05232
8	.07789	.059792	.054531	.023384	.062879	.050343
9	.078964	.059079	.061235	.02211	.066668	.051238
10	.079455	.058182	.063763	.021373	.066661	.050197
...	...	...	...	...	...	...
16	.080549	.057556	.072352	.02264	.06672	.049417

Table 52: Variance decomposition, risk taking channel to real economy

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