The Effects of Quantitative Easing on the Swedish Economy

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Abstract

This paper estimates the macroeconomic effects of the quantitative easing (QE) policies, employed by the Riksbank during the years 2015-2017, on the Swedish economy. Using monthly data on various macroeconomic variables, we estimate a structural vector autoregressive (VAR) model, in order to study the effects of the QE on CPI, industrial production, interest rates and real equity prices. Additionally, we extend the baseline structural VAR model in order to explore some of the possible transmission channels through which the QE policies might have impacted the economy. The results from the baseline structural VAR model suggest that industrial production increases by approximately 0.25 percent and CPI by roughly 0.11 percent, following an asset purchase announcement shock of one standard deviation. We find no statistically significant results for the interest rates or real equity price estimations. Furthermore, we find no statistically significant evidence supporting either of the transmission channels examined. This paper therefore contributes to the understanding of QE generally, and more specifically, to the impacts of QE on the Swedish economy.

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The size of the standard deviations is equal to 0.0248 and 0.0038 respectively.
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1. Introduction

Following the financial crisis in 2008, policymakers aggressively cut interest rates towards the zero-lower bound (ZLB)\(^3\) in order to stimulate the economies, while simultaneously engaging in other types of stimulative fiscal policies. In the presence of the ZLB, the effects of conventional monetary policy such as interest rate cutting, quickly diminish. As the crisis continued, both the Federal Reserve (Fed) and the Bank of England (BoE) decided to employ more expansionary unconventional monetary policy. These decisions took the form of various stimulative measures, including large-scale asset purchases of government bonds in early 2009, in an attempt to combat the crisis (Fisher, 2009; Labonte, 2014). The European Central Bank (ECB) and the Riksbank abstained from these types of unconventional asset purchase programs at first. However, in late 2014, the ECB announced that they would introduce a quantitative easing (QE) program, in order to stimulate the economy and push the inflation upwards (ECB, 2015). Shortly thereafter, in February 2015, the Riksbank announced a similar program that included purchases of government bonds to a value of ten billion SEK, with the same goals as the program announced by the ECB (Sveriges Riksbank, 2015a). Additionally, the Riksbank announced that they were prepared to do more at short notice, given that the effect of the initial purchase program would turn out to be inadequate.

Previous research regarding the effects of QE have mostly been conducted on asset purchase policies employed by the US, the UK, and Japan. Most of these studies have focused on estimating the effects of QE on a single part of the economy, such as the financial markets or the interest rate markets. Kapetanios, Mumtaz, Stevens and Theodoridis (2012) examined how the QE employed by the BoE affected the long-term government bond yields, GDP and CPI in the UK. Krishnamurthy and Vissing-Jorgensen (2011) studied what effects the large-scale purchases of government bonds and securities had on the interest rates in the US. They also analyzed through which transmission channels the interest rates were affected. Joyce, Lasaosa, Stevens, and Tong (2011) studied the effects of QE on asset prices in the UK. The effects were estimated through various asset price transmission channels, using several methods, including

\(^3\) The zero-lower bound is the point where the nominal interest rates hit the zero mark (0 percent), making conventional monetary policy such as cutting interest rates less effective (Joyce, Miles, Scott & Vayanos, 2012). This is because agents can effectively limit the effect of interest rates cuts below zero, since they always can hold non-interest-bearing cash. This means that there is also a lower limit to how much central banks can lower the rates before it is no longer possible to further cut the rate.
an event study and a vector autoregression (VAR) model. Schenkelberg and Watzka (2013) estimated the effects of QE on the Japanese economy, when facing the ZLB. Weale and Wieladek (2016) studied the effects of large-scale asset purchases on real GDP and the CPI in the UK and the US, using a Bayesian VAR model.

Studies conducted on Sweden regarding QE are scarce. However, De Rezende, Kjellberg and Tysklind (2015) studied the effects of the QE programs employed by the Riksbank and what effects it had on the Swedish financial markets. Knezevic, Nordström and Österholm (2019) examined the relationship between municipal and government bond yields during the time when the Riksbank employed asset purchase programs.

The purpose of this study is therefore to assess the economy-wide effects of the QE policies, which were employed by the Riksbank during the years 2015-2017. This is done by estimating the effects of the asset purchases on the following macroeconomic variables: interest rates, equity prices, CPI and industrial production. Additionally, we explore some of the possible transmission channels through which the QE policies might have impacted the economy.

To estimate the effects of the Riksbank’s asset purchases on the macroeconomic variables, the study incorporates a structural VAR model with a recursive identification similar to the first identification used by Weale and Wieladek (2016). The exception is that we are using industrial production as a measure of economic activity instead of GDP, since monthly data for GDP is unavailable for Sweden. Compared to most previous literature, this study includes a larger amount of observations, as the time period ranges from 2009-2019 and monthly data is used.

The main contribution of this study is to provide evidence from Sweden to the debate regarding how QE affects the economy, in the presence of ZLB. The results of this study could possibly be used as an indication of how similar future policies might affect Sweden or an economy similar to Sweden. The results could therefore be used as a tool of guidance in the decision-making process of policymakers that contemplates the use of QE, when facing interest rates at the ZLB.

The remainder of this paper is structured as follows. Section 2 explains the background of QE policies employed by central banks. Section 3 goes through the theoretical background supporting QE and section 4 reviews previous literature in the research area. Section 5 presents
the data being used, while section 6 presents the methodology and the econometric model. Section 7 presents the results of the study and a discussion relative to prior literature, along with a sensitivity analysis and robustness checks of the baseline results. Section 7 is followed by Section 8, which concludes the paper.

2. Actions Taken by Central Banks

2.1 The Bank of Japan
A central bank that has employed the use of an unconventional monetary policy is the Bank of Japan (BoJ) (Joyce et al., 2012). The QE-policies utilized by the BoJ were initially employed in the end of the twentieth century following the burst of the real estate bubble in Japan. In an attempt to provide more liquidity to the banks in Japan, they purchased government securities held by the banks. By purchasing these government securities, the BoJ intended to increase the cash reserves held by the banks in an attempt to increase lending in Japan, leading to increased asset prices and suppression of deflationary pressure.

2.2 The Federal Reserve
Following the financial crisis, the Fed started to buy mortgage-backed securities (MBS) (Joyce et al., 2012). By these asset purchases, the Fed was able to lower the interest rates on mortgages as well as providing additional credit lines to a distressed housing market.

By the end of 2008 the Fed announced large-scale asset purchases (Labonte, 2014). These asset purchases amounted to 500 billion dollars’ worth of MBS and 100 billion dollars’ worth of U.S. agency debt. The month following these announcements the Fed also declared a cut in the federal funds rate. By the beginning of 2009 the Fed announced new large-scale asset purchases. Combined with the announcement declared in 2008 they announced that U.S. Treasury securities, U.S. agency debt and MBS would be purchased. At the same time, they also announced that the federal funds rate would be maintained at the new lower level. The announcement of purchases of U.S. Treasury securities and agency debt amounted to a total of 500 billion dollars and the announcement of MBS purchases amounted to 1.25 trillion dollars. These purchases were going to be executed in the following months.

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4 Added together, these two asset purchases represented approximately 4.2 percent of US 2008 nominal GDP. The US nominal GDP for year 2008 amounted to 14.449 trillion dollars (The World Bank, 2020).
By the end of 2010 the Fed launched what is known as QE2. By this time, they declared new large-scale asset purchases. However, this announcement only included purchases of U.S. Treasury securities (Labonte, 2014). This announcement amounted to a total of 600 billion dollars and the securities were going to be bought in the near future months. In late 2011 the Fed launched Operation Twist. The purpose of Operation Twist was to buy long-term U.S. Treasury securities and at the same time sell short-term U.S. Treasury securities for the same amount. The total amount of long-term U.S. Treasury securities that were announced to be bought amounted to 400 billion dollars. Operation Twist was declared to be ongoing for nine months.

During the autumn of 2012 the Fed declared purchases of agency MBS of 40 billion dollars each month for an indefinite time period (Labonte, 2014). This announcement is known as QE3. However, by the end of 2013 the Fed declared that a process to reduce security purchases would begin.

2.3 The Bank of England

In the UK the BoE also proceeded with asset purchases following the financial crisis (Joyce, et al., 2012). When proceeding with the asset purchases, they chose to purchase government bonds from the private sector, excluding the ones held by banks. Similar to the US, the purpose of the BoE asset purchases was an attempt to impact asset prices and asset yields, in order to stimulate the economy.

By the beginning of 2010, the BoE had invested a total amount of 200 billion pounds in bonds in the UK economy (Joyce et al., 2011). Between 2008 and 2009 they also reduced the Bank Rate from five percent to 0.5 percent. As the BoE launched their initial QE program, they announced that both assets from the private and public sector would be bought. The main purpose of buying assets from the private sector was providing liquidity, as it would increase the private sector spending. Because of this, the expectation was that as the nominal private sector spending would increase, the UK would reach the inflation target level of two percent.

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5 The purchases of 200 billion pounds represented roughly 13 percent of the UK 2009 nominal GDP. The UK nominal GDP for year 2009 amounted to 1.548 trillion pounds (FRED, 2020).
In the beginning of 2009, the BoE launched The Bank of England Asset Purchase Facility Fund, which served as a subsidiary to the BoE, and was designed to focus on asset purchases (Joyce et al., 2011). However, even though the outspoken objective was to purchase assets from both the private and public sector, it was thought that most resources would be used buying gilts. This turned out to be true, since of the 200 billion pounds spent by the beginning of 2010, 198 billion had been spent on gilts.

2.4 The European Central Bank

During the year of 2014 the ECB declared an asset purchase program (ECB, 2020). This asset purchase program was divided into four different programs, where most investments were made between the years of 2014 and 2018. However, the investments resurfaced during the end of 2019. The program had, in March 2020, amounted to a total of 2,783 billion euros. The investments made in the program have been divided between corporate bonds, public sector securities, asset-backed securities and covered bonds.

During mid 2016, the ECB started to invest in the corporate sector purchase programme (CSPP) (ECB, 2020). However, the public sector purchase programme (PSPP) is the program in which the ECB has invested the largest amount in during the time of their asset purchase programs. As of early 2020, the ECB had invested a total amount, of 2,180,882 million euros in their PSPP, and 206,359 million euros in the CSPP.

Relative to the other still active programs, the asset-backed securities purchase programme (ABSPP) is one of the smallest programs (ECB, 2020). In the beginning of 2020, the total amount invested in the ABSPP amounted to 31,589 million euros. Of the programs still active, the covered bond purchase programme 3 (CBPP3) is the program in which the ECB has invested second most in (ECB, 2020). The total sum invested in this program as of early 2020 amounted to 277,937 million euros.

In the beginning of 2019, the ECB started to reinvest the interest rates earned on the active programs and by the end of 2019 the ECB made new net purchases in all of the active programs.

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6 Gilts are government bonds, equivalent to treasury bonds in other countries, issued by the UK government and listed on the London stock exchange (United Kingdom Debt Management Office, 2020).
2.5 The Riksbank

Following the path of other central banks after the financial crisis, the Riksbank decided in 2014 that the Swedish repo rate would be cut to zero (De Rezende, Kjellberg & Tysklind, 2015). They also announced that except cutting the repo rate, other measures could be used to reach a more expansionary monetary policy. At this point in time, the Riksbank had scarce empirical evidence of the effects of negative policy rates. Because of this, other measures could be used as a supplement to the repo rate cuts. One of the measures used was buying government bonds, similar to the previously mentioned central banks. In February 2015 the first announcement that the Riksbank was going to buy government bonds was presented.

During the time period between 2015 and 2017 the Riksbank made eight asset purchase announcements. The size of these announcements ranged between 10 billion SEK and 65 billion SEK. Associated with these asset purchase announcements, the Riksbank also declared several cuts in the repo rate. Figure 1 shows the asset purchases made by the Riksbank, accumulated over time.

**Figure 1. Cumulative Asset Purchase Announcements.**

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Note: This figure shows the cumulative asset purchase announcements made by the Riksbank. Expressed in billion SEK. Horizontal axis represents time in years. The time period starts at 2009 and ends in 2019.
Source: Sveriges Riksbank.

7 The asset purchase of 65 billion SEK represented approximately 1.45 percent of Sweden 2015 GDP. The nominal GDP for Sweden in 2015 amounted to roughly 4500 billion SEK (Bloomberg, 2020).

8 Table 1A in Appendix A shows a compilation of the asset purchase announcements declared by the Riksbank and the cuts in the repo rate.
According to the Riksbank, the inflation in February 2015 was too low and there were concerns it would not reach the target level without expansionary measures (Sveriges Riksbank, 2015a). They therefore decided to cut the repo rate to negative (-0.10 percent) and at the same time declare a government bond purchase of 10 billion SEK. These actions were taken since the Riksbank had concerns regarding price setting and the development of wages which both are affected by the inflation. A more expansionary monetary policy could therefore help driving up the underlying inflation.

Since the declaration of the asset purchase and cut in the repo rate in February, the Riksbank had noticed that inflation was on upturn (Sveriges Riksbank, 2015b). However, as the SEK had appreciated there was also a risk that the rise in inflation might stop. Therefore, in March 2015 the Riksbank declared a new cut in the repo rate. This time the Riksbank decided to cut the repo rate by 0.15 percentage points and therefore maintained a negative repo rate (-0.25 percent). At the same time a new purchase of government bonds amounting to 30 billion SEK was declared.

Evidence from the previous asset purchase announcements and the cuts of the repo rate indicated that these unconventional monetary measures affected the Swedish economy positive (Sveriges Riksbank, 2015c). There was also evidence that inflation had started to rise, and to keep this positive tendency, a third announcement was made in 2015. In this announcement, the Riksbank decided to declare an unspecified government bond purchase that would range between 40 to 50 billion SEK. They also announced that a negative repo rate of -0.25 percent would be kept.

During the summer of 2015 the inflation was still on upturn and the Swedish economy was still affected positively by the expansionary monetary policy (Sveriges Riksbank, 2015d). Despite this, there was uncertainty in other economies around the world and the SEK had appreciated further. The Riksbank therefore believed that an even more expansionary monetary policy was necessary to reach the target level inflation. Therefore, the fourth asset purchase announcement was declared. This asset purchase announcement amounted to 45 billion SEK. Additionally, a new cut in the repo rate was made, lowering the rate to -0.35 percent.

In late 2015, the Swedish economy was still on a positive trend and the inflation was on upturn (Sveriges Riksbank, 2015e). However, the uncertainty in other economies was still noticeable and to make sure there would be no interruption of the inflation upturn, more government bonds
would be bought. As the Riksbank expected a lower inflation in 2016 and 2017, they decided to announce government bond purchases of 65 billion SEK. Moreover, they decided to retain the repo rate at -0.35 percent.

In 2016 two additional asset purchase announcements were declared by the Riksbank. The first was made in April 2016 when they declared an asset purchase of 45 billion SEK (Sveriges Riksbank, 2016a). Even though the measures used by the Riksbank had contributed to a positive trend in the Swedish economy, the upturn in inflation was not steady and the uncertainty in other economies was still present. The assessment of the Riksbank was that the path of a more expansionary monetary policy had to continue.

In late 2016, the second asset purchase announcement of the year was made. This announcement amounted to 30 billion SEK and the Riksbank decided to leave the repo rate unchanged (Sveriges Riksbank, 2016b). The reason behind this announcement was that inflation and economic activity were still rising but there were threats against the upturn in inflation. Additionally, the inflation in December 2016 was lower than expected and therefore the Riksbank proceeded with a more expansionary monetary policy.

In 2017 the last asset purchase announcement was made. Once again, the repo rate was left unchanged and the asset purchase announcement amounted to 15 billion SEK (Sveriges Riksbank, 2017). The Swedish economy was still on a positive trend but the Riksbank had its doubt about the upturn in inflation, and the belief was that it might take longer before it would hit the target level. Therefore, the Riksbank announced the asset purchase of 15 billion SEK and also declared their believes that a rise in the repo rate would not be made until 2018.

3. Theoretical Background

During the financial crisis, the usage of short-term interest rates was the main tool of conventional monetary policy in order for central banks to reach the inflation target level (Joyce, Miles, Scott, & Vayanos, 2012). The results of this monetary policy tool on inflation and market rates was well documented and supported. Despite this, the conventional monetary policy tools used could not restrain the bursting of asset market bubbles. Therefore, the main question following the financial crisis was if current monetary policy would be enough to stimulate the economies. This turned out to be false, and conventional monetary policy failed. Because of this, central banks started to use unconventional monetary policy tools.
Using negative interest rates is one example of an unconventional monetary policy tool (Joyce et al., 2012). Expanding of central banks’ balance sheet is another example. Expanding the balance sheet of a central bank can be done by asset purchases, which can be both government bonds and private sector bonds. These purchases are one way of providing the economy with liquidity through shifting the composition of asset-portfolios held by the private sector.

As QE is a rather new phenomenon, especially empirically, there is still debate whether it is effective or not (Joyce et al., 2012). Previous studies such as Eggertsson and Woodford (2003) argues that QE should be ineffective since asset purchases should, in theory, be neutral. This is based on the assumption of a single representative individual who face no credit restrictions, is rational and has an infinite time-horizon. This individual makes no difference between government assets, assets held by the central banks and his/her own private assets. These assumptions are clearly strong ones and could be questioned, especially in a financial crisis where markets are not operating optimally. Moreover, these assumptions might not hold when considering market frictions such as credit constraints and distortionary taxes, or when considering the fact that agents have different preferences for government bonds. Another paper written by Curdia and Woodford (2011), claims that QE should be ineffective even without these assumptions. The model used in their paper incorporates the idea that government bonds is paying a rate identical to the central bank repo rate, which also is the same rate paid on bank reserves. In addition, they state that, in this scenario, reserves and government bonds should be viewed as perfect substitutes. Furthermore, they argue that for QE to be effective, portfolio changes for investors need to matter, meaning government bonds and reserves cannot be perfect substitutes. Having gone over some of the arguments against QE, we now turn to the other side, the possible transmission mechanisms that could make QE an effective tool for central banks.

3.1 Transmission Channels

The purpose of buying government bonds and cutting the repo rate in Sweden was an attempt to steer the inflation towards the target level decided by the Riksbank, which is stated to be two percent (Alsterlind, Erikson, Sandström & Vestin, 2015). It was also an attempt to steer the expectations of inflation in line with the target level. By cutting the repo rate, the expectation is that salaries and demand will rise through different mechanisms resulting in higher prices, and hence the inflation will rise. The decision to cut the repo rate could also lead to increased
exports and decreased imports. An increase in exports could be beneficial for Sweden since the Swedish economy is dependent on exports for economic growth, employment and wealth (Government Offices of Sweden, 2015). However, individuals and firms are not affected directly by the cut in the repo rate (Alsterlind et al., 2015). Instead they are affected by the interest rates they are facing, which are affected by the repo rate. As the repo rate moves towards the ZLB, other measures such as buying government bonds or issuing loans may be used.

3.1.1 Portfolio balance channel
There are several channels through which QE can impact the economy. The most natural and the most commonly used transmission channel in previous literature is the portfolio balance channel (Joyce et al., 2012). The working of this channel relies on the fact that assets are imperfect substitutes. This means that central banks can, by varying the relative supply of financial assets, affect the yields of these assets. This also leads to an influence on real investment decisions, since yields differ. Greater effects on real investment decisions will lead to more actions being made by investors, which can lead to greater impact on other market rates (Alsterlind et al., 2015). The actions taken by investors is to rebalance their portfolios by buying additional assets, since the asset purchases of the central bank increases the amount of money held by the sellers of the assets. This leads to lower yields and higher asset prices, which is stimulative for households and firms, since it lowers borrowing costs (Joyce, Tong & Woods, 2011). Higher asset prices also stimulate spending additionally, as net wealth of asset holders increases. Moreover, this channel works when monetary policy successfully influences long-term bond rates through a rate cut (Alsterlind et al., 2015). However, the effect primarily impacts through the premium, not the expected future repo rate. For this channel to be effective, investors need to have different preferences for their portfolio, i.e. there needs to be heterogeneity across individuals.

An example of how QE could be effective through the portfolio balance channel is given by examining the model of Kiyotaki and Moore (2019). In their model, financial assets have different levels of liquidity, meaning that investors can only finance a limited amount through issuing of equity. This means that they hold some amount of liquid assets in order to invest, should an attractive opportunity appear. The model also makes the assumption that a liquidity shock causes the relative share of good investment projects to drop, since issuing equity becomes tougher. In this case, central banks can ease the effect of a liquidity shock by
purchasing less liquid asset with newly printed money, and therefore change the relative stock of assets with different characteristics.

3.1.2 Signaling channel
Central banks can also influence the economy through signaling of future economic decisions. For example, the Riksbank can signal to the market that interest rates will remain low for a foreseeable future (Alsterlind et al., 2015). By purchasing government bonds when interest rates are facing the ZLB, the Riksbank can create a credible path of low interest rates. This is credible since a quick rise in rates would mean that the Riksbank would suffer losses on issued bonds that have not yet reached maturity.

This channel impacts all interest rates on the bond market, since the rates set by the central bank affects all market rates (Krishnamurthy & Vissing-Jorgensen, 2011). This also means that the central bank can, through policy announcements, portray the state of the underlying economy going forward, which can boost spending and inflation (Joyce, Tong & Woods, 2011). The signaling channels working therefore relies on what the market expects relative to the central bank’s own view of future monetary policy (Alsterlind et al., 2015).

3.1.3 Liquidity channel
A third channel QE might impact the economy through is the liquidity channel. This channel works through the increase of liquidity to commercial banks provided by the central bank, when asset purchases are made (Alsterlind et al., 2015). The purchases increase the amount of central bank money in the banking system, which also decreases the risk of a single bank having a deficit compared to other banks. Additionally, by increasing the liquidity of investors, the liquidity price premium on treasury bonds will decline. This comes as a result of the liquidity flowing to the bonds. As the liquidity price premium on the treasury bonds decline, the yields of these bonds increase, since prices decline (Krishnamurthy & Vissing-Jorgensen, 2011). This effect is therefore impacting the economy because of the fact that the Riksbank is paying for the bonds, which provides the economy with liquidity, which lowers the liquidity premiums.

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9 The liquidity premium is the premium associated with the liquidity risk of assets (Damodaran, 2006). Lower liquidity results in higher asset prices, while increased liquidity results in a decline in asset prices, as the liquidity price premium decline.

10 Christensen and Gillan (2019) argues that QE programs that target government bonds is similar to a persistent buyer with large financial muscles, this will affect the liquidity price premiums for the targeted bonds. As investors are rational, they can use the strategy of bidding in the QE auctions and selling the targeted securities, if faced with unfavorable prices in the open market. Therefore, Christensen and Gillan states that when the bargaining power tilts towards the sellers, all participants are willing to accept lower liquidity premia.
(Alsterlind et al., 2015). The downside with this channel is that it only persists while the central bank is actively conducting asset purchases (Joyce, Tong & Woods, 2011).

3.1.4 Expectations management channel

Additionally, asset purchases might impact the economy by reducing the uncertainty among households and individuals. Deaton (1992) showed how consumption is negatively affected when uncertainty among individuals is present. Dixit and Pindyck (1994) showed that investments decline when investors are faced with uncertainty. According to Joyce, Tong and Woods (2011), this channel works beyond the effects of higher asset prices, contrary to the earlier described transmission channels. As an example, an improved economic outlook might lead to an increase in consumer confidence, which can boost individual’s willingness to spend. This channel might, however, also contribute to higher asset prices, as an increase in consumer confidence can reduce the risk premia of assets (Joyce, Tong & Woods, 2011).

4. Previous Studies

There are several studies which have examined the subject of QE. However, most of the previous literature examine the effects of QE in the US, Japan and the UK.

Following the financial crisis in 2008-2009, Weale and Wieladek (2016) examined how QE affected the real GDP and inflation in the US and the UK. By using a Bayesian VAR, the effects of government bond purchases by the Fed and the BoE were estimated. Additionally, they examined through which channels these effects emerged by using four different identification schemes. The effects of QE were estimated using monthly data from March 2009 until May 2014 on variables such as real GDP, consumer price indices, real equity prices, asset purchase announcements, governments bonds, long- and short-term interest rates, a stock market volatility index and household uncertainty. Their results suggested that an asset purchase shock resulted in an increase in the real GDP and the inflation for both the UK and the US. Putting these results into figures, a shock that represented an asset purchase of one percent of the respective country nominal GDP resulted in an increase of 0.58 percent in real GDP and 0.62 percent of inflation in the US. The corresponding figures in the UK were an increase of 0.25 percent in real GDP and 0.32 percent in inflation. Given these results, Weale and Wieladek concluded that the QE used by both the US and the UK were important actions taken by the central banks following the financial crisis.
Schenkelberg and Watzka (2013) examined how QE affected the Japanese economy when the nominal short-term interest rates were near the ZLB. In order to estimate how the effects of QE by the BoJ have affected the Japanese economy, a structural VAR with sign restrictions was used. Schenkelberg and Watzka used monthly data and their sample stretches all the way back to March 1995 to September 2010. The authors used variables such as inflation, bank reserves, the yield of ten-year Japanese government bonds and the real exchange rate of the yen. However, instead of using GDP as one of the variables in their study, an industrial production index was used. The results from this study showed that the effects of QE from the BoJ increased the industrial production. Schenkelberg and Watzka also pointed out that there is a slight delay of the effects from QE. Their results suggested that two years after a QE-shock, the industrial production in Japan increased about 0.4 percent. The QE-shocks also had an effect on the inflation, even though this effect was lower. Schenkelberg and Watzka concluded that using QE could help stimulating the real economy and therefore their results could be important for other countries facing ZLB as well.

Joyce et al. (2011) estimated the effects of QE on asset prices in the UK. The effects on asset prices were estimated by studying asset price channels such as the portfolio balance channel and the liquidity channel. The effects of QE performed by BoE on these channels were explored by using various methods including event-study methods. Similar to other studies regarding QE, Joyce et al. also used a VAR model. The sample period for their VAR analysis ranged from December 1990 to June 2007, and the sample consisted of data on asset purchase announcements, government bond yields, government bond spreads, a proxy for market expectations, nominal GDP, consumer price index and overnight index swaps. Joyce et al. found that medium- and long-term government bond yields were approximately 100 basis points lower than they would have been following a QE purchase, based on market reactions. The authors suggested that this effect presents itself through the portfolio balance channel. Overall, the analysis showed that the asset purchases have had a significant effect on financial markets, and specifically on government bond yields. Moreover, the authors stated that the effectiveness of large-scale asset purchases will be determined by their effect on the macroeconomy as a whole, and many of those impacts are still uncertain.

Krishnamurthy and Vissing-Jørgensen (2011) examined how the Fed’s purchase of government securities and long-term bonds affected the interest rates in the US for the time period of 2008-2009 and 2010-2011. To assess the effect of QE on the interest rates in the US,
Krishnamurthy and Vissing-Jorgensen used an event-study to examine through which channels QE might affect the interest rates. The effect on interest rates was examined through various transmission channels. Their article contained data on Treasury yields, corporate yields, credit default swaps, inflation swaps, implied interest rate volatility, agency yields and agency MBS yields. Given the results, Krishnamurthy and Vissing-Jorgensen argued that nominal interest rates on treasuries, agencies, corporate bonds and MBS was reduced because of the QE performed by the Fed. However, there were differences in the reduction of the nominal interest rates among the securities and between the time periods.

Kapetanios et al. (2012) studied the impacts of the initial QE employed by the BoE, on macroeconomic variables. In order to estimate the impact, the authors used three different VAR models: a large Bayesian VAR, a change-point structural VAR and a time-varying VAR. In contrast to other studies, Kapetanios et al. identified monetary policy effects as a decrease in the spread between the long- and the short-term rate. They showed empirical evidence which suggested that the asset purchases had lowered the long-term government bond yields by around 100 basis points. Furthermore, the estimations of the models showed that the impacts of QE had a peak effect of 1.5 percent on real GDP and a maximum effect of 1.25 percentage points on annual CPI inflation. Additionally, they stated that the obtained results were subject to uncertainty, as results varied significantly across the various models.

De Rezende, Kjellberg and Tysklind (2015) examined how purchases of government bonds by the Riksbank affected Swedish financial markets. Given the results from the expansionary monetary policy measures used by other central banks, the announcements were expected to have a significant impact on market rates. As several government bond purchases were announced in 2015, two of the largest ones were expected to give the best measures of the effects. These announcements were those made in March 2015 and July 2015. De Rezende, Kjellberg and Tysklind found that as a consequence of three of the announcements in 2015 the government bond yields dropped. According to the authors, the drop in government bond yields was affected not only by the asset purchase announcements but also by the cut in the repo rate. Another consequence of the expansionary monetary policies was that the SEK did not become too strong relative to the euro which, according to the authors, was important in the attempt to reach the inflation target level. Additionally, the authors demonstrated that both mortgage and corporate bond yields dropped, as with the government bond yields. The evidence from this
study showed that because of the monetary policies used by the Riksbank, the expectations of inflation were stabilized.

Knezevic, Nordström and Österholm (2019) studied the relationship between the five-year Swedish municipal bond yield and the related government bond yield during the time when the Riksbank employed their asset purchase programs. The authors used a traditional event study combined with a VAR approach. The event study aimed to study the short run effects and was conducted by analyzing the event window following the asset purchase announcements made by the Riksbank. The bivariate VAR models were used in order to examine the dynamic relationship between the yields. The results from the event study suggested that the short run effect of the asset purchase announcements contributed to 40-50 basis points decline for the government bond yields and 30-35 basis points decline for the municipal bonds. The VAR analysis suggested that a shock to government bond yields initially caused a rise in the spread between the two yields, but reversed after approximately four weeks, causing the spread to be lower than observed initially.

5. Data

The data sample used in this thesis contains monthly data ranging between 2009-2019 on various macroeconomic variables. The reason behind choosing a longer time period than the actual asset purchase announcements is that it provides the opportunity to analyze the effect of the purchases for a longer period afterwards. Additionally, it adds a large amount of observations, which is positive for the statistical inference of the study. The variables included is data from Sweden on consumer price index (CPI), long- and short-term interest rates, a consumer confidence indicator index (CCI), an industrial production index, the Swedish government budget balance, ECB balance sheet data, nominal euro area GDP, oil prices and prices of the Swedish equity index OMXS30. Additionally, data on the Riksbank asset purchase announcements and Swedish annualized nominal GDP for each respective quarter of the announcements have been collected.

The industrial production index includes data from the standard industrial sectors included by the Statistics Sweden, the mining-, quarrying- and manufacturing industries, which has been collected from the Statistics Sweden. The data including the industrial production is collected

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11 A brief summary of the data is available in Appendix B.
in fixed prices, calendar adjusted and is seasonally adjusted. When used in the models, this variable has been transformed to be expressed in natural logarithm.

The equity prices of OMXS30\textsuperscript{12} have been collected from Nasdaq. This data consists of the daily average closing prices of the index, which is then calculated as an average monthly closing price for each month of the studied period. This data has been transformed to be expressed in real terms, which was done by dividing the equity prices with the CPI. The real equity prices have also been transformed to be expressed in natural logarithm. The data regarding the inflation is the CPI, which has been collected from Statistics Sweden. Moreover, the CPI data has been transformed to be expressed in natural logarithm. The asset purchase announcements have been collected from the Riksbank, where both the dates of the announcements and the purchase amount of the asset purchases have been collected. The asset purchases have been divided by annualized nominal GDP for each respective quarter of the announcements, in order to obtain the purchases as a fraction of the current GDP, at the time of the announcement. When used in the model, this data is presented as accumulated over time, as previously shown in Figure 1.

The short-term interest rates used are the fixed three-month Stibor\textsuperscript{13} and the six-month Stibor. These interest rates have been collected from the Riksbank at their monthly yields which then have been calculated as an average of the daily yields. The long-term interest rates are the Swedish five-, ten- and 20-year government bond yields. As with the short-term interest rates, the yield of the five- and the ten-year government bond yields have also been collected from the Riksbank and is calculated as the monthly average of the daily yields. The 20-year government bond yields have been collected from Bloomberg, which provided the monthly yields. However, the data including the 20-year government bond yields have two missing values, the first and the second month of 2009.

The CCI has provided by Statistics Sweden. The CCI is based on survey questions asked to individuals living in Sweden. The survey questions include among other, the individual’s beliefs about their private economy and Sweden's economy today and for the coming twelve

\textsuperscript{12} The OMXS30 is an index containing the 30 most frequently traded stocks on the Swedish stock market (Nasdaq, 2020).

\textsuperscript{13} Stibor is the Stockholm Interbank Offered Rate, which represents the average rate offered by Swedish banks to each other without requiring collateral (Sveriges Riksbank, 2020).
months. When used in the model, this variable has been transformed to be expressed in natural logarithm.

To test for omitted variables in the model and to check for robustness of the results, data for three control variables has been collected. Bloomberg provided an index of monthly figures of the Swedish government budget balance, which has been transformed to be expressed as a fraction of the annualized Swedish quarterly nominal GDP. Additionally, monthly data on the ECB total assets has been collected from FRED. This data has been transformed to be expressed as a fraction of the nominal euro area GDP. Data on the nominal prices of Brent crude oil has been taken from Bloomberg. These prices have been divided by the Swedish CPI to obtain prices in real terms.

Lastly, data on the nominal euro area GDP and the nominal Swedish GDP, used when expressing asset purchase announcements, the Swedish government budget balance and ECB total assets as fractions, have been provided by ECB and Statistics Sweden.

Time series plots of the variables are summarized in Figure 2.\textsuperscript{14}

\textsuperscript{14} Descriptive data of the variables are available in Appendix C.
Figure 2. Time series plot.

Note: This figure shows a time series plot of all used variables except the asset purchase announcements, since a figure of the announcements is provided in section 2.5. The time series starts at 2009 and ends in 2019. The data for the 20-year bond yields has missing values the two first months of 2009. Sources: Bloomberg, ECB, FRED, Nasdaq, SCB, Sveriges Riksbank and own calculations.

Figure 2 shows that time trends are present in several variables. CPI and the real equity prices seem to trend upwards, while the five-year, ten-year and 20-year bond yield, along with the Stibor rates show downward time trends. Apart from the obvious time trends, Figure 2 also clearly shows that the Swedish government budget balance display considerable patterns of seasonality. Unfortunately, we have not been able to retrieve seasonally adjusted data for this variable. However, as this variable acts as a control for changes in domestic fiscal policies, which could stimulate the Swedish economy, we decide to include it.

Additionally, we can observe that the two other control variables, ECB total assets and real oil prices, display considerable changes around year 2015. The increase in ECB total assets points to the fact that ECB initiated their asset purchase programs in 2014, which potentially also
could have stimulated the Swedish economy. Also, the oil prices declined during these years, which could stimulate the Swedish economy. A summary of studies who examined the effect of a decrease in oil prices has been conducted by the Riksbank (2015f). The majority of these papers clearly shows that a decline in oil prices leads to an increase in GDP. This motivates the inclusion of these two variables as control variables.

6. Empirical Model

To estimate the effect of QE on the Swedish macroeconomic variables, the following baseline VAR model will be used. The model is identical to the one used by Weale and Wieladek (2016), with the exception of using industrial production instead of real GDP. The reason for this is that monthly data for GDP is unavailable for Sweden. Industrial production is used instead, since this macroeconomic variable is commonly used as an indicator of economic activity (Schenkelberg & Watzka, 2013). Additionally, when estimating the model Weale and Wieladek (2016) used a Bayesian statistical method. However, our estimates rely on a standard structural VAR method, as the Bayesian method is out of the scope of this paper. The baseline results are estimated with the following equation:

\[
Y_t = a_c + \sum_{k=1}^{l} A_k Y_{t-k} + e_t, \ e_t \sim N(0, \Sigma)
\]

where \(Y_t\) is a vector of a set of endogenous variables, at time \(t\). The set consists of the following variables: the announcements of asset purchases\(^{15}\) divided by nominal GDP, CPI, industrial production, the yields of the Swedish 10-year government bond\(^{16}\) and real equity prices. The array of coefficients linked to the corresponding lagged vector for lag \(k\) is represented by \(A_k\). \(e_t\) is a vector of residuals, which is assumed to be normally distributed with \(\Sigma\), the variance-covariance matrix.

When estimating the baseline model, the variables used are expressed in levels. Additionally, following Weale and Wieladek (2016), CPI, industrial production and real equity prices are expressed in terms of natural logarithm. Using logarithms in economic models is common and there are several reasons for this (Mayr & Ulbricht, 2007). For example, the residuals of a log-

\(^{15}\) Following the line of reasoning expressed by De Rezende, Kjellberg & Tysklind (2015), we use the announcements of asset purchases instead of the actual purchases, as the effects on market prices occur when the new information is announced rather than when the actual purchases take place.

\(^{16}\) The ten-year government bond is presented as the “Long Rate” throughout the results.
model should more closely mimic a normal distribution, which could improve the accuracy of the estimations.

In addition to the use of the baseline model, which follows the methodology of Weale and Wieladek (2016), we also include two additional models. These models are extensions of the model used by Weale and Wieladek and serves as a sensitivity analysis to the baseline model.

The first model is the growth rate model, which is estimated with the same equation as the baseline model, equation 1. However, in this model, CPI, industrial production and real equity prices have been transformed to be expressed in terms of year percentage change. This is a common transformation in studies of economic variables. Moreover, in a more econometric sense, this can be done in order to account for non-stationarity in the variables. To test for stationarity in the baseline model variables, we performed an augmented Dickey-Fuller test. The results of this test showed that we could not reject the null hypothesis for any of the variables, meaning that the variables should be considered non-stationary. When including the first difference we could reject the null hypothesis for all variables in the baseline model except the CPI. Finally, including the second difference, we could reject the null hypothesis for the CPI as well. This motivates the use of year percentage change transformations, to account for non-stationarity in the variables.

As we discussed in data section, some of the variables used in the baseline model display patterns of time trends. To account for these trends, we include the trend model as the second additional model. The trend model is estimated with the same variables as the baseline model, while also including an exogenous trend variable, \( b_t \). The results including the trend variable are estimated with the following equation:

\[
Y_t = a + b_t + \sum_{k=1}^{L} A_k Y_{t-k} + \epsilon_t, \quad \epsilon_t \sim N(0, \Sigma)
\]

When constructing a structural VAR model, one important part to consider is the lag length of the model. There are several ways to do this, but one commonly used method is to use one or more information criteria which suggests what lag length should be used. Akaike Information

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17 The null hypothesis for the augmented Dickey-Fuller test is that the variable has a unit root. This means that if the null hypothesis cannot be rejected, we cannot rule out the possibility that the variable has a unit root. The variable should therefore be considered non-stationary.
Criterion (AIC), Hannan-Quinn (HQ) Information Criterion and Schwartz Bayesian Information Criterion (SC) are examples of information criteria that could be used. When defining the lag length of the baseline model and the trend model, the AIC and the HQ suggested lag lengths of two while the SC suggested lag lengths of one. When determining the lag length for the growth rate model, both the HQ and the SC suggested lags of one. According to Ouliaris, Pagan and Restrepo (2018) one should use the most parsimonious model, which in this case would be to use the models with one lag. Because of this, a lag length of one has been used in all three models.

6.1 Identification

As stated by Weale and Wieladek, “The challenge for structural VAR models is to disentangle orthogonal, structural economic shocks, $\varepsilon_{c,t}$, from the correlated reduced form shocks $\epsilon_{c,t}$.” (Weale & Wieladek, 2016, p 83). Therefore, the identification scheme used in this thesis replicates the first recursive identification used by Weale and Wieladek (2016).

The assumption of the identification scheme is that asset purchases do not react contemporaneously to interest rates or equity prices (Weale & Wieladek, 2016). Therefore, only industrial production and CPI are assigned before asset purchases. It is also assumed that these two variables react to the asset purchase announcements with a lag. As mentioned in the theory section, if market frictions such as imperfect substitutability or heterogeneity across investors are present, economic theory suggests that by reducing the term premia of bonds through the portfolio balance channel, the interest rates on long-term government bonds will fall (Joyce et al., 2012). However, even without these kinds of frictions, asset purchase announcements can reduce long-term interest rates by signaling that short-term rates will remain lower in the near future through the signaling channel. This will lead to a rise of real equity prices, since lower yields on long-term bonds will push some investors to invest in other, more risky assets (Weale & Wieladek, 2016). Therefore, the following identification scheme is used:
When estimating the effects of each of the transmission channels, additional variables will be added separately to the model as a sixth variable. Testing for the signaling and the portfolio balance channel will include short-term and long-term interest rates. These rates are added to the model identification alongside the already used long rate, as they can be expected to respond to an asset purchase shock in a similar way. When examining the portfolio balance channel, the five-year and the 20-year bond yields will be separately included in the model as a sixth variable. If there were an impact through the portfolio balance transmission channel, one would expect the term premia on long-term bonds to fall, resulting in a negative sign for the estimation (Weale & Wieladek, 2016). When examining the signaling channel, one would expect that short-term rates should face downward pressure as a consequence of the asset purchase announcement, as rates should be expected to remain lower for a longer time (Bauer and Rudebusch, 2014). This means that we expect this estimation to also carry a negative sign.

When studying the uncertainty channel, the CCI data will be included as a sixth variable and placed next to the real equity prices in the model identification. Both of these variables can be interpreted as indicators for the confidence regarding the future state of the economy and are therefore expected to react similarly. Reducing uncertainty of households through asset purchases should yield a positive estimation for the CCI variable, given that households expectations of future economic outlook have improved. Following the reasoning behind using variables in natural logarithmic form discussed in section 6, the CCI variable has also been transformed to be expressed in natural logarithm.

The asset purchase shocks estimated in our baseline model can also catch the effect of other stimulative measures, coinciding with the QE programs employed by the Riksbank. Examples
of such measures is changes to Swedish domestic fiscal policy, real oil prices changes and changes to the ECB monetary policy. As discussed in the data section, these measures can potentially stimulate the Swedish economy. Because of this, the following variables have been included as control variables. ECB total assets as a fraction of the euro area GDP, expressed in level, the Swedish government budget balance as a fraction of the Swedish GDP, expressed in level and real oil prices expressed in level and natural logarithm. These variables are then added to the baseline model separately, in various orders, to ensure the robustness of the baseline model estimates. The results of these estimations are presented in section 7.3

7. Results

7.1.1 Macroeconomic effects - baseline model

Figure 3 presents the impulse responses of the baseline model, to an asset purchase announcement shock with the size of one standard deviation. These estimations are based on the Cholesky decomposition scheme presented in the identification section.

*Figure 3. Macroeconomic impacts on the Swedish economy - baseline model.*

![Figure 3: Macroeconomic impacts on the Swedish economy - baseline model.](image)

Note: Impulse responses\(^{18}\) of the stated macroeconomic variables to an asset purchase announcement shock of one standard deviation.\(^{19}\) This estimation is done using the baseline model. Horizontal axis represents time in months. Sources: Nasdaq, SCB, Sveriges Riksbank, and own calculations.

\(^{18}\) The impulse responses are estimated over 80 months period, to allow for the responses to completely follow through.

\(^{19}\) The full impulse response for the baseline model is presented in Appendix D.
The results suggest that an asset purchase announcement shock should have a positive impact on both CPI and industrial production, and the effects are statistically significant during the peak impact period\textsuperscript{20}. Table 2 shows the maximum impact of the impulse response functions on the variables in the baseline model.

\textit{Table 2. Maximum impact of asset purchase announcement shock - baseline model.}\textsuperscript{21}

<table>
<thead>
<tr>
<th>Variable</th>
<th>Month</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPI</td>
<td>27</td>
<td>0.0011*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.00045)</td>
</tr>
<tr>
<td>Industrial Production</td>
<td>19</td>
<td>0.0025*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.00097)</td>
</tr>
<tr>
<td>Long Rate</td>
<td>1</td>
<td>-0.0002</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.00015)</td>
</tr>
<tr>
<td>Real Equity Prices</td>
<td>76</td>
<td>0.0024</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.00213)</td>
</tr>
</tbody>
</table>

Note: This table shows the maximum effects of an asset purchase announcement shock of one standard deviation on the stated variables, when estimating the baseline model. The numbers in the parentheses represents the standard deviation of the maximum impact at the peak impact month. The effect on CPI, industrial production and the real equity prices are measured in percent while the effect on the long rate is measured in percentage points. * indicates statistical significance at the 5 percent significance level at the peak impact.

Sources: Nasdaq, SCB, Sveriges Riksbank and own calculations.

The maximum impact of an asset purchase announcement shock on CPI is estimated to be approximately 0.11 percent, which occurs roughly after 27 months. The maximum impact of an asset purchase announcement shock on industrial production is estimated to approximately 0.25 percent. These results indicate that the QE employed by the Riksbank stimulated the economy through higher inflation and increased economic activity. Also, the results are in line with the results of Weale and Wieladek (2016). They showed that an asset purchase announcement shock of one percent of the respective country GDP had a positive impact on CPI and real GDP for both the US and the UK. They found an average increase of 0.62 percent for the US CPI and 0.58 percent for the US real GDP. The average increase in real GDP for the UK was 0.25 percent and 0.32 percent for the UK CPI. Kapetanios et al. (2012) found a positive effect of asset purchases on CPI inflation and real GDP in the UK. CPI inflation was quantified to a peak of 1.25 percentage points, while the impact on real GDP was estimated to peak around 1.5 percent. These impacts were estimated using a shock in terms of 100 basis points decrease in the yield spread between the ten-year government bond and the three-month treasury bill. Schenkelberg and Watzka (2013) found a positive initial impact on CPI and industrial

\textsuperscript{20} The sizes of the shocks in the baseline model are 0.0038 for CPI, 0.0238 for industrial production, 0.0017 for the long rate and 0.0032 for real equity prices.

\textsuperscript{21} The impacts have been rounded up/down to the nearest decimal.
production when studying the Japanese asset purchases. The impact on the Japanese CPI and industrial production was presented using a QE-shock that would raise reserves with approximately seven percent. Joyce, Tong & Woods (2011) found that a shock of 100 basis points on the ten-year gilt yield resulted in a maximum impact of 1.5 percent on real GDP and 0.75 percentage points on inflation in the UK.

These results are also in line with the theory discussed in the theory section. Considering impacts through some of the possible transmission channels such as the portfolio balance channel and the signaling channel, QE should stimulate the economy and push inflation higher. This would positively affect both industrial production and CPI.

Table 2 also shows the impact of the asset purchase shock on long-term bond yields. Here, the table shows that the asset purchases have had a statistically insignificant effect on the long rate. These results are contrary to previous literature such as Weale and Wieladek (2016), who found statistically significant declines in long-term rates for the US, following an asset purchase of one percent of the US 2009 GDP. Furthermore, De Rezende, Kjellberg and Tysklind (2015) and Knezevic, Nordström and Österholm (2019) both found declines in Swedish government bonds following the asset purchases conducted by the Riksbank. Additionally, Krishnamurthy and Visising Jorgensen (2011), Joyce, Tong and Woods (2011) and Joyce et al. (2011) found that US and UK bond yields declined following asset purchases. Finally, it is also contrary to Schenkelberg and Watzka (2013), who showed that long-term rates declined when asset purchases were conducted in Japan.

Lastly, Table 2 shows the effect of an asset purchase on real equity prices. However, as this effect is statistically insignificant, we treat it as a zero impact. This is also contrary to Weale and Wieladek (2016) who found statistically significant increases in real equity prices in both the UK and the US.

The results from the baseline estimates on the long rate and the real equity prices does not provide evidence of impact, following the asset purchases conducted by the Riksbank. However, considering that we find statistically significant increases in CPI and industrial production, one could still argue that the QE policies have been effective. This is because the main goal of the QE policies was to raise inflation and stimulate the economy (Sveriges Riksbank, 2015a).
7.1.2 Sensitivity analysis

In order to test the sensitivity of the results for the baseline model, two additional models have been estimated. Table 3 presents the maximum impacts for both of these models, along with the baseline model estimations as a comparison.

Table 3. Maximum impact of an asset purchase announcement shock – sensitivity analysis.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Growth rate model impact</th>
<th>Month</th>
<th>Trend model impact</th>
<th>Month</th>
<th>Baseline model impact</th>
<th>Month</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPI</td>
<td>0.0088* (0.00357)</td>
<td>19</td>
<td>0.0007 (0.00050)</td>
<td>24</td>
<td>0.0011* (0.00045)</td>
<td>27</td>
</tr>
<tr>
<td>Industrial Production</td>
<td>0.0389* (0.01890)</td>
<td>7</td>
<td>0.0041* (0.00129)</td>
<td>8</td>
<td>0.0025* (0.00097)</td>
<td>19</td>
</tr>
<tr>
<td>Long Rate</td>
<td>-0.0003* (0.00015)</td>
<td>2</td>
<td>-0.0002 (0.00015)</td>
<td>1</td>
<td>-0.0002 (0.00015)</td>
<td>1</td>
</tr>
<tr>
<td>Real Equity Prices</td>
<td>-0.2769 (0.19089)</td>
<td>19</td>
<td>-0.0081* (0.00278)</td>
<td>19</td>
<td>0.0024 (0.00213)</td>
<td>76</td>
</tr>
</tbody>
</table>

Note: This table shows the maximum effects of an asset purchase announcement shock of one standard deviation on the stated variables, when estimating the growth rate model and the trend model. For comparison, the right-hand column shows the maximum impacts of the baseline model estimation. The numbers in the parentheses represents the standard deviation of the maximum impact at the peak impact month. For both the trend model and the baseline model the effect on CPI, industrial production and the real equity prices are measured in percent while the effect on the long rate is measured in percentage points. For the growth rate model all effects are measured in percentage points. * indicates statistical significance at the 5 percent significance level at the time of the peak impact.

Sources: Nasdaq, SCB, Sveriges Riksbank and own calculations.

The first result column in Table 3 shows the maximum impacts of the estimation conducted with the growth rate model. These results show that the maximum impact on CPI and industrial production, following an asset purchase announcement shock of one standard deviation, still is statistically significant\textsuperscript{22}. As the impacts from this model are measured in percentage points, we cannot directly compare the sizes of these effects with the baseline model. However, we can compare the direction of the impacts.

The maximum impact on the growth rate of CPI, which is estimated to approximately 0.90 percentage points, is still positive, as in the baseline model. Therefore, it is also still in line with the theory and previous literature, as we expect a positive impact. The maximum impact for the industrial production growth rate is roughly 3.9 percentage points, which also moves in the same direction as the baseline model estimation.

\textsuperscript{22} The sizes of the shocks in the growth rate model are 0.0445 for CPI, 0.7151 for industrial production, 0.0017 for the long rate and 4.0606 for the real equity prices.
Additionally, Table 3 shows that the maximum impact for the long rate has turned statistically significant in the growth rate model estimation. The maximum impact on the growth rate of the long rate is 0.03 percentage points, and the sign is the expected one. The negative impact is in line with previous literature discussed in the baseline model results. For example, De Rezende, Kjellberg and Tysklind (2015), Knezevic, Nordström and Österholm (2019 and Weale & Wieladek 2016), found declines in long-term bond yields following asset purchases. The final variable in the growth rate model, real equity prices, has changed sign and is now negative instead of positive. However, as this estimation is statistically insignificant, we cannot draw any conclusion from this impact.

The impulse responses for the growth rate model are presented in Figure 4.

Figure 4. Macroeconomic impacts on the Swedish economy - growth rate model.23

As we can see in Table 3, the results for the trend model estimation are slightly different than the ones obtained from the baseline estimations24. The maximum impact on CPI is no longer statistically significant, contrary to the baseline model. This is also contrary to previous literature such as Kapetanios et al. (2012) and Joyce, Tong and Woods (2011), who found

23 The full impulse response system when estimating the growth rate model is available in Appendix E.
24 The sizes of the shocks in the trend model are 0.0037 for CPI, 0.0223 for industrial production, 0.0017 for the long rate and 0.0310 for the real equity prices.
statistically significant increases in CPI. Moreover, the maximum impact on industrial production in this estimation is roughly 0.41 percent, and still statistically significant. Even though this effect is larger than in the baseline model, both estimates suggest a positive impact on industrial production, as expected.

Additionally, Table 3 shows the maximum effect on the long rate and the real equity prices for the trend model estimation. The long rate is statistically insignificant, as in the baseline model. Contrary to our results, most previous studies on QE have found that interest rates decline, following an asset purchase (De Rezende, Kjellberg & Tysklind, 2015; Krishnamurthy & Vissing-Jorgensen, 2011; Schenkelberg & Watzka, 2011; Weale & Wieladek, 2016). For the real equity prices, the sign changes, turning negative. However, this effect is now statistically significant. The decline in real equity prices is contrary to several previous studies, which have shown that asset prices rise, following an asset purchase shock (Joyce, Tong & Woods, 2011; Weale & Wieladek, 2016).

The impulse responses for the trend model estimation is presented in Figure 5.

*Figure 5. Macroeconomic impacts on the Swedish economy - trend model.*

Note: Impulse responses of the stated macroeconomic variables to an asset purchase announcement shock of one standard deviation. This estimation is done using the trend model. Horizontal axis represents time in months. Sources: Nasdaq, SCB, Sveriges Riksbank and own calculations.

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25 The full impulse response system when estimating the trend model is available in Appendix F.
All in all, the only variable that changes sign when estimating the additional sensitivity analysis models is the real equity prices. The CPI impact estimates are statistically significant in the baseline model and the growth rate model, while the maximum impacts on industrial production are statistically significant in all three models. As the growth rate model expresses the impacts in percentage points, while the baseline and the trend model express the impacts (except the long rate) in percent, the sizes of these effects cannot be directly compared. When comparing the maximum impacts between the baseline model and the trend model, we observe some differences in the effect sizes, suggesting that the sizes vary with various model specifications. However, the direction of the impacts can be compared across models, and all of the statistically significant impacts have the expected signs when considering both theory and previous literature. The results of this sensitivity analysis therefore indicate that the baseline model estimates are accurate in terms of direction, while the size of the effects are uncertain to some degree.

7.2 Transmission channel impacts

When examining the transmission channel impacts, the baseline model has been used, while also including each transmission channel variable separately as a sixth variable in the structural VAR. Here, we present the impulse responses of the transmission channel variables to an asset purchase announcement shock of one standard deviation.

7.2.1 Portfolio balance channel

As discussed in the theory section, the portfolio balance channel is the most recognized transmission channel and the most commonly used in previous literature. To test for impacts of QE through this channel, the five- and 20-year government bond yields have been added separately to the baseline model. Figure 6 depicts the results of these impulse responses to an asset purchase announcement shock of one standard deviation.

Although the rates move in the expected direction following an asset purchase announcement shock, the effects are not statistically significant, making it hard to draw any conclusions. The indication of a decline in the long rates does however reason with the theory that asset purchases lower various rates through the portfolio balance channel, as investors are assumed to be heterogenous and react to the relative supply changes of government bonds made by the

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26 The impulse response systems for each of the transmission channel estimations are available in Appendix G.
central bank following an asset purchase. However, as we do not find statistically significant results, our results are contrary to the results of Weale and Wieladek (2016). They found statistically significant negative effects on 20- and 30-year government bond yields when estimating the impacts of the portfolio balance channel in the US. Their estimates for the UK, however, did not provide good evidence for impacts through this channel.

Figure 6. Portfolio balance channel.

![Portfolio balance channel graph](image)

Note: Impulse responses of five-year bond yields and 20-year bond yields to an asset purchase announcement shock of one standard deviation. Horizontal axis represents time in months. Sources: Bloomberg, Nasdaq, SCB, Sveriges Riksbank SCB and own calculations.

7.2.2 Signaling channel

Another possible way QE might impact the economy through is the signaling channel. As discussed earlier, this channel relies on the forward guidance of interest rates, or the implied forward guidance of interest rates through asset purchases conducted by the central bank (Alsterlind et al., 2015). Figure 7 presents the impulse responses of the three- and the six-month Stibor following an asset purchase announcement shock of one standard deviation.

The results of these estimations are expected in terms of impact direction, however, they are not statistically significant. As this is the case, the impulse responses show little evidence of QE impact through the signaling channel. This result is in line with Weale and Wieladek (2016), who found little to no evidence for QE impact through the signaling channel.
Figure 7. Signaling channel.

Note: Impulse responses of three-month Stibor and six-month Stibor to an asset purchase announcement shock of one standard deviation. Horizontal axis represents time in months. Sources: Nasdaq, SCB, Sveriges Riksbank and own calculations.

7.2.3 Expectations management channel

A third possible transmission channel QE could impact the economy through is the expectations management channel (Weale & Wieladek, 2016). As mentioned earlier, an increase in confidence among households will probably have a positive effect on the economy through increased consumption and investments. If asset purchases increase individual’s confidence in the economy going forward, and therefore also their willingness to spend, one should notice an effect on the consumer confidence indicator. Figure 8 presents the impulse response of the CCI to a one standard deviation asset purchase shock.

The results for the expectations management channel are the opposite of the expected, negative maximum impact instead of positive. This indicates that households react negatively, possibly decreasing their willingness to spend following an asset purchase shock. The effect is, however, not statistically significant, which makes it hard to draw any strong conclusion from this result. The result for this channel is the opposite of Weale and Wieladek (2016), who found that household uncertainty declined following an asset purchase announcement shock.
7.3 Robustness check

Omitted variable bias is a common and well-known problem when modelling small VAR models (Weale & Wieladek, 2016). As our baseline model consists of only five variables, the additional control variables, discussed in the data and methodology section, have been included separately to check the robustness of the baseline results.

These variables have been included in the model identification in various orders, to ensure the robustness of the results. Regardless of the placement of the variables, the maximum impacts for the baseline model variables only changed marginally. Therefore, we added the variables where they had the greatest effect on those variables. This resulted in both the ECB total assets and the Swedish government budget balance being included in-between the asset purchase announcements and the long rate, while real oil prices were added in-between the long rate and the real equity prices.

The results of the control variable estimations are presented in Table 4.
Our baseline result suggests that the effect on CPI and the industrial production are statistically significant while the effect on the long rate and real equity prices are not. Table 4 shows that, when including each additional variable, the effect of an asset purchase shock to CPI and industrial production are still statistically significant although the maximum impact changes slightly for the industrial production. Further, the table shows that the effect of an asset purchase shock to the real equity prices are subject to marginal changes when including each of the control variables. The inclusion of control variables does not change the impacts on the long rate. Therefore, the results of the robustness tests indicate that the results of the baseline model are robust.

8. Conclusions

Following the financial crisis, central banks employed various expansionary monetary policy tools in order to stimulate the economies into recovery. However, the Riksbank delayed their use of unconventional monetary policies until early 2015, when they declared their first asset purchase announcement. The effects of these policy programs have been unclear and remains a debated subject.

The aim of this paper has therefore been to estimate the effects of the unconventional monetary policies used by the Riksbank, as well as exploring some of the possible transmission channels QE might have impacted the Swedish economy through.
Our baseline model suggests that an asset purchase announcement shock of one standard deviation should have a maximum impact of approximately 0.11 percent on CPI and roughly 0.25 percent on industrial production. Both of these effects are statistically significant at a five percent significance level. The effect of an asset purchase announcement shock to the CPI and industrial production are also in line with the result of Weale and Wieladek (2016) who found an increase in the CPI and real GDP in both the US and UK economy, following an asset purchase announcement shock amounting to one percent of respective country 2009 GDP. These results are also in agreement with previous literature such as Kapetanios et al. (2012) and Joyce, Tong & Woods (2011) who found increases in both CPI and real GDP, along with Schenkelberg and Watzka (2013), who showed positive impact on CPI and industrial production.

The results of this paper also suggest that there is little evidence supporting impact of QE on real equity prices and on the long rate. This is contrary to previous literature such as Weale and Wieladek (2016), De Rezende, Kjellberg and Tysklind (2015), Knezevic, Nordström and Österholm (2019) and Krishnamurthy and Vissing-Jorgensen (2011), who have shown statistically significant declines in the long rate following asset purchases. Moreover, the statistically insignificant impact on real equity prices are opposite to the results of Weale and Wieladek (2016), who found statistically significant increases in real equity prices for both the US and the UK economy.

We also incorporate a sensitivity analysis consisting of two additional models, which we call the growth rate model and the trend model. This is done in order to test the sensitivity of the results for the baseline estimation. The sensitivity analysis shows that all variables except real equity prices have the same signs in all three models, which also are the expected ones when considering theory and results from previous literature. Moreover, the effect on industrial production is statistically significant in all three models, while CPI is statistically significant in the baseline model and the growth rate model. The sizes of the effects, however, varies across models. Therefore, these results indicate that the baseline estimates are accurate in terms of impact directions, although somewhat uncertain when it comes to the size of the effects.

To test the robustness of the baseline model results, we include three different control variables separately in the model. The estimated effect on both the CPI and the industrial production are still statistically significant and the maximum impact effect only changes slightly for the
industrial production. The inclusion of the control variables also only changes the impacts on the real equity prices marginally, and we see no changes on the long rate impacts. Also, neither of these effects turn statistically significant. Therefore, the results of these estimations indicate that the baseline results are robust.

Furthermore, this paper examines some of the possible transmission channels the QE programs employed by the Riksbank might have impacted the Swedish economy through. However, none of our estimated effects from the transmission channel tests turn out to be statistically significant. Therefore, we cannot draw any strong conclusions through which of the transmission channels the QE programs may have impacted the Swedish economy. The statistically insignificant results from the portfolio balance channel are contrary to the results of Weale and Wieladek (2016), as they found statistically significant evidence for this channel. Likewise, our estimates from the signalling channel are not statistically significant. This is, however, in agreement with the estimates of Weale and Wieladek, as they found little to no evidence supporting this channel. Lastly, we did not find any evidence for the expectations management channel and our results from this channel are the opposite of the expected. These results are also contrary to the results of Weale and Wieladek.

Our results indicate that the QE programs in Sweden conducted between 2015-2017 managed to stimulate the economy through higher inflation and increased economic activity, providing some evidence that these policies were effective in stimulating the Swedish economy. However, as the sample of the asset purchases is rather small, and as QE is a new phenomenon in Sweden, strong conclusions are hard to draw. Contrary to several previous papers, we did not use a Bayesian statistical method, which probably would have provided more reliant results. The reason for this is that those methods are out of the scope of this paper. While acknowledging these shortcomings, this paper is one of the first attempts to estimate the macroeconomic effects of the QE programs employed by the Riksbank.

Finally, continuing down the path of exploring the macroeconomic effects of QE policies in Sweden, this paper can serve as baseline estimates. More advanced methods such as Bayesian methods and more data will probably help researchers to provide more accurate estimates of these effects. However, there are still other aspects to QE that are important for determining the total effects on the economy, such as possible wealth and inequality aspects, which definitely deserve further investigation going forward.
References


https://fred.stlouisfed.org/series/UKNGDP?fbclid=IwAR0nDtlMXFZrTbVHFtZNBFtRFWwJzznsR8MsIlhJC_UtC8iJIZfYP7mzYvI [2020-05-28]


https://www.eviews.com/StructVAR/structvar.html [2020-03-10]

Sveriges Riksbank. (2015a). *Riksbank cuts repo rate to -0,10 per cent, buys government bonds for 10 billion and is prepared to do more at short notice.*  

Sveriges Riksbank. (2015c). *Riksbank purchases government bonds for a further 40-50 billion, lowers the repo-rate path significantly and holds the repo rate at -0,25 percent.*


Sveriges Riksbank. (2015d). *Repo rate cut to -0,35 per cent and purchases of government bonds extended by SEK 45 billion.*


Sveriges Riksbank. (2015e). *The Riksbank to purchase government bonds for a further sek 65 billion and keep the repo rate at -0,35 per cent for a longer time.*


Sveriges Riksbank. (2016a). *Riksbanken to purchase government bonds for a further SEK 45 billion and repo rate held unchanged at -0,50 per cent.*


[2020-02-15]

[2020-05-05]


[2020-05-28]

https://www.dmo.gov.uk/responsibilities/gilt-market/about-gilts/
[2020-05-08]

Appendices

Appendix A

Table 1A. A compilation of the Riksbank asset purchase announcements.

<table>
<thead>
<tr>
<th>Date</th>
<th>Announcement (in billion SEK)</th>
<th>Repo rate (percent)</th>
<th>Change in repo rate (percentage points)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12/2 – 2015</td>
<td>10</td>
<td>-0.10</td>
<td>-0.10</td>
</tr>
<tr>
<td>18/3 – 2015</td>
<td>30</td>
<td>-0.25</td>
<td>-0.15</td>
</tr>
<tr>
<td>29/4 – 2015</td>
<td>40-50</td>
<td>-0.25</td>
<td>-</td>
</tr>
<tr>
<td>2/7 – 2015</td>
<td>45</td>
<td>-0.35</td>
<td>-0.10</td>
</tr>
<tr>
<td>28/10 – 2015</td>
<td>65</td>
<td>-0.35</td>
<td>-</td>
</tr>
<tr>
<td>21/4 – 2016</td>
<td>45</td>
<td>-0.50</td>
<td>-</td>
</tr>
<tr>
<td>21/12 – 2016</td>
<td>30</td>
<td>-0.50</td>
<td>-</td>
</tr>
<tr>
<td>27/4 – 2017</td>
<td>15</td>
<td>-0.50</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: This table shows all of the asset purchase announcements declared by the Riksbank between 2015 and 2017. The table also shows the repo rate and the declared change in the repo rate at the time of the announcements.

Sources: Sveriges Riksbank.
### Appendix B

#### Table 1B. Data.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Data</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asset Purchase Announcements</td>
<td>Announcements from the Riksbank. Scaled by annualized quarterly GDP for each respective quarter of the announcements.</td>
<td>Referred to as Sveriges Riksbank (2015a; 2015b; 2015c; 2015d; 2015e), Sveriges Riksbank (2016a; 2016b) and Sveriges Riksbank (2017) in the list of references.</td>
</tr>
<tr>
<td>Five-year/ten-year/20-year yields on government bonds</td>
<td>Monthly average five-year, ten-year and 20-year government bond yields from the Riksbank and Bloomberg.</td>
<td>The yields of the five- and ten-year government bonds have been retrieved at <a href="https://www.riksbank.se/sv/statistik/sok-rantor--valutakurser">https://www.riksbank.se/sv/statistik/sok-rantor--valutakurser</a> [2020-02-25]</td>
</tr>
<tr>
<td>Variable</td>
<td>Data</td>
<td>Source</td>
</tr>
<tr>
<td>-----------------------</td>
<td>----------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Real Oil Prices</td>
<td>Monthly average price of Brent crude oil from Bloomberg. Divided by CPI.</td>
<td><em>Bloomberg: Brent Crude Oil, spot, monthly price (SEK per barrel).</em> [2020-04-30]</td>
</tr>
<tr>
<td>Swedish Nominal GDP</td>
<td>Swedish quarterly nominal GDP annualized to express the Swedish government budget balance and the asset purchases made by the Riksbank as a fraction of the Swedish GDP. Taken from Statistics Sweden.</td>
<td><a href="https://www.scb.se/hitta-statistik/statistik-efter-amne/nationalrakenskaper/nationalrakenskaper/nationalrakenskaper-kvartals-och-arsberakningar/">https://www.scb.se/hitta-statistik/statistik-efter-amne/nationalrakenskaper/nationalrakenskaper/nationalrakenskaper-kvartals-och-arsberakningar/</a> [2020-03-03]</td>
</tr>
</tbody>
</table>
## Appendix C

*Table 1C. Descriptive Statistics.*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs.</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPI</td>
<td>132</td>
<td>315.5308</td>
<td>9.6880</td>
<td>297.8800</td>
<td>337.6800</td>
</tr>
<tr>
<td>Industrial Production Index</td>
<td>132</td>
<td>103.4947</td>
<td>5.5089</td>
<td>93.4000</td>
<td>113.2000</td>
</tr>
<tr>
<td>Asset Purchases</td>
<td>132</td>
<td>0.0232</td>
<td>0.0275</td>
<td>0</td>
<td>0.0510</td>
</tr>
<tr>
<td>Government Bond 10-year yields</td>
<td>132</td>
<td>0.0153</td>
<td>0.0109</td>
<td>-0.0029</td>
<td>0.0370</td>
</tr>
<tr>
<td>Real Equity Prices</td>
<td>132</td>
<td>4.0977</td>
<td>0.7866</td>
<td>2.1543</td>
<td>5.3831</td>
</tr>
<tr>
<td>3M Stibor</td>
<td>132</td>
<td>0.0060</td>
<td>0.0101</td>
<td>-0.0061</td>
<td>0.0269</td>
</tr>
<tr>
<td>6M Stibor</td>
<td>132</td>
<td>0.0072</td>
<td>0.0101</td>
<td>-0.0046</td>
<td>0.0273</td>
</tr>
<tr>
<td>Consumer Confidence</td>
<td>132</td>
<td>98.8833</td>
<td>6.9355</td>
<td>74.1000</td>
<td>115.6000</td>
</tr>
<tr>
<td>Government Bond 5-year yields</td>
<td>132</td>
<td>0.0094</td>
<td>0.0110</td>
<td>-0.0067</td>
<td>0.0318</td>
</tr>
<tr>
<td>Government Bond 20-year yields</td>
<td>130</td>
<td>0.0215</td>
<td>0.0103</td>
<td>0.0005</td>
<td>0.0440</td>
</tr>
<tr>
<td>ECB Total Assets</td>
<td>132</td>
<td>0.2799</td>
<td>0.0758</td>
<td>0.1884</td>
<td>0.3993</td>
</tr>
<tr>
<td>Real Oil Prices</td>
<td>132</td>
<td>1.8495</td>
<td>0.4182</td>
<td>0.9087</td>
<td>2.6027</td>
</tr>
</tbody>
</table>

Note: This table shows descriptive statistics for all variables. The data for the 20-year bond yields has missing values in the first two months of 2009. All yields and interest rates are expressed in decimal form. The real equity prices and the real oil prices have been deflated by CPI and are expressed in SEK. The asset purchases are expressed as a fraction of the annualized nominal quarterly Swedish GDP for the respective purchase. The ECB total assets are expressed as a fraction of the annualized quarterly nominal euro area GDP. The Swedish government budget balance is expressed as a fraction of the annualized quarterly Swedish nominal GDP (GDP in million SEK). Sources: Bloomberg, ECB, FRED, Nasdaq, SCB, Sveriges Riksbank and own calculations.
Appendix D

Figure 1D. Macroeconomic impacts on the Swedish Economy - baseline model.

Note: This figure shows the full impulse response system of the stated macroeconomic variables to an asset purchase announcement shock of one standard deviation. This estimation is done using the baseline model. Horizontal axis represents time in months.
Sources: Nasdaq, SCB, Sveriges Riksbank and own calculations.
Appendix E

Figure 1E. Macroeconomic effects - growth rate model.

Note: This figure shows the impulse responses of the stated macroeconomic variables to an asset purchase announcement shock of one standard deviation. This estimation is done using the growth rate model. Horizontal axis represents time in months. Sources: Nasdaq, SCB, Sveriges Riksbank and own calculations.
Appendix F

Figure 1F. Macroeconomic effects - trend model.

Note: This figure shows the impulse responses of the stated macroeconomic variables to an asset purchase announcement shock of one standard deviation. This estimation is done using the trend model. Horizontal axis represents time in months.
Sources: Nasdaq, SCB, Sveriges Riksbank and own calculations.
Appendix G
Figure 1G. Portfolio balance channel.

Note: This figure shows the full impulse response function system when estimating the portfolio balance channel, when including the five-year bond yields. These results are estimated with the baseline model and the added transmission channel variable. Impulse responses to a shock of one standard deviation. Horizontal axis represents time in months.
Sources: Nasdaq, SCB, Sveriges Riksbank and own calculations.
Figure 2G. Portfolio balance channel.

Note: This figure shows the full impulse response function system when estimating the portfolio balance channel, when including the 20-year bond yields. These results are estimated with the baseline model and the added transmission channel variable. Impulse responses to a shock of one standard deviation. Horizontal axis represents time in months.

Sources: Bloomberg, Nasdaq, SCB, Sveriges Riksbank and own calculations.
Figure 3G. Signaling channel.

Note: This figure shows the full impulse response function system when estimating the signaling channel, when including the three-month Stibor. These results are estimated with the baseline model and the added transmission channel variable. Impulse responses to a shock of one standard deviation. Horizontal axis represents time in months.
Sources: Nasdaq, SCB, Sveriges Riksbank and own calculations.
Figure 4G. Signaling channel.

Note: This figure shows the full impulse response function system when estimating the signaling channel, when including the six-month Stibor. These results are estimated with the baseline model and the added transmission channel variable. Impulse responses to a shock of one standard deviation. Horizontal axis represents time in months. Sources: Nasdaq, SCB, Sveriges Riksbank and own calculations.
Figure 5G. Expectations management channel.

Note: This figure shows the full impulse response function system when estimating the expectations manage channel, when including the CCI. These results are estimated with the baseline model and the added transmission channel variable. Impulse responses to a shock of one standard deviation. Horizontal axis represents time in months.
Sources: Nasdaq, SCB, Sveriges Riksbank and own calculations.