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BACHELOR'S THESIS

Monetary policy approaches at the ZLB to solve post-crisis situation and their effectiveness

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Declaration of Authorship

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Prague, May 11, 2016

Signature

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Abstract

This thesis describes monetary policy tools implemented by central banks whose main monetary policy rates at some point after 2008 global economic crisis hit the zero lower bound. Central banks considered in this study are the Fed, the ECB, the SNB and the CNB. A smaller effectiveness analysis of the macroeconomic effects using a simple vector autoregressive (VAR) model is provided as well. The model is inspired by similar study of Gambacorta *et al.* (2012). With the use of monthly data over the sample period, the VAR tries to quantify the impact an increase in a central bank's balance sheet has on the main economic indicators—real output, consumer prices and implied volatility indices in the financial markets. Some of the results are comparable to those of the reference study mentioned above. This applies to the output results in a sense that the balance sheet shock has a slightly significant temporary effect on it. On the contrary, responses of the implied volatility indices and prices are less significant (or insignificant) and not at all comparable with the reference study. With some exceptions, there are no major discrepancies between individual country results in spite of different monetary policies adopted.

JEL Classification	C32, E31, E44, E51, E52, E58
Keywords	unconventional monetary policy, zero lower bound, Fed, ECB, CNB, SNB, VAR

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Abstrakt

Tato práce popisuje měnové nástroje realizované centrálními bankami, jejichž hlavní měnověpolitické sazby po roce 2008 narazily na nulovou dolní mez. Mezi zkoumané centrální banky patří Federální rezervní systém, Evropská centrální banka, Švýcarská národní banka a Česká národní banka. Práce se také zabývá efektivitou výše zmíněných nástrojů. K analýze byl využit jednoduchý VAR model inspirovaný podobnou studií v této oblasti od Gambacorty *et al.* (2012). S využitím měsíčních údajů se VAR model snaží kvantifikovat dopad nárůstu bilance centrální banky na hlavní ekonomické ukazatele—reálné HDP, spotřebitelské ceny a implikovanou volatilitu indexů na finančních

trzích. Některé výsledky jsou srovnatelné s výsledky referenční studie zmíněné výše. Šok do aktiv má dočasný vliv na zvýšení reálného HDP. Na druhou stranu, vliv šoku na ceny a indexy volatility je ve většině případů velmi malý a nesignifikantní. Až na výjimky nejsou mezi výsledky jednotlivých zemí navzdory různým přijatým politikám významné rozdíly.

Klasifikace JEL	C32, E31, E44, E51, E52, E58
Klíčová slova	nekonvenční měnová politika, nulová dolní mez, Fed, ECB, ČNB, SNB, VAR

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Acronyms

CBPP Covered Bond Purchase Programme

CNB Czech National Bank

CPI consumer price index

ECB European Central Bank

FGLS Feasible Generalized Least Squares

GDP gross domestic product

LSAP Large Scale Asset Purchase

NIRP negative interest rate policy

QE quantitative easing

SMP Securities Markets Programme

SNB Swiss National Bank

SVAR structural vector autoregression

VAR vector autoregression

ZLB zero lower bound

Bachelor's Thesis Proposal

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Proposed topic	Monetary policy approaches at the ZLB to solve post-crisis situation and their effectiveness

Motivation The economic situation of the developed world has gone through a very dramatic process lately because of the severe financial crisis. Currently, a major problem is economic stagnation associated with deflation and low interest rates in both Europe and the United States. In this work, I will focus primarily on the Fed, the ECB, the SNB and the CNB and, respectively, on their monetary policy approaches to solve this situation.

I will mainly examine the ZLB and unconventional monetary policies of aforementioned central banks during the crisis, such as quantitative easing or foreign exchange interventions. The question this thesis aims to answer is: what was the macroeconomic effect of the implemented measures, and is this effect temporary or persistent over time?

Methodology To analyze the effectiveness of the implemented monetary tools I used a simple VAR model inspired by a similar study in this field. With the use of monthly data over the sample period from the four economies, the VAR tries to quantify the impact an increase in central bank's balance sheet has on the main economic indicators: real output, consumer prices and implied volatility indices in the financial markets. Furthermore, independent country results will allow me to compare the four economies.

Outline

1. Introduction
2. Central Banks & Monetary Tools
3. VAR Model

4. Results & Comparison
5. Variations & Limitations
6. Conclusion

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Chapter 1

Introduction

In a situation of crisis, when aggregate demand is inadequate, the main monetary policy institution of a country shifts the nominal interest rate lower and lower to stimulate the demand and exit the crisis. In case this is not sufficient and these short-term rates cannot be pushed lower, it is no longer applicable as a monetary policy tool—it hits the zero lower bound (ZLB). In order to stabilize the economy, it is now required that the real interest rates are negative. This can be done with significantly positive inflation expectations. If there is no way to achieve this, economy falls deeper into recession, which in turn pushes the inflation towards negative values and further into deflation trap. This works in the exact opposite direction than this situation requires; it basically makes the real interest rate positive, which is undesirable. Households and businesses decrease their spending and rather save money, which in turn has another downward pressure on prices and deepens deflation and recession. In this case, the main monetary policy institution (such as a central bank) can still fight the situation as long as the economy does not reach the ZLB. Fortunately, there are ways to ease the monetary policy when it does. Many tools can be used to fight disinflationary environment at the ZLB. Even before the economic crisis started in 2008, some economists brought attention to solving this problem through lowering long-term real interest rates and increase in inflation expectations. This can be achieved by, for example, quantitative easing (QE), qualitative easing, weakening of the exchange rate, forward guidance, or implementing the negative interest rate policy (NIRP). These policies will have some impact if and only if they are credible and a clear signal is sent out by the central bank (Franta *et al.* 2014). Economic debate over the ZLB and its effect on macroeconomic models started in late 1990's mainly due to

the Japanese scenario and its inability to escape the liquidity trap. The 2008–2009 crisis brought new impulse to this discussion, with new approaches to ease the monetary policy. Many economists also proposed various models to treat the effectiveness of those unconventional alternatives, for example, Hamilton & Wu (2011), Wu & Xia (2014), and Krishnamurthy & Vissing-Jorgensen (2011). Wu and Xia found that the large-scale asset purchases and forward guidance in which the Fed engaged after 2008 helped the unemployment rate to decrease by 0.13% more than it would be without the actions. Krishnamurthy & Vissing-Jorgensen (2011) found that the first two rounds (QE1, QE2) of American way quantitative easing lowered the interest on various securities mainly through two transfer channels—signaling and portfolio balance channel. Hamilton & Wu (2011) also indirectly calculated the QE1 and the QE2 effects. But the effectiveness of the monetary easing was not the only goal to analyze. It was also predicting economic development at the ZLB and analyzing the exit strategies. Apart from the positive effects of the QE, some economists worry that artificial boosting of the asset prices helped financial institutions in spite of the fact that these institutions in many ways unleashed the crisis by undisciplined behavior. Other often presented criticism comes from the fear of hyperinflation once the crisis is overcome and the money starts to circulate faster. A considerable amount of economists also complain about pro-cyclical effects of the Federal Reserve's QE policies in emerging market economies (EMEs) (The Economist, b). This meant capital flood into EMEs when there were already high capital inflows prior to the crisis and capital outflow in the opposite case (Fratzscher *et al.* 2013). Even though a considerable part of the academic community (and, of course, central banks that are concerned by such debate) is involved in an empirical analysis mentioned above, the modeling techniques that are used now cannot be proved surely enough due to the short amount of time that has passed since the first occurrence of a ZLB situation in concerned countries (Franta *et al.* 2014). So from the point of view of many economists (Franta *et al.* 2014; Gambacorta *et al.* 2012), results of such analyzes are waiting to be proven in the future.

Constructing the dynamic stochastic general equilibrium (DSGE) model, or similar, to analyze the efficiency of said policies has one significant disadvantage. It simulates the result of shifting the monetary policy rates near zero (to the ZLB) based on the data from the period when those rates were well above zero (Franta *et al.* 2014). Another approach to model the ZLB regime is using

vector autoregression (VAR). The study provided in this thesis is inspired by a paper by Gambacorta *et al.* (2012). Authors here use a structural vector autoregression (SVAR) to model effectiveness of quantitative easing in various countries (for more detailed explanation, see Gambacorta *et al.* (2012)). More precisely, this study uses a simple VAR model with monthly data over a sample period from January 2007 to February 2016. During this time, the sample central banks of, namely, the United States, the euro area, Switzerland, and the Czech Republic, have introduced various types of unconventional monetary easing policies, whereby they also sharply increased their balance sheets. This closely reflected the volume of the implemented measures. The model is designed to capture the macroeconomic effect of the increased money base using an aggregate output and prices and also an impact on uncertainty of the financial markets using the implied stock market volatility.

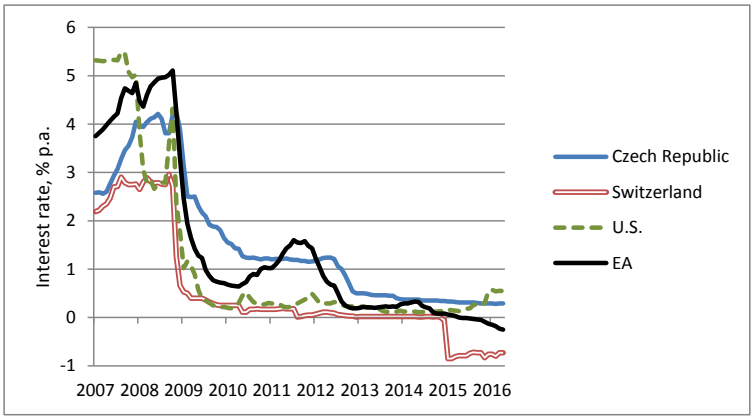
This paper is conceived as follows. Firstly, some types of monetary policy tools, i.e., quantitative easing, qualitative easing, credit easing, and exchange rate weakening are briefly presented. Secondly, these tools are explained again in a frame of each sample country specifics and their economic environment. In Chapter 3, a VAR model is constructed as a simple way to undertake the empirical analysis of effectiveness of the unconventional monetary policy tools at the ZLB for each of the sample countries. First, the benchmark model is constructed. It proceeds with the data description and the analysis itself. Results are provided in Chapter 4. A comparison of the results for the countries and an explanation of some variation between these results and the results from the paper (Gambacorta *et al.* 2012), which was an inspiration for this study, is also provided. In Chapter 5, the results from a slightly changed benchmark model are provided. In addition, there is a discussion over some pitfalls and disadvantages of the model and ways the estimation can be improved, which opens the door for further deep analysis in the future. Chapter 6 summarizes the main findings.

Chapter 2

Central Banks & Monetary Tools

In a situation where low inflation is driven by insufficient aggregate demand and monetary policy rates already hit the ZLB, a central bank must resort to other means of conducting the monetary policy. This is exactly the scenario of many central banks all over the world. The following study deals with four of them, the Federal Reserve, the European Central Bank (ECB), the Swiss National Bank (SNB) and the Czech National Bank (CNB), and shows how these central banks managed to handle this situation respectively. The development of the short-term interest rates is shown in Figure 2.1. There are many ways to deal with the ZLB situation. The tools that can be introduced are, for example, quantitative easing, qualitative easing, credit easing, weakening of the exchange rate, forward guidance, or negative interest rate policy. This is not the full list; however, we will focus only on these. The first reason is a close link and frequent confusion between some of them and the second is the fact that the sample central banks were actually involved in those.

Figure 2.1: Short-term interest rate, Per cent per annum



Source: author's computations. Data: OECD

2.1 Types of Unconventional Monetary Tools

Quantitative Easing In simple words, *quantitative easing* is buying assets from private institutions, forcing prices of those assets to increase while lowering their yield. At the same time it means increasing the monetary base by buying assets on the secondary market (not directly from the government, see paragraph Printing Money below), such as long-term government bonds, which leads to decrease of the long-term real interest rate and increase in inflation expectations. Growing size of the central bank balance sheets accompanies quantitative easing, but it also accompanies other means of unconventional monetary policy, so it does not represent only the QE. Providing liquidity to banks then leads to easier lending and it supports investment. QE may cause higher inflation than desired if money supply growth outperforms the nation's economic growth. Nevertheless, QE can fail to encourage higher demand through increased inflation if the banks refuse to lend the money to the real economy or if businesses and households hold the cash. Even though, as QE lowers yields, it helps banks to pay off the existing debt. QE can also spur the demand through the fiscal effect since the overall lower interest rate decreases government's borrowing costs, which in turn decreases future taxation (The Economist, b).

Qualitative Easing On the other hand, *qualitative easing* keeps the balance sheet of the central bank constant—it only changes structure of the assets to shift riskiness of those assets higher. This also provides financial sector with more liquidity because the risky assets on the balance sheet of the financial institutions are exchanged for those of the central bank. An example of a qualitative easing might be the Securities Markets Programme (SMP) employed by the ECB (see Section 2.2). This tool also has some caveats. A central bank does not deal only with the liquidity problems of the financial sector, but it also takes over part of the solvency issues of the financial sector with the risk. This might result in losses of the central bank and bring on the moral hazard.

Credit Easing *Credit easing* also involves expansion of the central bank's balance sheet. Although, as was mentioned above, quantitative easing is aimed at asset side of the balance sheet. Using proper language it should rather be liability side because pure QE focuses on bank reserves (as was, for example, the case of Japan before 2007). Credit easing involves central banks buying

financial assets from private institutions, not from the government. This is the distinction between the case of Japan and the United States. As former chairman of the Federal Reserve called it: "the Federal Reserve's credit easing approach focuses on the mix of loans and securities that it holds and on how this composition of assets affects credit conditions for households and businesses" (Bernanke 2009). Despite that, this study uses more common designation of the policy that, for example, the Fed undertook—and that is quantitative easing.

Printing Money It is also crucial to distinguish between these kinds of monetary easing and simple *printing money*. Using new money to buy government debt or to finance its deficit is called monetizing the debt. However, these procedures are no longer a solution and are prohibited in developed countries in Europe or in the United States. Central bank cannot buy the debt directly. Instead, it buys government bonds on the secondary market. The difference is in the target of the action—to stimulate the economy, not to finance a government deficit. And after a recession is over, the central bank resells these securities and other assets back to the market (Thornton 2010).

Foreign Exchange Interventions *Foreign exchange interventions* is a tool available to an open economy. This monetary policy tool, used in circumstances where main monetary policy rates hit the ZLB, is different to that used in normal economic environment. The latter implies fixed amount of foreign exchange purchases and the effect on the exchange rate in not specified, whereas using the tool at the ZLB suggests specifying more or less fixed exchange rate with unlimited amount of foreign exchange purchases within unspecified amount of time. The effect on the balance sheet of the central bank is also upward. This tool is very powerful because it pushes the inflation expectations and therefore jump-starts the economy by both the real interest rate transmission channel and the exchange rate transmission channel. Due to simple implementation by the central bank, and therefore credible commitment, inflation expectations grow and the real interest rate is more negative at the ZLB as was explained in Chapter 1. Weakening of the exchange rate kickstarts the exports and also affects the import prices, which in turn has an impact on price developments in the case of a small open economy (The European Central Bank's website, b).

Forward guidance Not all policies have to affect balance sheets. For example *forward guidance* is about communicating a monetary policy strategy with the economic agents. Forward guidance about future direction of the policies and decisions might actually influence today's behavior. The Fed started implementing this tool a long time before the crisis struck the world and after 2008 it was still one of the most important policy tools. Another example would be the ECB in 2013 making statements about the interest rate. However, the policy is effective as long as the announcements of a central bank are credible.

Negative interest rate policy Last but not least is the *negative interest rate policy*. NIRP is a recent phenomenon, employed primarily to motivate consumer spending or to depreciate currencies. Some of the first examples of implementing NIRP are Japan (which has been struggling with deflation and stagnation for a very long time), the euro zone, Switzerland, Sweden, or Denmark. Observing results of NIRP in Europe, there was some success in depreciating currencies (Switzerland, Sweden) but in the eurozone it had hardly any effect on the wider economy. Since NIRP is relatively new measure, a full evaluation of the policy is not possible. However, some dangerous consequences have already come to attention, such as creating asset bubbles (Sharma 2016).

For the analysis briefly introduced in the beginning, four economies are taken into account. The United States are included because they were the first to apply QE as an answer to the October 2008 events. The euro area is included as it is one of the biggest players in the global economy, and the ECB governs monetary policy of majority of the European countries. The Czech Republic brings the value added to this thesis in the context of comparative analysis between the above mentioned countries. Lastly, Switzerland is included as it is in a similar position as the Czech Republic—both in relation to the eurozone or the European Union and in the openness of the economy. In the next section, a short description and implementation of different types of unconventional monetary policies in the context of the four economies is provided.

One can divide the four countries into two groups: "QE countries" and "QEE" countries. The first group, quantitative easing (QE) countries, is characterized by drop in money multiplier since 2008 and slow economic growth. QE is used to raise asset prices. The second group, quantitative easing or exchange rate intervention (QEE) countries, is also characterized by decline in

money multiplier after 2008 but economy is evolving normally and the weaker multiplier comes from the exchange interventions. QEE countries are, for example, Switzerland and the Czech Republic. QE are the United States or the eurozone (Dorgan 2014).

2.2 The Four Economies

The United States First, it is crucial to point out that the financial crisis, being the starter for the global economic crisis, had begun in the United States. In order to better understand the monetary policy implemented afterwards, one should analyze what preceded the financial crisis. At the heart of the crisis were unambiguously the subprime mortgages, which where packed through securitization into collateralized debt obligations (CDOs) that could be sold to investors. Up to the time when interest rates were still very low, this has not posed any problem. But after 2004, the Federal Reserve, in fear of inflation (which was groundless), started to increase the basic interest rate, making the subprime mortgages non-repayable (La Monica 2005). But the Fed underestimated the crisis that was knocking on the door and played with the interest rate. Until 2008, it decreased the interest rate drastically, but banks did not balance previous losses. Between 2004 and 2007, the biggest U.S. investment banks became more sensitive to financial shocks and were highly indebted. In the middle of September 2008, the fourth biggest U.S. investment bank Lehman Brothers went bankrupt thus becoming the starting point for the financial crisis. Two other investment banks, Bear Stearns and Merrill Lynch, were sold. Those "too big to fail", that have not been sold or gone bankrupt, became commercial banks or received government help. With the subprime-mortgage crisis, panic on the inter-bank market arose and due to the close connection between financial institutions all over the advanced world, global financial crisis hit.

To better understand what actually happened in the U.S. after 2008, it is interesting to analyze the money supply behavior. If we look at the money multiplier more thoroughly, we can compare the M2 (cash and "near money") and the monetary base (currency and reserves). The M2 money increased at a stable rate during the recession, but the monetary base surged very quickly within a couple of months. So, obviously, the money multiplier plummeted during 2008. As opposed to the Great Depression, when the money multiplier

declined because of the banks' failure and distrust, now it was a result of massive injections of the base money by the Fed—loans and deposits still grew but not as rapidly as the base (Lothian 2009). One can find simple economic ideas about behavior of monetary aggregates and money multiplier in many macroeconomic textbooks. Almost constantly a very close relationship is described between the base money and appropriate monetary aggregate (Papadia & Daluiso 2013). Other highly accepted ideas are that a central bank can stabilize the price level by changes in the base money. In simple words—monetary aggregates help predict inflation. In the case of the United States, the money multiplier had almost disappeared due to the boundless increase in the high-powered money and almost no growth in M3; increase in the base money was irrelevant for inflation. During normal times, when the money multiplier is constant (at least one), there is a target for increase in the money stock to target inflation at, for example, 2%. The money base, then, should not increase more than the money stock target in order to not overshoot the inflation target. But when the multiplier has disappeared (or got stuck close to zero), there is no limit for the money base injections and similarly for the QE asset buying programs. This is valid not only for the U.S. but for all countries whose money multiplier dropped after 2008. So, a very important question is—what was the macroeconomic effect, if any, of the injections into the money base and central banks' balance sheets? As was already previously stated in Chapter 1, this study will attempt to reveal (in very simple analysis) this crucial issue and clarify at least some of the concerns related to this topic.

Quantitative easing was not the only measure that U.S. monetary policy imposed. To solve the credit crunch and the lack of trust on the interbank market, the central banks of the U.S. and Europe implemented several tools such as, for example, increasing guarantees on deposits and the guarantees on interbank loans, recapitalization, and, most importantly, programs for bailouts of the bad assets by governmental funds (Hromádka 2009). The most known program is the Trouble Asset Relief Program (TARP). Other measures to solve the liquidity crisis were: extension of the maturities of financial instruments, extension of the framework of assets that serve as the collateral, increase in the volume of individual operations, and extension of the variety of financial institutions to which central banks are willing to loan money. All these were very helpful measures implemented by the Fed, the U.S. government and the ECB. Concerning QE, the Fed involved in many counter-cyclical policy mea-

sures such as the so-called Large Scale Asset Purchase (LSAP), during which it included huge amounts of mortgage backed securities (such as CDOs) and other securities into its balance sheet. This policy was conducted in several rounds known as QE1, QE2, QE3. More precisely, the first round (QE1) measures involved liquidity injections to support the banks and financial market, LSAPs of agency debt, mortgage-backed securities (MBS), and Treasury securities. The second round started in halfway through the year 2010 and was also involved in LSAPs of the Treasury securities. Another action that Fed was involved in was the so-called Operation Twist, whose primary aim was extending maturity of the securities that Fed kept on its balance sheet. Finally, the third round of QE was announced at the end of 2012; it focused on MBS purchases. Direct lending and liquidity provisions were dominant in the beginning of the crisis, whereas LSAPs became a main tool soon after, driving the vast majority of the Federal Reserve's balance sheet dynamics. The first aim of LSAPs was to reduce mortgage interest rates, but while introducing QE2 and focusing on the U.S. Treasury bonds, the main goal was to decrease long term interest rates and increase asset prices in order to stimulate demand and economic activity. The main logic behind this was that Fed's purchases of long term assets affect financial assets held by the public—changes in assets available to investors decrease their yields and yields of other assets that are alike, forcing these investors to shift to other assets (Fratzscher *et al.* 2013).

Regarding the efficiency of American QE, the majority of studies found positive effects of the large-scale asset purchase programs. Krishnamurthy & Vissing-Jorgensen (2011) agree with QE1 and QE2 lowering the interest on various securities mainly through two transfer channels—signaling and portfolio balance channel. Central banks buying the long-term bonds send out a signal that interest rates will be kept low for an extended period of time, since the central banks would have suffered losses otherwise. The second transfer channel works with increased price of the securities because of the purchase programs. Findings of Fratzscher *et al.* (2013) suggest that the first round of QE was very effective in increasing asset prices, lowering the U.S. bond yields and appreciation of the U.S. dollar, whereas QE2 more or less led to depreciation of the dollar and has not lowered the yields. A more interesting finding was that LSAP announcements were much less effective than the consequent operations, which suggests that economic agents did not fully respond to the announcements.

The euro area Like the policy of the Fed, the ECB started by implementing similar measures to provide liquidity to the financial institutions as mentioned above. However, the first round of QE in the eurozone was delayed after the American one and was much smaller in volume. The delay in the action and more careful approach of the ECB is sometimes criticized. Along with the European debt crisis it is considered to be the reason why the euro area economy grows slower than the U.S. economy and why it struggles harder with meeting the inflation target. The second round was implemented due to the European debt crisis to improve liquidity. The main programs which were responsible for the measures were, for example, expanded Long-Term Refinancing Operation (LTRO) designed to lend money to banks, two rounds of Covered Bond Purchase Programme (CBPP) from July 2009 to October 2012, and SMP from May 2010 to September 2012. The CBPP was introduced as a response to the lack of confidence on the interbank market in early 2009. Covered bonds are essentially asset-backed securities such as those in the U.S. except that covered bonds are much safer for the holder and there is less danger of doing a securitization with lower quality loans or mortgages (Fawley & Neely 2013). The SMP was a name for various interventions in the debt securities market (large purchases of government bonds of the Eurosystem) to lower the interest rates of those government bonds, without changing the monetary base (The European Central Bank's website, a). Following the example of the Federal Reserve, the ECB was also involved in forward guidance. In July 2013, the ECB announced that it would keep the interest rates low for a prolonged period of time (Bernoth *et al.* 2014). But in January 2015 the ECB announced large-scale asset purchase program, within which the central bank would buy up to EUR 60 billion every month until at least September 2016 to further ease the monetary policy. Observing Figure A.3, there is an obvious reason. After initial recovery from the 2008–2009 crisis and increase in inflation, the European debt crisis shocked the euro area economy and prices started to decline over again until the start of 2015 when they reached zero and the economy slipped into deflation. Asset purchases should provide easier access to money for all economic agents, thus jump-start the economy and head towards 2% inflation target. The ECB will buy mostly government bonds issued by the euro area central governments and by European institutions.

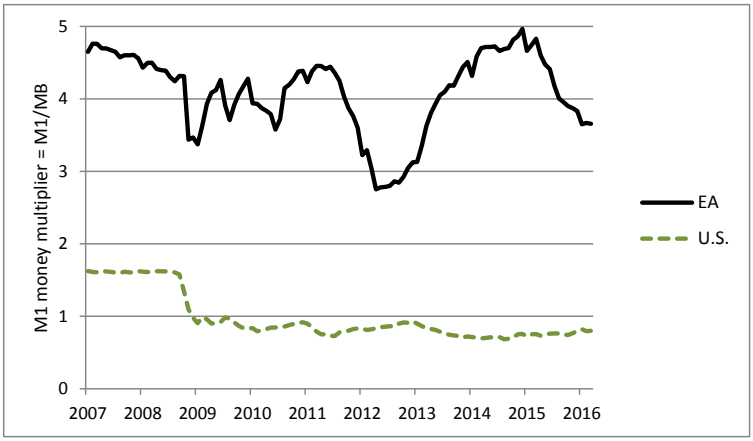
Although quantitative easing using the government bonds has been the easiest way to raise the monetary base in many central banks, it turned out

that in a case of the eurozone it is also politically the most challenging one. Most criticism comes from the German part of the eurozone, and the reason is that besides buying bonds from countries more endangered by fiscal default, the ECB will also buy its credit risk, which may, at the end, represent possible losses for the ECB. Now it seems clear why especially the German Bundesbank stands behind this argument because the future burden will lie on German taxpayers. However, some economists such as Ji & De Grauwe (2015) oppose this argument, that no fiscal transfers are needed in this particular case of QE. Their reasoning relies on the fact that after the central bank purchases the government bonds and keeps it on its balance sheet, interest payments paid to the central bank are refunded in the same amount according to the equity shares between the countries (in theoretical case of uniform interest rates on the bonds). If one country defaults, it stops paying interest, but other governments will get exactly the amount of money they paid earlier. If anything, taxpayers will be relieved because their government will not have to pay extra interest on the bonds if it was in circulation. The only risk that comes with QE is inflation risk, which is desired in the end. The only fiscal transfer comes with different interest rates (more realistic assumption). Fiscally weaker countries will pay higher interest, so the ECB's profit, which contains more of the less healthy governments, will still be redistributed among countries according to the equity shares—more payments will go to more fiscally prudent countries such as Germany (Ji & De Grauwe 2015).

By studying evolution of the money multiplier (see Figure 2.2) and the ECB's assets at the same time, we can conclude that a sharp decline since 2008 and an even sharper drop in 2011 is entirely due to shifts in the balance sheet (Powell 2015). And again the sharp increase of the money multiplier in 2013 is accompanied by a drop in the ECB's balance sheet. This was due to the returning of the borrowed money from the LTROs, and it also coincided with a steady decline in inflation since 2012 to even negative values at the end of 2014 and start of 2015. We can expect, with relatively new European monetary policy, a further decline in the money multiplier.

Concerning efficiency of the CBPP, it lowered the long-term rates on the covered bonds and improved market liquidity. The SMP had impact through the signaling channel, the portfolio balance channel, and the liquidity channel like in the case of LSAPs in the U.S. (Bernoth *et al.* 2014)

Figure 2.2: M1 money multiplier

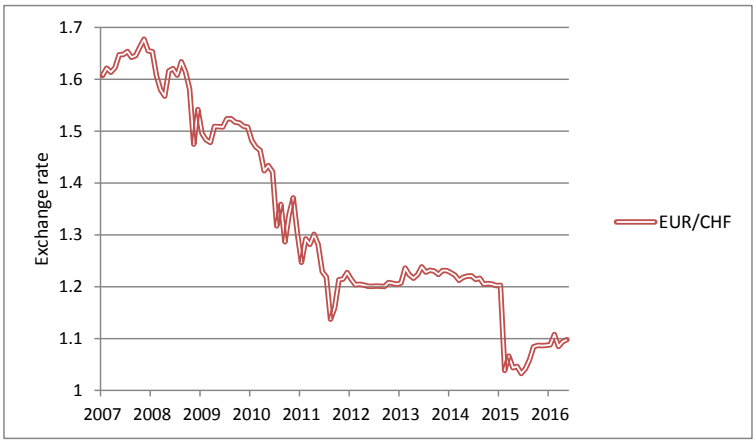


Source: author's computations. Data: ECB, Federal Reserve Bank of St. Louis

Switzerland After 2008, the SNB has cut the policy rates down until it reached its effective lower bound in March 2009. In addition, the Swiss franc began to appreciate strongly in the end of 2008 due to the Swiss safe-haven status (development of the EUR/CHF exchange rate is shown in Figure 2.3). The appreciation caused serious deflationary pressure despite low interest rates. Such situation called for monetary easing, in which the SNB was indeed involved. By 2009, it enforced various types of unconventional monetary policy such as foreign exchange interventions, extension of repo operations and bond purchase program. By the time of stopping the unconventional policies, the SNB's balance sheet already fired up and doubled its volume by the end of 2010 as can be seen in Figure A.4 in the Appendix A. However, as the programs were discontinued, the risk of the Swiss franc appreciation and danger of inflation was getting bigger and bigger in part due to increasingly visible European debt crisis (Christensen & Krogstrup 2015).

In August 2011 the SNB promised to provide liquidity to the Swiss markets and increased central bank reserves to roughly CHF 200 billion from the original CHF 30 billion. Despite huge injections into the SNB's balance sheet, the Swiss franc continued to appreciate. So in September 2011 the SNB chose one-sided exchange rate commitment with a rate going no less than CHF 1.20 to the euro. To keep the peg, SNB were forced to buy huge amounts of Euro-denominated assets, which together made up to 40% of SNB's balance sheet by the end of 2014. If we look at Figure A.4 in the Appendix A, SNB's balance sheet grew the most of all the sample countries, relative to its original level in 2007. But this is not the only record. The SNB's assets to gross domestic product (GDP)

Figure 2.3: EUR/CHF exchange rate



Source: author's computations. Data: www.investing.com

ratio is around 80% (January 2015). For comparison, Fed's assets or ECB assets are around 20%–30% of their GDP (The Financial Times).

Then in January 2015 the SNB dropped the peg for several reasons. To start with, having high percentage of foreign exchange reserves in the balance sheet makes Switzerland vulnerable to volatility, which would in turn affect the central bank's credibility. Secondly, by keeping the peg, the SNB would risk buying much more euros since the ECB announced its huge QE program in January that would devaluate the euro even more. This is the reason for leaving the peg in January 2015. Otherwise SNB would have bought more and more foreign exchange assets and soon have swung over 100% balance sheet to GDP ratio (The Financial Times).

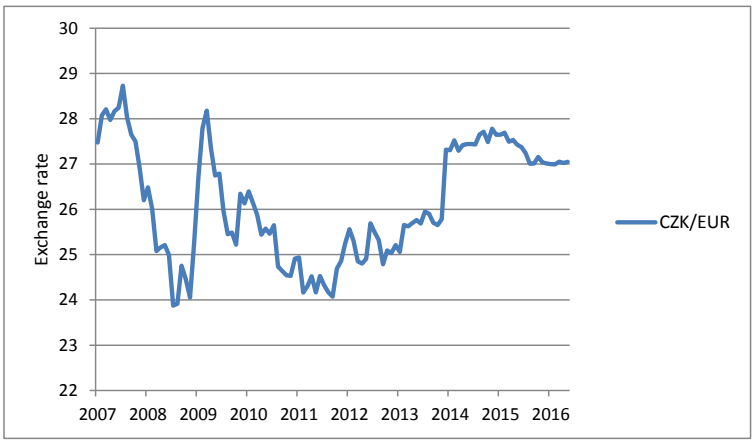
After leaving the peg, the exchange rate of the Swiss franc against the euro fell from 1.20 EUR/CHF to 0.85 EUR/CHF (before going to 1.02 EUR/CHF) which immediately caused a shock for the markets. The worst is estimated for the exporters. According to some specialists, the loss effect on export could be about 0.7% of the Swiss GDP (The Economist, a). Also, the inflation will probably remain low for a long time. Many economists agree that leaving the peg was the right decision with all its unfortunate aspects but at the same time they agree that pegging the currency was the bad decision in the first place. However, without it, the Swiss franc would have probably stayed highly overvalued (The Economist, c).

The Czech Republic The story of the Czech Republic is very different from those of the euro area, the United States and Switzerland. Slowing of the economy was of course initiated in 2008 by the start of the global financial crisis. Observing the development of the Czech GDP suggests that the original drop was followed by 3 years of recovery but then the GDP fell again due to procyclical fiscal policy. This second downturn was not powered only by that but also by small domestic demand. According to the Czech National Bank's forecasts, negative output gap would not have closed until the end of 2015 having considered all the negative inflation and interest rate forecasts (Franta *et al.* 2014).

The response of the CNB was clear. In 2012 it lowered the main monetary policy rates, which then hit the zero lower bound at the end of 2012. In November 2013, Czech economy faced a very strong recession with a threat of liquidity and deflation trap. Low interest rates were not able to pick up Czech economy; inflation continued to decrease and economy needed negative interest rates. To avoid dangerous scenarios, the CNB employed an unconventional monetary policy, a publicly declared asymmetric exchange rate commitment respectively. This use of an exchange rate as a monetary policy instrument differs from that in common economy conditions. As a conventional tool, a central bank sets a specified volume of foreign exchange interventions and the impact on the exchange rate is ambiguous. Whereas here CNB declared a stable rate close to CZK 27 to the euro (see Figure 2.4), which it is ready to maintain if necessary—by intervening in the foreign exchange market in unlimited volume for an unlimited amount of time. Supporting interventions were needed only in the first days after announcing the commitment and then in summer 2015; these interventions were comparable in volume. In a way this is a unique occurrence of such tool, so the Czech experience may be very useful for possible future need of implementing this by other countries with similar economic conditions and environment.

In spite of broadly accepted advantages listed in Section 2.1, some empirical studies like, for example, Franta *et al.* (2014), computed the size of the effect of the changes in the exchange rate on the prices and concluded that 10%–15% of the exchange rate changes were reflected in consumer prices. What is also interesting is the variability of this impact in relation to the length of stay at the ZLB. The longer an economy stays there, the greater is the impact of weakening of the exchange rate. This also stresses the importance of expectations such

Figure 2.4: CZK/EUR exchange rate



Source: author's computations. Data: www.investing.com

as expectations about nominal interest rates. Only if economic agents rely on nominal interest rates at the ZLB, the exchange rate transmission channel can work well.

Another unexpected result of the 2013 interventions was a drop in observed inflation. So the November 2013 action can be seen as a counterforce to tough anti-inflation pressures in the Czech Republic and the euro area that only partly compensates these tendencies that have not been known yet in the 2013 forecasts. At the time of writing, observed inflation struggled below 1% as shown in Figure A.3 in the Appendix A, so there are still some deflationary tendencies overweighting weak Czech koruna. The real economy, on the other hand, experienced strong growth mainly due to increased domestic demand. Expected impact on export is also very significant.

Chapter 3

VAR Model

The reference study Gambacorta *et al.* (2012), used as a base for the following analysis, analyzed eight economies using a structural panel VAR model. Comparative analysis in this work will not be as sophisticated and econometrically challenging as in the reference study but it brings a new country into the sample, the Czech Republic. It did not involve in an unconventional monetary policy for such a long period (starting in November 2013). There was some effort to quantify the effect on the economy, but it was not substantial. This analysis can be very interesting not only for the results of macroeconomic effectiveness themselves but also for the comparison to Switzerland for example, which used a very similar tool and is comparable to the Czech Republic in openness and relations with regards to the euro area, as was pointed out in the previous section. The two other countries analyzed are the United States and the euro area for the reasons stated in Chapter 2. A simple VAR approach is very easy to follow, which is the reason why a not so econometrically skilled author has chosen it. But it has some serious caveats that, for example, the panel VAR can overcome. Chapter 5 will be devoted to the limitations of the simple VAR model and will suggest possible future improvements that can be implemented in the diploma thesis.

VAR model enables us to explore the dynamic effects of monetary policy shocks within each country. Getting the individual country estimates allows us to compare the results between all countries, having in mind that economic structure and environment of the countries are not the same. However, all the countries at some point after the onset of the crisis decreased their main monetary policy rates to its effective lower bound. With the rates close to zero and the economy far from the recovery point, central banks of the four sample

countries implemented various unconventional monetary policy tools mainly to lower the long-term interest rates and to provide liquidity to the turbulent financial sector in general. These policies increased the balance sheets of all the central banks rapidly. The similarity ends when focusing on the balance sheet structures. In the Fed's balance sheet, the increased items were primarily LSAPs of the private and government bonds. The ECB's balance sheet inflation was driven mainly by the CBPP and the SMP and lending to the financial sector. The Swiss expansion was caused by foreign exchange purchases and so was the CNB's balance sheet expansion.

On one hand, the behavior of the central banks was, to some extent, homogeneous which allows us to compare between the individual country results. On the other hand, we need to pay attention to interpreting the results since each implemented policy has, in turn, a different effect. However, the results will hopefully reveal the differences in the effects.

3.1 Model Specification

A general VAR model is built in the following way.

$$\boldsymbol{Y}_t = \boldsymbol{\alpha} + \sum_{i=1}^{p} \boldsymbol{\Phi}_i \boldsymbol{Y}_{t-1} + \boldsymbol{\epsilon}_t$$

The Y_t comprises of four endogenous variables. Φ_i is an autoregressive parameter matrix, α is a vector of constants, and ϵ_t is a matrix of disturbances. Following the reference study, the four endogenous variables are: first difference of logarithms of seasonally adjusted real GDP[1], first difference of logarithms of seasonally adjusted consumer price index (CPI), first difference of logarithms of seasonally adjusted central bank assets and implied volatility of the stock market index.[2]

Real GDP[3] and CPI variables are present to capture the macroeconomic effect of the shocks on the central bank's balance sheet. Central bank assets are

[1]The GDP underwent seasonal and calendar adjustment already. CPI and central bank assets were seasonally adjusted using a method described in a book of Baum (2006).

[2]Based on various augmented Dickey-Fuller tests in Stata, real GDP, CPI and central bank assets exhibited unit root processes, so all data except the implied volatility indices were first differenced after taking logarithms.

[3]Quarterly real GDP data were for each country converted into monthly using cubic spline interpolation, described at https://columbiaeconomics.com/.

included to represent the unconventional monetary policy tools while the economies are at the ZLB, and interest rates cannot be included. Sharp increases in the balance sheet are consistent with the implemented tools described in the previous section. It is a sign of large-scale asset and bond purchases, and lending in case of the U.S. and the euro area or foreign exchange interventions to keep the rate from appreciation in case of Switzerland and the Czech Republic. Implied stock market volatility index is used here as an indicator of financial turbulences and uncertainty. It is important to include the volatility index in the analysis to differentiate between increase in the balance sheet as a response to financial risk and increase due to exogenous shock to the balance sheet.

3.2 Data

The VAR model covers a sample period from January 2007 to February 2016, which is another extension of the reference analysis. Data were taken primarily from the OECD database, minor part was got from the Eurostat database, Federal Reserve Bank of St. Louis and national statistical databases.[4]

A very similar development of key macroeconomic variables can be seen over the period starting before the crisis up till now, April 2016, for all sample countries: the United States, Switzerland, the euro area and the Czech Republic. Figure A.1 to Figure A.5 in the Appendix A show charts with some of the variables of interest combined for all countries—real GDP, CPI, nominal central bank assets and volatility indices.

Real GDP dropped substantially due to the collapse of Lehman Brothers and returned to its pre-crisis level at the end of 2010 except for the Czech Republic and the euro area. In 2011, the European debt crisis hit the economy (Lenzner 2011), which obviously had an impact on the Czech Republic as a member of the European Union but had smaller impact on Switzerland. We can see similar patterns in GDP for both the Czech Republic and the euro area. On the other hand, the impact on Switzerland as a non-EU country was rather mitigating the sharp rise in GDP. In the last two years, Czech economy rose the most rapidly of all the sample countries. Concerning retail sales that are reported in Figure A.2 in the Appendix A, a not so similar development can be

[4]VSMI: http://www.six-swiss-exchange.com/ ; VIX, Fed's balance sheet, ECB's balance sheet: https://research.stlouisfed.org/ ; VSTOXX: https://www.stoxx.com/ ; CNB's balance sheet: http://www.cnb.cz/ ; SNB's balance sheet: https://data.snb.ch/

seen in the real GDP of the variable across countries. Variation in the results is commented in Chapter 5.

As was already mentioned earlier, the decline in economic activity was accompanied by fall in inflation. Consumer price index fell significantly for all countries in October 2008 but for the Czech Republic. The inflation rates were even below zero for a substantial period. After inflation rates reached the bottom, they started to rise rapidly, but in 2015 nearly all countries fell into deflation again.

Along with the strong correlation among economic variables across countries, Figure A.5 in the Appendix A shows strong correlation in "fear indices" across sample countries. Volatility indices are used here for approximation of the financial market risk aversion. And indeed, as a crisis struck at the end of 2008, there is a noticeable increase in the financial market volatility indices. However, implied volatility stock market index for the Czech Republic is missing. Due to very low activity or almost absent option market in the Czech Republic, historical volatility index is counted mostly from historical volatility of PX and exchange rate CZK/EUR. The Czech National Bank stopped reporting the historical volatility index—nevertheless, historical volatility is very highly correlated with global volatility indices. In addition, whatever happens in a stock market in Europe or in the United States immediately affects Czech markets. So, for the analysis, VIX index is used as a proxy for Czech historical volatility index. Regarding the general development of the volatility indices, it is clear that it was on the rise since the beginning of 2007, a long time before the bankruptcy of Lehman Brothers. But soon after that it magnified very quickly, followed by an equally rapid retreat. Again, there was a major increase in VIX in 2011 associated with the European debt crisis. From 2013 until the end of 2015 the index stabilized at low levels, but from the end of 2015 to the start of 2016 it started increasing again.

A sharp rise in central banks' balance sheets indicates a shift in monetary policy tools. As was already said before, the main conventional monetary policy tool, the short-term interest rates, was replaced by unconventional tools resulting in injections to central banks' balance sheets.

3.3 Estimation

A VAR model can distinguish between the dynamics driven by other variables and the dynamics driven by the lags of the variable itself. Then the system of equations has one important property: each variable is described by its own lags and the lags of all the other variables. The right hand side of each equation in the system is therefore identical (Martin *et al.* 2013). According to the lag-length selection criteria, a benchmark model with real GDP was selected to have 3 lags of the dependent variables, which is different from the reference study where two lags were suggested by the information criteria. Three lags were chosen mostly by the Hannan and Quinn information criterion (HQIC) and Schwarz's Bayesian information criterion (SBIC).

The estimation is carried out in the following way. For each country, a set of pre-estimation commands are executed to make sure that the time series don't follow the unit root process. After that, for all countries, the VAR model well satisfied the stability condition, only after first differencing the variables (except the volatility indices). The VAR model itself looks like the following:

$$\boldsymbol{Y}_t = \boldsymbol{\alpha} + \boldsymbol{\Phi}_1 \boldsymbol{Y}_{t-1} + \boldsymbol{\Phi}_2 \boldsymbol{Y}_{t-2} + \boldsymbol{\Phi}_3 \boldsymbol{Y}_{t-3} + \boldsymbol{\epsilon}_t.$$

To account for an autocorrelation in the disturbances, which is almost always an issue when using GDP in the analysis, the Feasible Generalized Least Squares (FGLS) estimator is used instead of the Ordinary Least Squares (OLS) estimator. In the presence of autocorrelation and/or heteroskedasicity, the FGLS estimator produces consistent estimates. The way the GDP data were divided into monthly observations also generates some autocorrelation by definition. This might or might not be a problem—a possible impairment in the autocorrelation can be detected by simple comparison of the estimates or of the impulse responses before and after the interpolation.[5]

[5]However, in this case, comparing the estimates from analysis with only 30 observations does not make much sense and the results are inconclusive. We can count only on the FGLS estimator.

Chapter 4

Results

In Figure A.6 to Figure A.9, the impulse responses of all the variables, real GDP, CPI, implied volatility index and central bank assets, to the unconventional monetary policy shock are presented individually for each country. All graphs in these figures are with central bank assets as an impulse variable as this is the variable of interest. The impulse responses are reported with a 90% confidence interval. However, the confidence interval in almost all graphs covers also zero, which indicates no response at the 10% significance level. This situation is, of course, a consequence of the large number of coefficients to be estimated in one VAR; in fact, a VAR(3) model with four variables calls for 3 lags of all 4 variables and an intercept to be included in only one equation. This results in a serious slump of degrees of freedom and, in turn, wide confidence intervals. Nevertheless, following interpretation will abstract away from the confidence intervals and focus on the impulse response curves themselves. If we first look at the responses of the output, we can observe a similar structure in the Czech Republic, Switzerland and the United States. It supports the theory that shocks to the central banks' balance sheets are macroeconomically effective. The output seems to increase with the peak effect after six months and then it fades out relatively quickly, within two years. The fade out, however, is not gradual but rather wavy until complete smoothing. If it was not for the wide confidence intervals, the highest dynamic output effect would be observable in the case of the Czech Republic. This suggests that the foreign exchange intervention is the most effective measure; although part of the 2015 recovery in the Czech Republic was caused by strong fiscal policy, big government investments in transportation infrastructure respectively. On the other hand, the Fed's impulse response has narrower confidence intervals, which is

probably the result of a more persistent shock to the balance sheet in the U.S. This is apparent in the graph with central bank assets as the response variable. Surprising results are found for the eurozone. The output displays a decrease, exactly the opposite than the impulse responses of the other countries. This is really not an expected result and the study will address these unexpected and seemingly senseless findings later.

In contrast with the reference analysis, a response of prices is ambiguous. Gambacorta *et al.* (2012) found smaller and less persistent, yet significant and obvious increase in prices. They find the peak effect takes place after six months after the shock as was the case of the output. The magnitude of the effect is merely a half of the effect of the output. For Switzerland, they found insignificant impulse response to prices. However, a simple VAR estimation with prolonged period showed in case of the Czech Republic significant decrease in prices, for the U.S. a less significant decrease, for the eurozone a slightly significant increase and then immediate decrease and the Swiss reaction was not significant at all, just as in the reference analysis. The effect, significant or not, fades out after six months. All the impulse responses are rather counterintuitive since the effect on output was positive in most cases, so one could assume that the effect on prices would also be positive. One explanation proposed by Gambacorta *et al.* (2012) is the nominal wage and price stickiness. A shock to aggregate demand (also caused by monetary policy) then has smaller effect on prices than on output. But what actually might cause the negative impulse responses are still strong deflationary pressures. These pressures are consequence of the positive supply shock, a drop in oil prices respectively.

Concerning the implied volatility index as a response variable, the dynamic effect to the VIX of a shock to central bank assets is very insignificant. It supports the theory that the monetary policies implemented by central banks have no impact on financial markets whatsoever. In the reference analysis, authors found a very significant downward effect on the VIX.

After the analysis itself, various post-estimation commands were executed to see how the model stands. Firstly, it is important to check whether the coefficients are jointly statistically significant. Secondly, the Wald statistic is performed to test whether all the endogenous variables at a given lag are jointly zero for each equation and for all equations jointly. Third, Granger causality tests provide a clue whether past values of variable A can be used for predicting

B, given the past values of variable B. Lastly, Lagrange multiplier test checks the autocorrelation in the residuals of the VAR model. The next part will be devoted to the results of those tests and how can these be connected to the impulse response results described above.

The United States Coefficients in the VAR model for all equations are jointly significant. The Wald statistic showed that all equations seemed to have a very similar lag structure; but in the equation for the CPI and VIX, we cannot reject the null hypothesis that all four endogenous variables have zero coefficients at the third lag. Nevertheless, we can strongly reject the hypothesis that the coefficients of the endogenous variables on the first, second and third lag are jointly zero. The problem with the third lag in the two equations calls for some constraining of the VAR model. This has been done by constraining some of the most insignificant coefficient estimates without changing an economic meaning of the whole estimation, of course. However, it changed the results by a very small amount. Performing the Granger causality test showed that for all four equations, we can reject the null hypothesis that the coefficients on all three lags of all dependent variables are jointly zero. For less general causality tests (H0: central bank assets do not Granger-cause CPI, GDP and volatility index) we can reject the null hypothesis at almost 10% significance level. Lagrange multiplier test of no autocorrelation at a lag order showed major autocorrelation issues of first and third order. However, the estimates are, at least, consistent.

Not so weak Granger causality tests for the shock in the balance sheet are actually compatible with the almost significant increase in the GDP impulse response (all tests and impulse responses are based on the same estimates and standard errors). As was already mentioned before, the U.S. GDP response is the closest to have significant increase of all the countries; this might be a result of a longer and more effective implementation of the QE rounds, especially in the first phases, which is also visible in the balance sheet response. The shock is the most persistent compared to the other countries.

The Euro area Coefficients in each equation are jointly statistically significant at 10% significance level. Performing a Wald test statistic and Granger causality tests also calls for placing some constraints. Six constraints were put on the second or third lags in all equations combined, which consequently made

each equation significant at almost 1% significance level. The hypothesis that the coefficients of the endogenous variables on the first, second and third lag are jointly zero can now be strongly rejected as well. Again, constraining the model also changed some of the Granger statistics and we can say that the coefficients on all three lags of all dependent variables are not jointly zero.

Although the model passed general tests for the lag-selection and causality, description of the EA impulse responses themselves is the most challenging of all the countries. Negative response of the output may originate in the short amount of time that had passed from the start of the large-scale asset purchase program in January 2015, which followed after a significant period of decreasing the ECB's balance sheet. In addition, the eurozone is struggling with deflation and other budget deficit problems, which may mitigate the effect on the output—this can actually lead to a visible decrease in impulse response functions.

Switzerland The coefficients in all equations are significant at 1% significance level except for the central bank assets equation which is very insignificant. The Wald test showed that all equations seemed to have a very similar lag structure; but in the equation for CB assets, we cannot reject the null hypothesis that all four endogenous variables have zero coefficients at the first, second and the third lag. Nevertheless, we can strongly reject the hypothesis that the coefficients of the endogenous variables on the first, second and third lag are jointly zero. Performing the Granger causality test revealed that for the GDP, CPI and volatility equation, we can reject the null hypothesis that the coefficients on all three lags of all dependent variables are jointly zero. The LM test of autocorrelation in disturbances proved autocorrelation of the third order. Imposing six constraints on the most insignificant variables changed significance of some of the estimates. The coefficients in the central bank assets equation are now almost significant at 10% significance level. The lag selection situation improved only a little bit. Concerning Granger causality tests, central bank assets still do not seem to affect real GDP or CPI. This is consequently partly imported into impulse responses (with the GDP and the CPI as a response variable), whose confidence intervals are very wide and contain zero all the time. There is still some autocorrelation of the third order in the disturbances.

The Czech Republic The coefficients in all equations are significant at 1% significance level except for the central bank assets equation, which is very insignificant. The Wald test showed that all equations seemed to have a very similar lag structure; but in the equation for the central bank assets we cannot reject the null hypothesis that all four endogenous variables have zero coefficients at the first, second and the third lag. Nevertheless, we can strongly reject the hypothesis that the coefficients of the endogenous variables on the first, second and third lag are jointly zero. Performing the Granger causality test revealed that for the GDP equation and CPI equation, we can reject the null hypothesis that the coefficients on all three lags of all dependent variables are jointly zero. However, this does not apply to the other two equations. Imposing eight constraints on the most insignificant variables changed significance of some of the estimates. The lag selection is now more or less the same in all equations.

It is interesting how similar are the responses of the output especially in the case of Switzerland and the Czech Republic. Even though the implemented policies (foreign exchange interventions) were essentially the same, the duration, the volume and even their purpose was very different in both countries. This suggests that in spite of the heterogeneity in the policies, in the economic environment, etc., the effectiveness of the policies is very similar across countries (which applies to all the countries collectively, except the euro area). The central banks can thus be considered as equally successful in fighting the crisis despite the differences in the country specifics.

It is important to point out that the major differences between this and the reference analysis might be caused by more than doubled sample period, different data management and, of course, different model applied. The panel SVAR model with zero and sign restrictions applied had resulted in (along with the selection of the statistical software) narrower confidence intervals for example. However, the highest importance should be assigned to different datasets and slightly different models.

Concerning the results themselves, it would be premature to use them as an argument against the QE policies, inflating the central banks' balance sheets. If these policies are implemented at a time when an economy rushes into deflation, then the effect might outweigh the originally profound negative impact of deflation. So the slightly positive or zero effects graphed in the impulse re-

sponses (meaning the width of the confidence bounds) might actually represent a success of those actions. The problem here is the absence of a hypothetical scenario of falling into deflation. The results of analyzes should be compared with this scenario to confirm statements regarding their effectiveness. Without it, we might just guess what a situation would be without applying the QE policies (or other policies leading to a boost of the balance sheets).

Chapter 5

Variations & Limitations

5.1 Variations to the Benchmark Model

One possible variation to the benchmark model is to replace the artificially generated monthly real GDP estimates with retail sales that are reported each month. Observing Figure A.1 and Figure A.2, there is hardly any visible correlation between the real GDP and the retail sales, so some of the results presented in Figure A.6–Figure A.9 are different from those in Figure A.10–Figure A.13.

Since lag selection-order criteria chose two lags instead of three in the case of using real GDP, the Wald statistics, Granger causality tests and tests of autocorrelation in disturbances provide different results. For all countries, the shock to the central bank's balance sheet has a very similar impact on the balance sheet. For the United States, impact on prices is basically the same for the case with the retail trade variable and for the case with GDP. Observing the response of the retail trade, we can see a faster and bigger increase of the retail sales. For the eurozone, the results are mostly the same. Impulse responses show zero effect on retail sales and similar response of the prices. As in the case of the United States, the Swiss impulse to the central bank assets has had a slightly increasing effect on the retail sales (however, still insignificant) but larger in magnitude and faster than in the case with GDP. The estimation for the Czech Republic revealed similar responses to the Swiss ones. Impulse response of the retail trade was almost the same but bigger in magnitude. A comparison with the response of the GDP shows the same results as was in the case of Switzerland. So using retail sales instead of the GDP shows more or less the same effects. Minor differences in the speed of the effect and the magnitude

are due to different development of the GDP and retail sales variables as can be seen in Figure A.1 and Figure A.2.

5.2 Limitations

The first limitation mentioned in Chapter 3 was using individual country estimates instead of panel VAR analysis. Panel VAR obtains more efficient estimates and, in combination with mean group estimator used in the reference study, it "takes into account the correlation amongst the residuals across countries to capture (unobserved) factors that are common to all economies while unconventional monetary policy shocks are simultaneously identified" (Gambacorta *et al.* 2012, pg. 7). Other improvement that can be done is implementing zero and sign restrictions to identify the structural VAR. On one hand, this could be done even in this analysis, on the other hand, the statistical software (Stata 13) does not allow for sign restrictions. In addition, here we have used a reduced form VAR model. However, even in the first step of the panel VAR analysis, the reduced form VAR is estimated for each country individually. Usually this is done by estimating every equation by Ordinary Least Squares (OLS) separately, but in the case of Gambacorta *et al.* (2012), the reduced form VAR is estimated by the FGLS estimator instead (which has been used in this work as well). This can in fact take into account the correlation in the residuals of the variables across economies; exogenous factors that affect all the economies but are not captured by either of the variables are also included in the analysis.

The second limitation is still the not so long sample period over which the analysis is done. This can be simply seen on some very different results between the outcome of this analysis and the analysis in the reference study. However, even though a considerable part of the academic community is involved in such analysis, the modeling techniques that are used now cannot be proven surely enough due to the short amount of time that has passed since the first occurrence of the ZLB situation in concerned countries. So, from the point of view of many economists (Franta *et al.* 2014; Gambacorta *et al.* 2012), the results of such analyzes are waiting to be proven in the future. Prolonging the sample period has another advantage. In Chapter 3, there was an outlined problem about the autocorrelation caused by interpolated data. Despite the fact that using non-interpolated retail sales instead of interpolated GDP showed

similar development of the impulse responses, interpolation still generates some autocorrelation in the errors which might pose a problem to the estimation. This, of course, does not invalidate the analysis, it should just draw attention to building the model carefully. As was pointed out in Chapter 4, prolonging the sample period might have another advantage. Even now, time has passed since the start of the large-scale asset purchase program of the ECB in January 2015—doing the analysis in two years might actually generate sligthly different results.

The third limitation that probably cannot be overcome is missing counterfactual scenario of falling into deflation also described in Chapter 4. However, the topic introduced in this thesis might be interesting to extend in the diploma thesis for a number of reasons.

Chapter 6

Conclusion

When the Great Recession struck the world, it came to show how various central banks all over the world were not prepared for immediate action. The central banks at some point after 2008 used up their main policy rates to spur the demand that still remained sluggish even after the policy rates in all concerned countries hit the ZLB. The real GDP was declining and so was the inflation. The main concern in this situation is lowering the real interest rate, which strongly depends on positive inflation expectations. With policy rates stuck at their effective lower bounds in a disinflationary environment, central banks still have some possibilities to ease the monetary policy, i.e. unconventional monetary policy tools. Before the crisis, many economists dealt with this problem and introduced various types of policies to bring down the long-term real interest rate. The central banks of the United States, the eurozone, the Czech Republic and Switzerland, that are of interest in this thesis, employed different kinds of monetary easings—quantitative easing, credit easing, forward guidance, foreign exchange interventions, etc. These policies involve big inflation of the central bank's balance sheet. The Federal Reserve introduced measures to solve the liquidity crisis and injected money into the most needful areas of the financial market. It also came up with Large Scale Asset Purchases, which had the largest share in boosting the balance sheet. The European Central Bank enacted Covered Bond Purchase Programme but most recently it introduced a huge asset purchase program which would hopefully lead the euro area out of the deflation. Both Switzerland and the Czech Republic used foreign exchange interventions to ease the monetary policy, but for different reasons. The policies were in some ways very similar, and this consistency is also visible in the development of M2 or M3 aggregates. Despite the great increase in the

balance sheets and almost the same increase in monetary bases, the monetary aggregates increased more or less at the same pace as before. The banks held the extra liquidity as reserves and did not provide the credit to the public.

There has been some effort to quantify the impact of the policies on the economy and their effectiveness. This thesis, with the help of a previously written study by Gambacorta *et al.* (2012), tried to find out whether the policies in the four economies were effective or not. It used a simple VAR model to graph the influence of the unconventional shock into the balance sheet on the GDP, inflation, and the financial market uncertainty. The main contribution was in this case the inclusion of the Czech Republic in the analysis and a prolonged sample period that cover more than just the crisis period, so the estimation is based on more data. Due to rather wide confidence intervals the results should be treated with caution. Although the results were counterintuitive in some cases, we can say that the injections into the balance sheet have a temporary influence on the real output (except the euro area) but a small and insignificant effect on prices. No effect was found in the case of financial market turmoil. Replacement of the GDP with the retail sales variable showed minor differences in the results; the impulse responses were mostly bigger in magnitude and the effect faded out faster. This not so convincing conclusion might be a result of an uncertainty about how would the economic environment and macroeconomic variables have developed without the introduction of these policies. It would be a premature and imprudent step to say that, based on these results, the unconventional policies have no impact on broader economy. Zero or even a slightly negative (meaning the inclusion of the confidence intervals in the impulse responses) result might conceal even very convincing effects.

There are many ways how the analysis can be improved. The panel SVAR, for example, offers more efficient estimates, another extension of the original model might be a combination of zero and sign restrictions, which could make the results easier to interpret. As of April 2016, deflation in the advanced world is still an issue, and for some countries too little time has passed since the QE programs were cancelled, or, for some, are still in effect. So estimating the model on an even more prolonged sample period would be interesting for future analysis.

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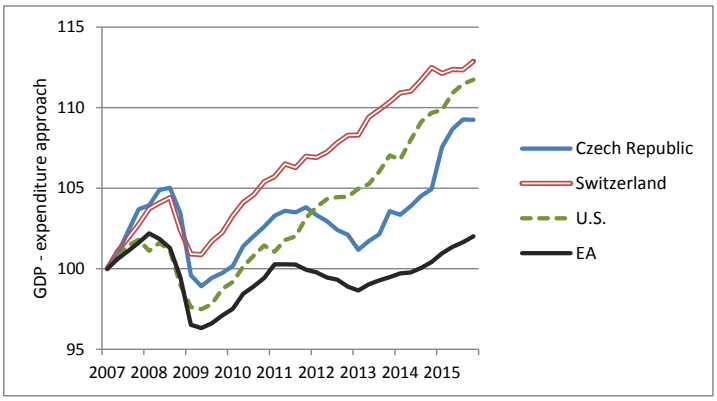
Appendix A

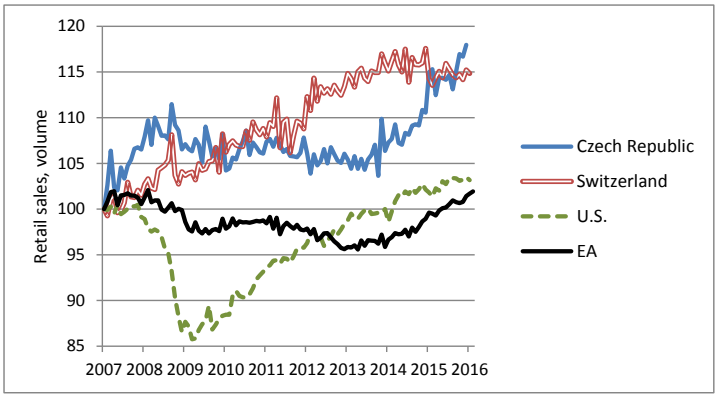
Macroeconomic dynamics & IRFs

Figure A.1: Real GDP indexed to 100 in the first quarter of 2007



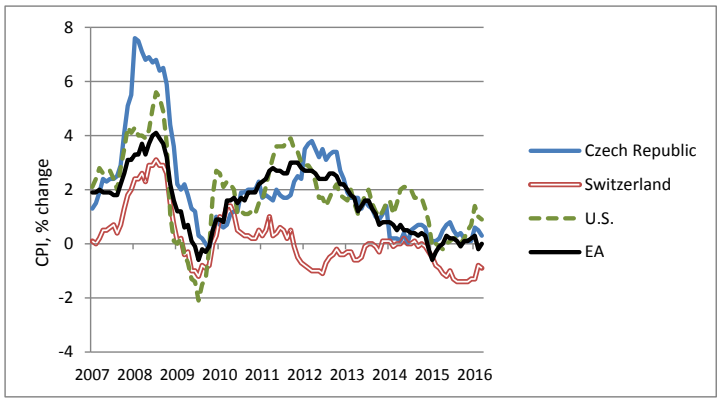
Source: author's computations, OECD. GDP—expenditure approach, measured in national currencies, volume estimates, seasonally adjusted.

Figure A.2: Retail sales indexed to 100 in the first quarter of 2007



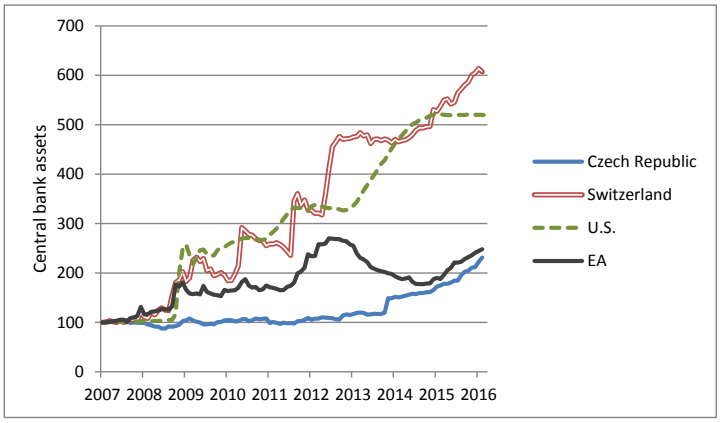
Source: author's computations, OECD. Total retail trade, volume, seasonally adjusted.

Figure A.3: CPI



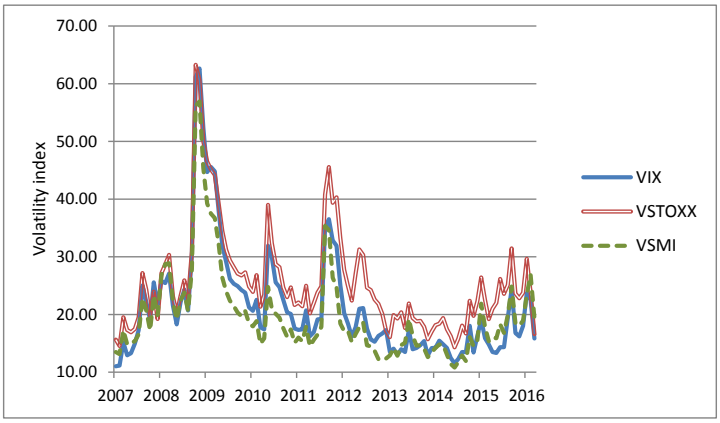
Source: author's computations, OECD. Percentage change of CPI on the same period of the previous year.

Figure A.4: Central bank assets indexed to 100 in the first month of 2007



Source: author's computations, Federal Reserve Bank of St. Louis, SNB, CNB. Central bank assets in nominal terms, measured in national currencies.

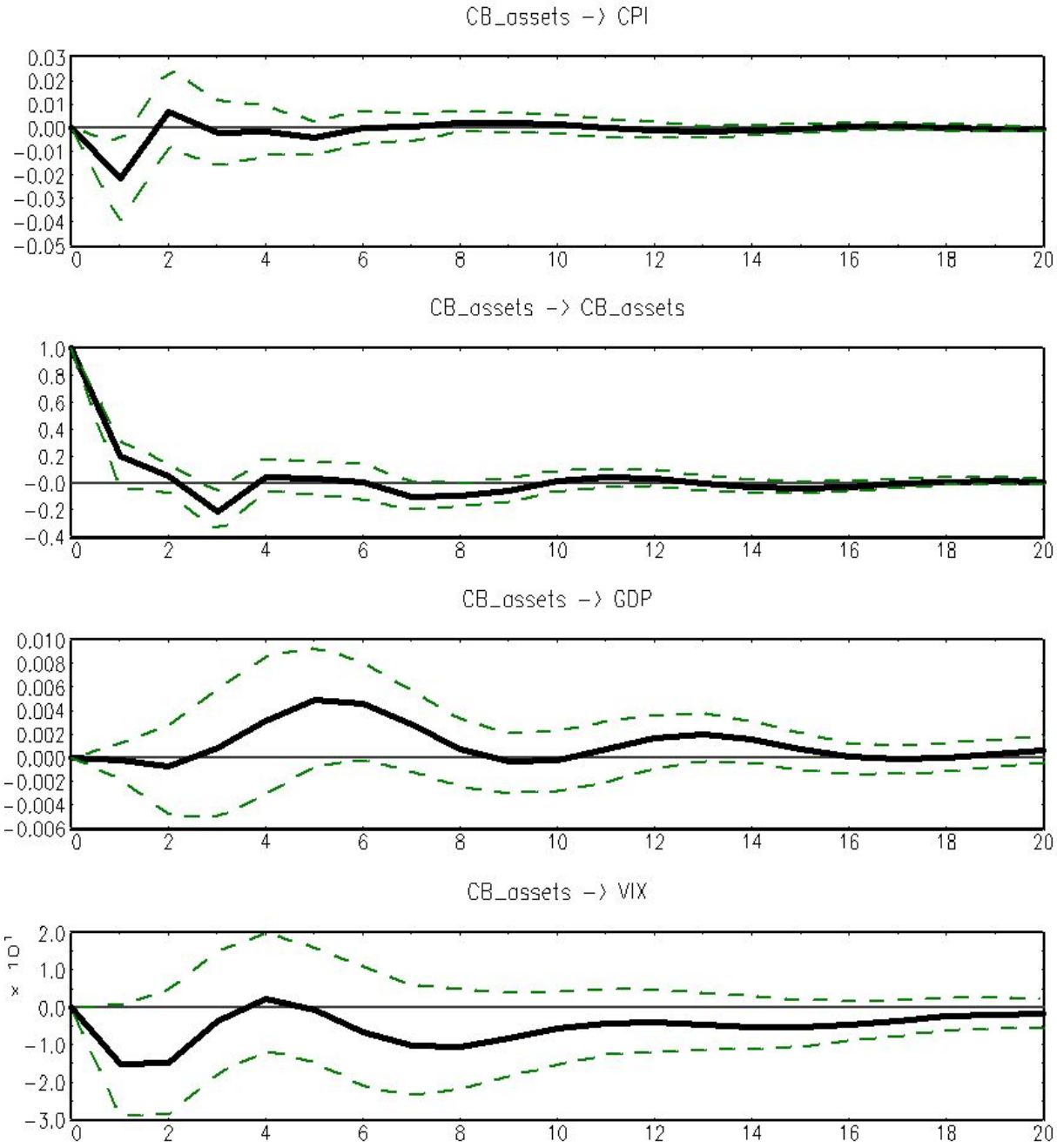
Figure A.5: Implied volatility indices



Source: author's computations, Federal Reserve Bank of St. Louis, SIX Swiss Exchange, STOXX Exchange.

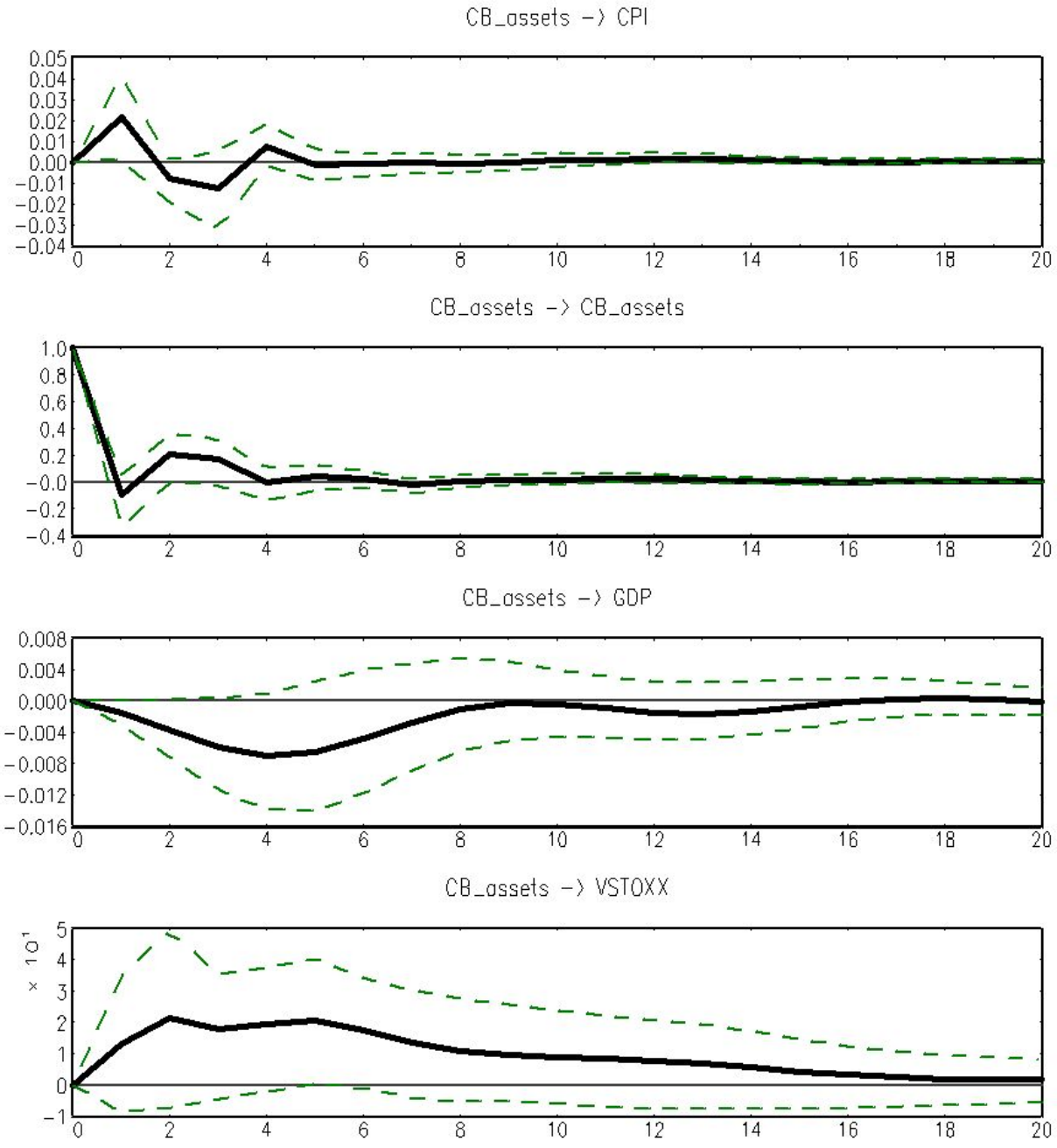
A.1 Impulse responses

Figure A.6: United States



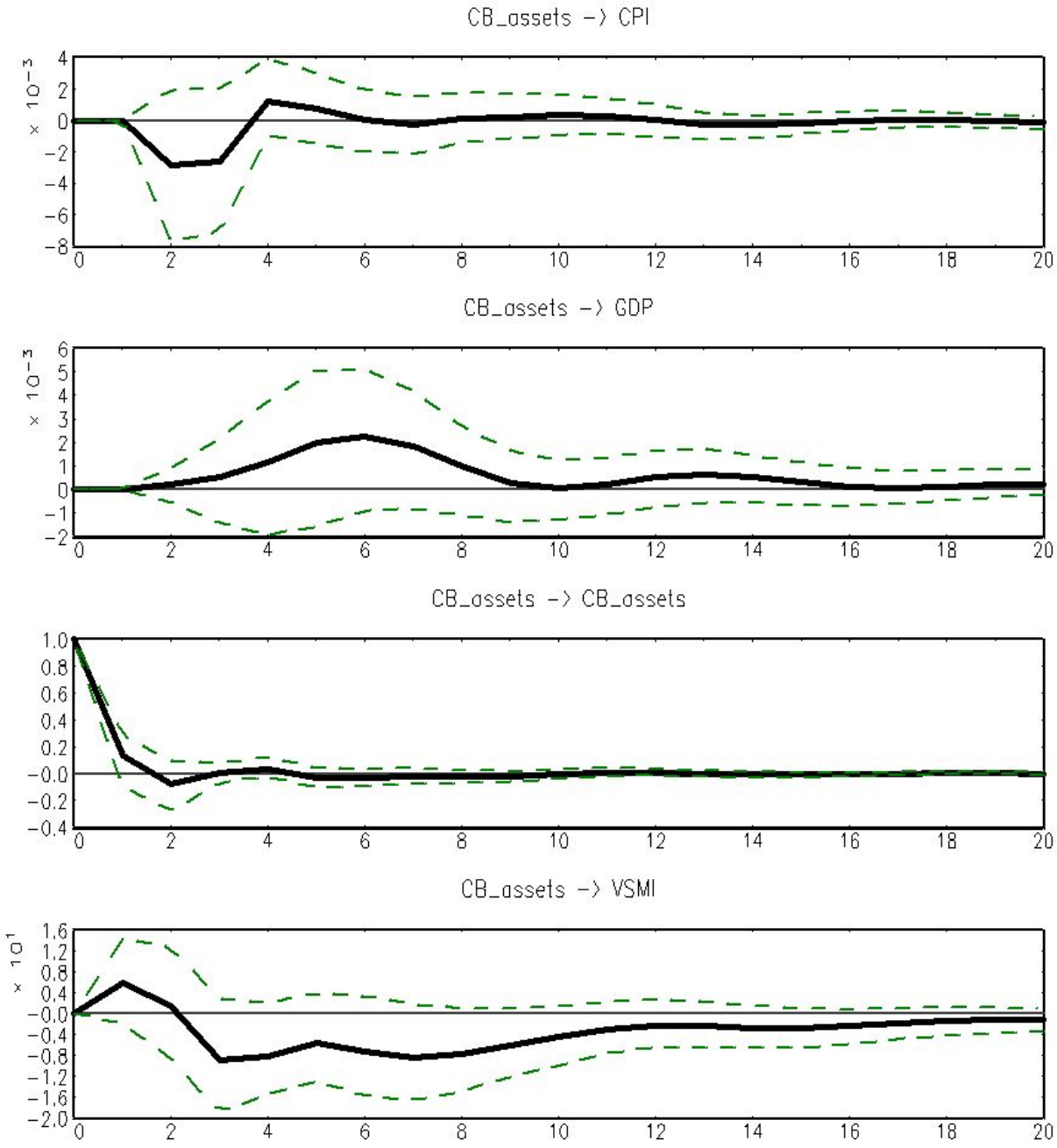
Source: author's computations using JMulTi statistical software, data: see Section 3.2. Monthly horizon, dashed lines—90% Efron Bootstrap Percentile CI.

Figure A.7: Euro area



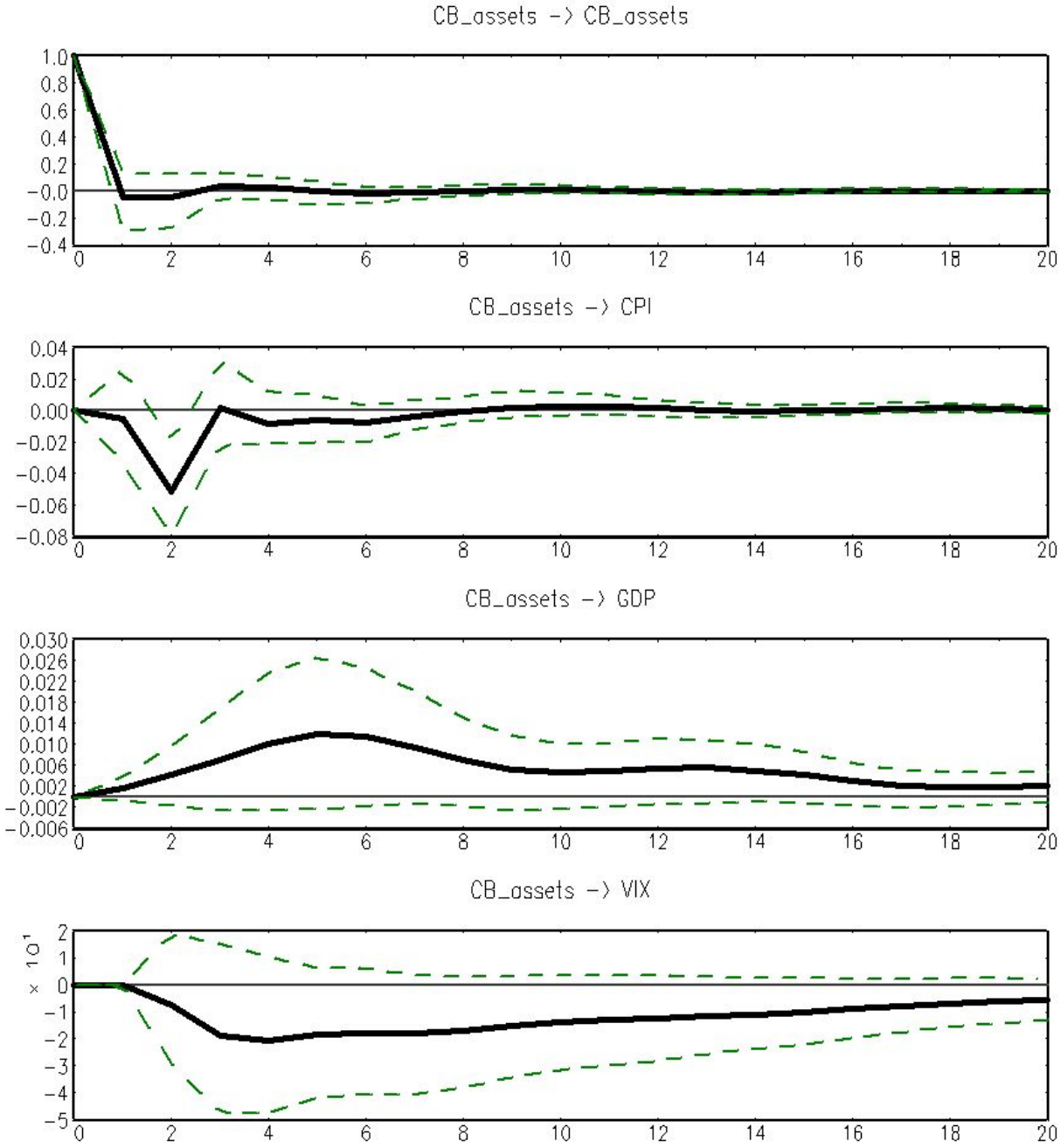
Source: author's computations using JMulTi statistical software, data: see Section 3.2. Monthly horizon, dashed lines—90% Efron Bootstrap Percentile CI.

Figure A.8: Switzerland



Source: author's computations using JMulTi statistical software, data: see Section 3.2. Monthly horizon, dashed lines—90% Efron Bootstrap Percentile CI.

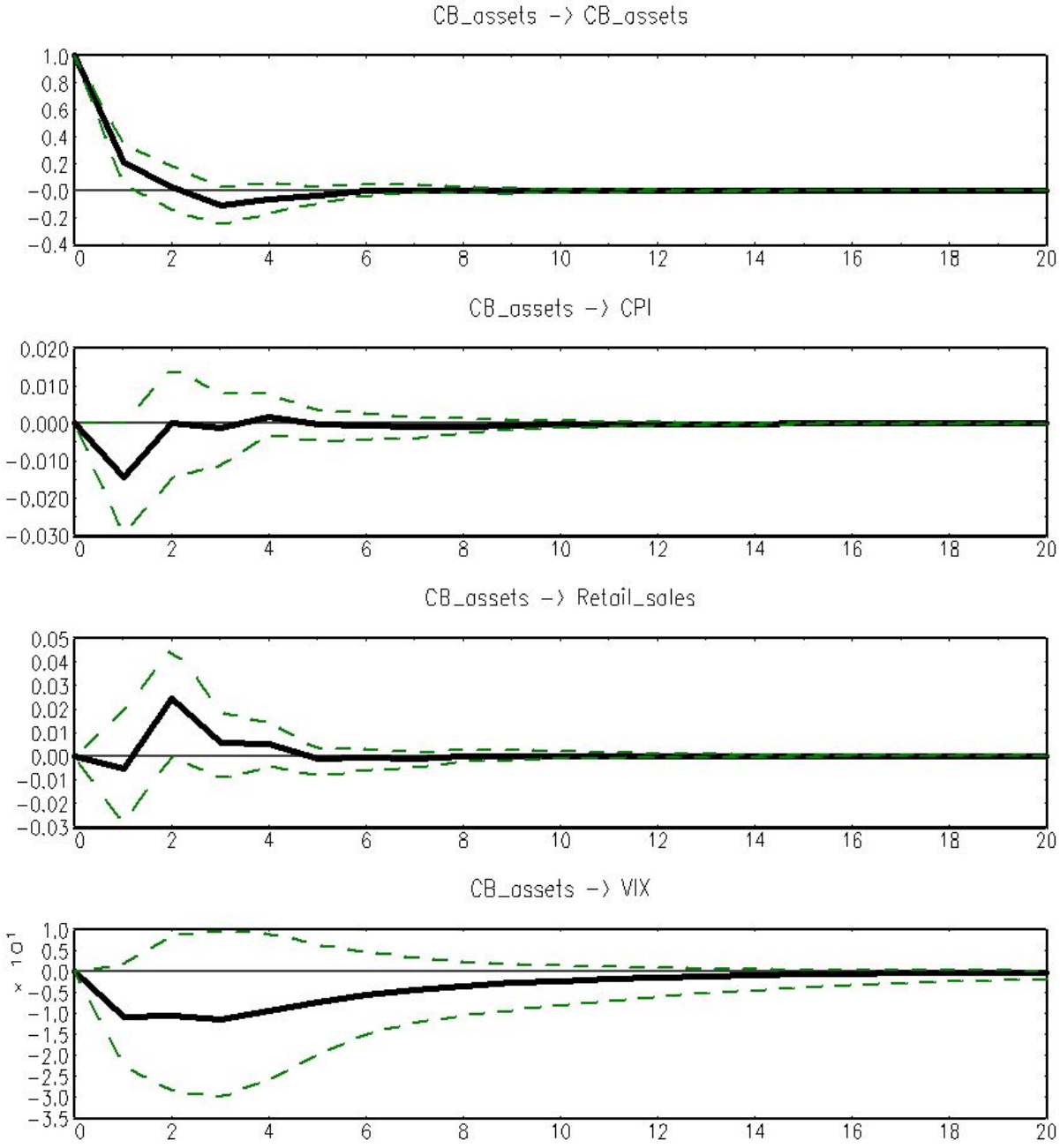
Figure A.9: Czech Republic



Source: author's computations using JMulTi statistical software, data: see Section 3.2. Monthly horizon, dashed lines—90% Efron Bootstrap Percentile CI.

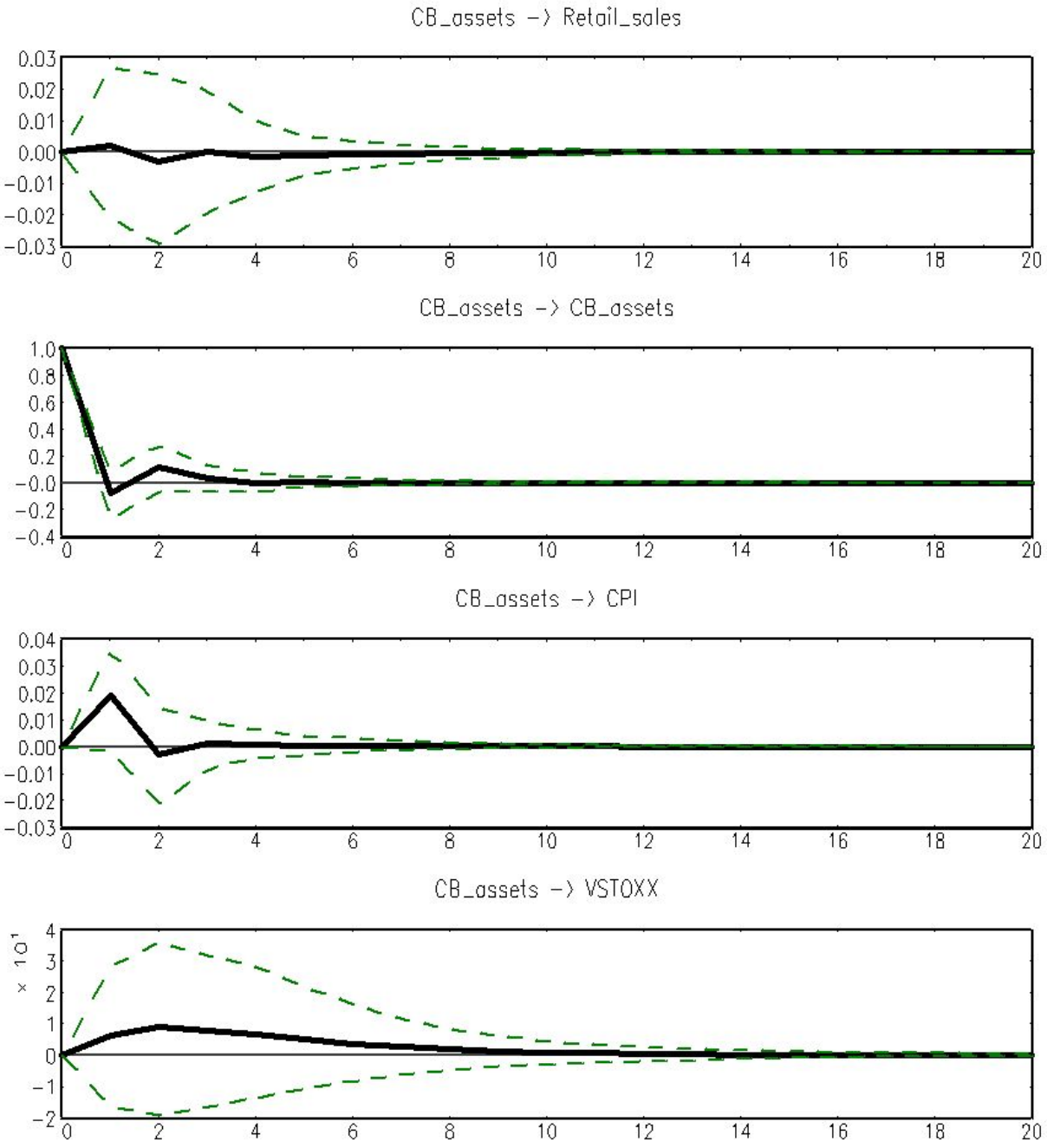
A.2 Impulse responses when retail trade is used instead of GDP

Figure A.10: United States



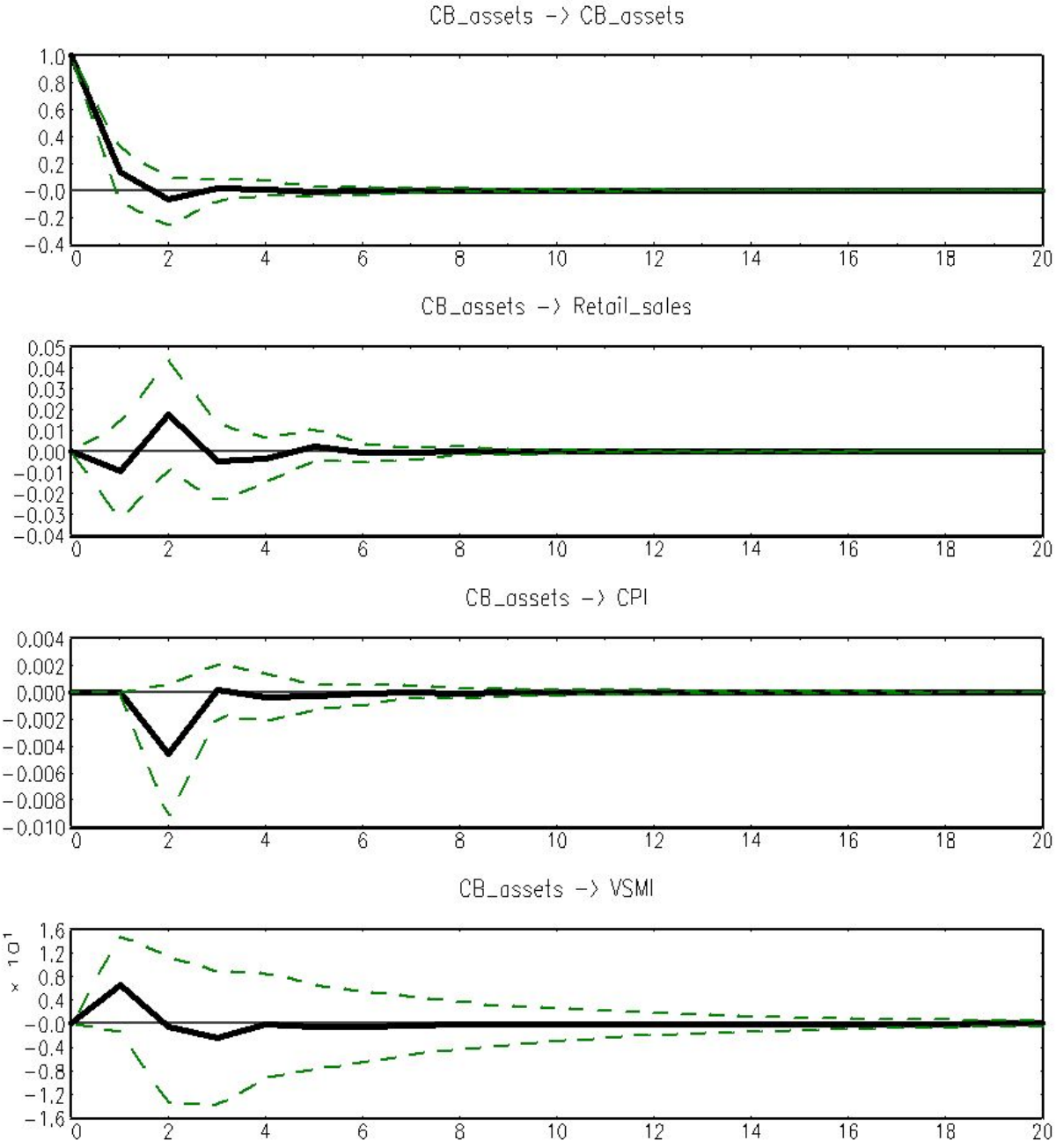
Source: author's computations using JMulTi statistical software, data: see Section 3.2. Monthly horizon, dashed lines—90% Efron Bootstrap Percentile CI.

Figure A.11: Euro area



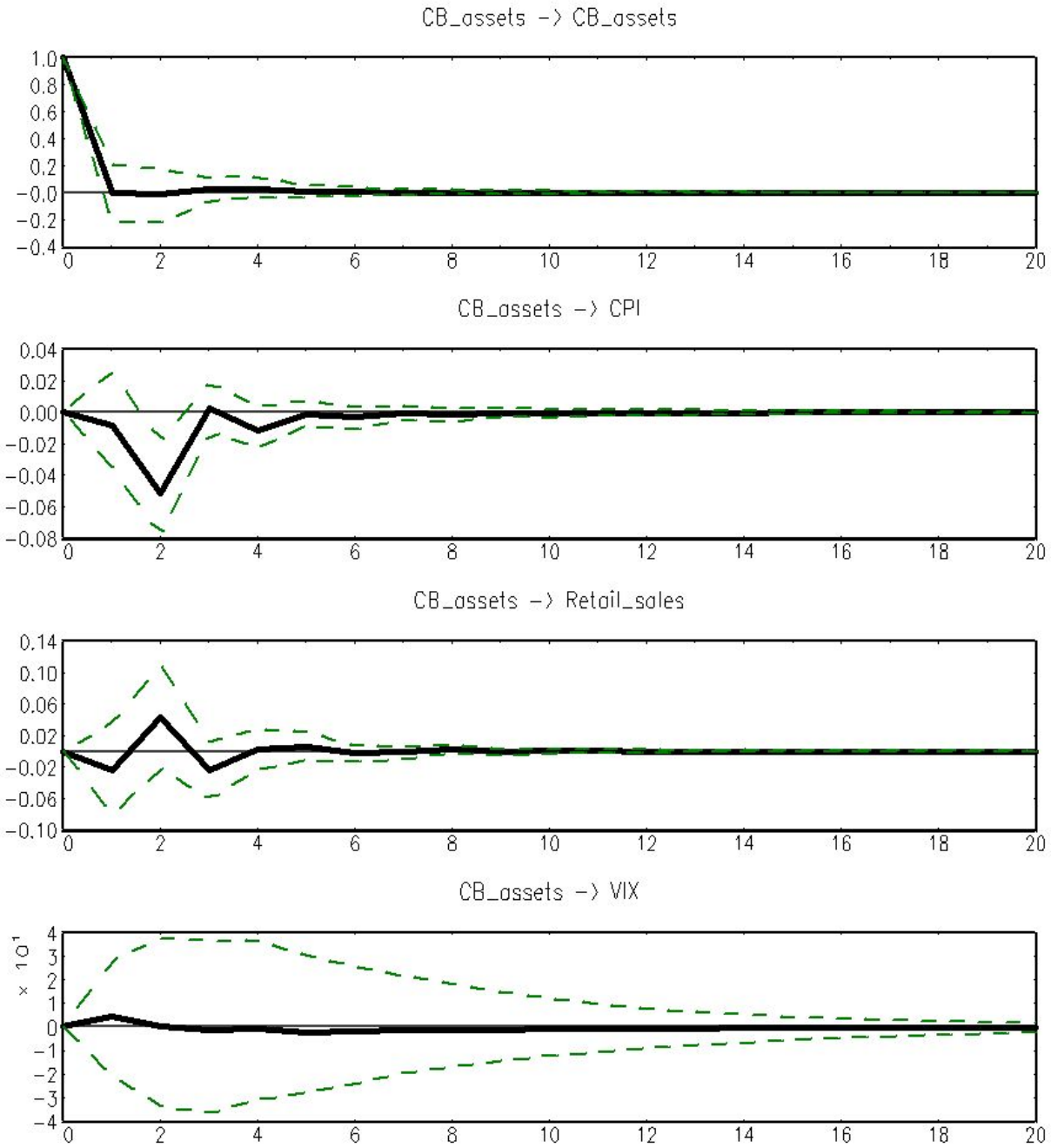
Source: author's computations using JMulTi statistical software, data: see Section 3.2. Monthly horizon, dashed lines—90% Efron Bootstrap Percentile CI.

Figure A.12: Switzerland



Source: author's computations using JMulTi statistical software, data: see Section 3.2. Monthly horizon, dashed lines—90% Efron Bootstrap Percentile CI.

Figure A.13: Czech Republic



Source: author's computations using JMulTi statistical software, data: see Section 3.2. Monthly horizon, dashed lines—90% Efron Bootstrap Percentile CI.