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THE EXIT FROM UNCONVENTIONAL MONETARY POLICY: IS THE EUROPEAN CENTRAL BANK AT RISK?

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Abstract

The contemporary central banking has seen a wide range of non-standard monetary policy instruments applied for stimulation of economies hit by the 2008 financial crisis. In a decade's time after the turmoil, as economies are regaining growth and stability, major central banks seek ways to taper their stimuli. However, the shift to contractionary monetary policy, followed by increases in interest rates, can significantly reduce the value of assets held by central banks, which creates problems for their balance sheets and policy targets.

While major central banks of the world see potential support in respective central fiscal institutions, the absence of a central fiscal institution in the Eurozone makes exit strategies more complicated for the ECB. Namely, if a central bank faces extreme losses that threaten its policy targets, the central fiscal institution has to recapitalize it; however, it is not clear whether the ECB can rely on this support, and what the central bank should do if it is forced to declare insolvency.

Using methodological approaches developed for the economies of the US and Japan, we provide a comprehensive stress-resistance check of the Eurosystem. Our research has an important implication for policymaking, since it provides quantitative evidence that the ECB can overcome large demand shocks and corresponding interest rate rises without declaring insolvency. Our study also serves as a stepping stone for further research on exit strategies from the unconventional monetary policy of the European Central Bank, suggesting that although insolvency scenarios are unlikely, a more evident link between fiscal and monetary authorities in the Eurozone is required.

Keywords

Unconventional monetary policy, central fiscal institution, central bank insolvency, VAR, shadow rate

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1. Introduction

In the aftermath of the 2007-2008 financial crisis, major central banks have relied on stimulating monetary policies, aiming to revive plummeting economies. Pressured by the European debt crisis that started in 2009, the European Central Bank alike has resorted to a reduction of the key interest rate, plunging into the negative zone in 2015. Besides, the ECB balance sheet has expanded significantly through asset purchase programmes: since 2014 average net purchases have constituted 60 billion EUR per month; from April 2016 until March 2017 – 80 billion EUR per month on average; whereas from March 2015 till March 2016 the average pace was at the monthly level of 60 billion EUR. These measures are referred to as tools of non-standard or unconventional monetary policy. They have been resorted to by the ECB with the primary objective to sustain the inflation in the Eurozone at the level close to, but slightly below 2%, as well as to restore economies of the monetary union.

The stimulated economies of the currency union started to recover and regain stable growth in the beginning of 2017, and the European Central bank is currently establishing ways to moderate the intensive stimuli. Indeed, recent ECB press releases confirm that a smooth exit strategy is a primary concern for the bank. Although Mario Draghi, President of the ECB, is certain that asset purchase programmes will continue at least until September 2018, the Governing Council of the ECB has halved the value of monthly asset purchases, reducing them to 30 billion EUR per month starting from January 2018.

Nevertheless, the exit blueprint is not as straightforward as it seems to be, since even if the ECB downsizes asset purchases, the proceeds will be reinvested for some time after the QE horizon, maintaining the size of the balance sheet. The importance of the general question – an exit strategy from exceptional stimulating measures – is explained by the inverse relation between interest rates and bond prices.

In other words, even a slight shift to a more contractionary monetary policy will increase long-term interest rates and may lead to a heavy erosion of the ECB balance sheet. As of October 2017, the ECB accumulated €2,180,526 million of holdings from its asset purchase programmes, which accounts for 49.86% of the bank's assets. Thus, as economies get back to a stable growth, the shift to a more conservative monetary policy does not seem straightforward.

This issue has been extensively covered in recent academic research. Studies by such authors as Vice President of the Federal Reserve Bank of New York Marco Del Negro and Nobel Laureate Christopher A. Sims (2015), Chen, Filardo, He, and Zhu (2017), Fujiki and

Tomura (2017), Carpenter, Ihrig, Klee, Quinn, and Boote (2015), and Hall and Reis (2015) closely analyze the linkages between central bank balance sheets and unconventional monetary policies. A crucial input by Del Negro and Sims (2015) is that they incorporate fiscal policies into their models – the authors study and emphasize the importance of fiscal support and fiscal backing when central banks face solvency threats. They conclude that the Federal Reserve System will only require fiscal support in extreme scenarios, and it can generate enough seigniorage to avoid insolvency, given its policy targets and asset composition at that moment.

However, the authors have mainly considered the instances of the Federal Reserve System and the Bank of Japan. Accounting for the differences between the researched states and the Eurosystem, the aforementioned findings cannot be immediately applied to draw conclusions for the ECB. First of all, the US, Japan, as well as the Eurosystem developed and recovered differently from the turmoil of 2008; besides, they feature different macroeconomic conditions. What is more, the key distinction between these cases and the ECB is that the Eurosystem does not have a central fiscal institution, which questions the availability of fiscal support for the ECB. Finally, the authors who have considered the ECB balance sheet and feasible ways to withdraw from the unorthodox monetary policy, such as ECB representatives (e.g. Constâncio, 2015 and Belke, 2016), have not developed fundamental mathematical or econometric models to assess possible exit strategies for the ECB.

Given the absence of a central fiscal institution in the Eurozone, it is crucial to test the reaction of the European Central Bank to a macroeconomic shock to see the impact of a swift economic recovery on the ECB balance sheet. Consequent scares might result in heavy erosion of the ECB balance sheet, which will force the European Central Bank to require urgent support. Therefore, it is essential to be aware of how vulnerable the ECB balance sheet is to unforeseen events and shocks.

Based on the models developed for the Federal Reserve System and the Bank of Japan, we perform a stress test of the ECB, considering that the central bank holds medium and long-term bonds on its balance sheet, which can make it vulnerable to large interest rate shifts. It should be stressed that we are not developing the most probable baseline recovery scenario. Instead, we model some black swan-like destructive events and show how likely the ECB is to declare insolvency under these extreme conditions. Thus, based on our results we will be able to see potential risks for the ECB, given the economy is facing a faster recovery.

Therefore, we have developed the following research question:

How vulnerable is the European Central Bank to shocks in the economy, given the absence of a central fiscal institution in the Eurozone?

The current thesis fits smoothly into the existing literature and research, adding the novelty through building an econometric model of central bank insolvency for the euro area. We run Vector Autoregressions to see the impact of macroeconomic shocks on interest rates, which enables us to estimate expected losses for the ECB if a black swan-like event takes place. The key advantage of this approach is that it is empirical and driven by actual euro area data. Besides, it requires a smaller set of strict assumptions, and it is less complex than the academic models that are typically used in this line of research (e.g., in Del Negro and Sims, 2015).

The second section of the study is devoted to an analysis of the existing literature and the links between the previous academic research and the question of the current thesis. It also elaborates on some notions used in this study, laying the basis for the methodology and discussion. The third section includes the empirical methodology: description of the VAR model, shock simulation, and a discussion of insolvency conditions. Sections four and five include discussion of results, robustness checks, and conclusions.

2. Literature Review

2.1 Links Between Monetary and Fiscal Policy

One of the earliest studies on the importance of coordination between monetary and fiscal policies was conducted by Sargent and Wallace (1981), and it suggests that monetary policy should be backed by fiscal measures to sustainably control inflation rates over the long run. The authors argue that if fiscal policy is dominant in an economy, it sets target levels of budget surplus/deficit. In some cases, central banks have to allow for seigniorage to sustain a certain degree of budget deficit, which inevitably leads to higher inflation. Thus, the authors make a fundamental conclusion that inflation targeting is impossible without coordination between fiscal and monetary policy measures.

Based on this conclusion, Nobel Prize Laureate Christopher A. Sims develops his ideas that macroeconomic theory does not take into account close links between monetary and fiscal policies. He creates several mathematical models to take a closer look at how to efficiently conduct monetary policy. For instance, Sims (2004) develops fundamental ideas for cases when there is more than one monetary and/or fiscal institution, such as in currency boards and monetary unions. Later Sims (2005) emphasizes certain limitations to inflation targeting, related to political reasons and central bank independence. He argues for more transparency – central banks have to explain what they do if they want to avoid panics and enhance credibility, – and again demonstrates that inflation targeting is much more limited without appropriate fiscal backing.

Finally, in his more recent study, Sims (2016) draws a bigger picture: the author makes connections between taxation, government spending, and open market operations of a central bank when explaining inflation. He looks at monetary policies conducted in the US, the Euro Area, and Japan, trying to explain their pitfalls and relate them to policy interaction. Supporting his previous research and conclusions, Sims demonstrates that the lack of necessary fiscal support at the zero lower bound of interest rates is the reason for excessively large balance sheets and extremely low inflation rates. In his further research, Sims (2016) argues that a need for fiscal support can be a strong argument for those against central bank independence, which might create incentives for central banks to use fiscal support as a measure of last resort, as well as create political pressure.

In other words, academic literature provides a profound insight into why fiscal coordination of monetary and fiscal policies, as well as fiscal support, are necessary for a smooth and efficient functioning of a central bank and its inflation rate targeting. As we know, the Eurosystem is not backed by a central fiscal institution, and, thus, it is more vulnerable compared with the Federal Reserve System and the Bank of Japan. This makes potential balance sheet erosions a more serious issue for the ECB, and it has been discussed since Sims (2001) who argued for the creation of a centralized fiscal institution in the Eurozone.

2.2 Fiscal Support vs. Fiscal Backing

The earlier research by Sargent and Wallace (1981) along with contemporary studies by Del Negro and Sims (2015) and Reis (2015) emphasize that fiscal support of a central bank has to be distinguished from fiscal backing of monetary policy. Del Negro and Sims (2015) draw a dichotomy between the notions, clarifying that fiscal support stands for a within-government transaction that banks have to require in case of solvency threats; whereas, fiscal backing is a fiscal policy that is consistent with an inflation target set by the central bank.

Sargent and Wallace (1981) also claim that under certain circumstances monetary policy is not even efficient in controlling short-term inflation, which suggests that fiscal backing is an essential part of monetary policy efficiency. They demonstrate it by showing an example where a central bank tries to reduce inflation by introducing tighter monetary policy measures, and, hence, the public expects the central bank to increase money supply growth rates in the future. The authors argue that since money demand is a function of expected inflation rates, current prices are determined by all future levels of the money supply. In other words, if people expect high money supply in the future, price levels will adjust immediately, causing high levels of inflation in the present. Thus, through similar examples, the authors show that higher inflation levels cannot be controlled by tighter monetary policy measures alone.

In other words, monetary policy is only efficient in targeting inflation if it is backed by fiscal policy. Fiscal backing is designed to go in line with monetary policy, as well as to support the central bank if it becomes vulnerable due to its nonstandard monetary measures. However, before we can argue about the role of a centralized fiscal institution and its supportive measures, it is important to clearly define central bank insolvency and the role of the government in this process.

2.3 What is Central Bank Insolvency?

As argued by Adler et al. (2016), a central bank cannot default by definition, since it can always print fiat money to cover its nominal liabilities through seigniorage. This could mean that the central bank balance sheet composition is irrelevant, since any potential losses can be immediately offset by money growth. However, this strategy makes inflation targeting impossible, and a central bank committed to its policy objectives has to set a limit on seigniorage in order to restrict money growth, and, thus, control inflation rates.

Further, Reis (2015) argues that as long as the liabilities of a central bank are supported by fiscal authorities, the former cannot be insolvent separately from the overall government. However, he argues that guidelines, laws, and procedures for recapitalization of a central bank through a within government transaction have not been defined for most major central banks, including the Federal Reserve System and the Bank of Japan. Thus, one cannot guarantee that these central banks (as well as the ECB) have full government support and cannot become insolvent separately from the government.

Additionally, Del Negro and Sims (2015) discuss a different case where modern-type central banks can increase their reserve deposits without significant inflation pressure. The authors argue that if interest-bearing liabilities are not offset by interest-bearing assets or higher taxation, the private sector will be receiving an infinite stream of interest payments from the central bank, which will eventually cause high inflation even if there is no money supply growth. In other words, this will violate the private sector's transversality condition, which implies that increasing interest-bearing liabilities as a means to pay the bills is very limited.

Thus, Del Negro and Sims (2015) argue that a central bank that is concerned about controlling inflation in the long run has to be able to rely on support from fiscal authorities in case its policy rule is threatened. Following the methodology suggested by Del Negro and Sims (2015), we further define central bank insolvency as the inability of a central bank to carry out its monetary policy, i.e. stay committed to the targeted inflation level without fiscal support. Primarily speaking, the authors claim that a central bank declares insolvency if its interest-bearing liabilities exceed interest-bearing assets. In the Methodology section, we look at the ECB balance sheet and determine specific levels of losses that will force the bank to require fiscal support and, thus, declare insolvency. Besides, we estimate potential losses for the ECB under the baseline scenario and test whether these losses are sustainable.

2.4 Current Research

Despite being recent, the research by Del Negro and Sims (2015) is cited in a large number of works on interactions between monetary and fiscal policy, as well as when estimating how central banks react to interest rate changes. Their study has been very relevant for the Federal Reserve System and its withdrawal from the intensive monetary stimulus; besides, the research also provides some implications for the Eurosystem, as it incorporates insolvency analysis and fiscal policy engagement in the monetary measures.

Reis (2015) applies the conclusions developed by Sargent and Wallace (1981) to the major modern central banks, such as the Federal Reserve System and the European Central Bank. He claims that both banks are committed to transferring positive income to the Treasury every year; however, cases of transfers in the inverse direction, which might imply the recapitalization of an insolvent central bank, are not considered. Further, he distinguishes between three types of central bank insolvency, suggesting that a central bank is solvent as long as the present value of its payments to the treasury is non-negative. Finally, he makes important conclusions about seigniorage, and how it changes with inflation, suggesting that a runaway inflation can threaten central bank's solvency too.

In a subsequent study, Reis (2017) considers quantitative easing as a stimulating measure during a fiscal crisis. He looks at QE during the financial crisis and tests whether the policy measure is still reasonable given several recent increases in the federal funds rate and other signs of a global economic recovery. Motivated by historically high debt levels in the US, the UK, Japan, and the Euro area, instead of looking at exit strategies, Reis focuses on a potential fiscal crisis and how useful the QE will be under such a scenario. The author concludes that quantitative easing is an efficient means against a potential fiscal crisis, since it can stimulate the economy in two very important ways. The first way is through altering the sensitivity of inflation to fiscal shocks by adjusting the public holdings of government debt. The second is that QE absorbs a certain portion of risk that is related to government bonds that cannot serve as safe collateral during the crisis. This prevents financial markets from freezing, since the central bank takes the risk on its balance sheet.

Additionally, Harrison (2017) argues that in spite of the significant influence of QE on central bank balance sheets, there has been little research on how asset purchase programmes should be conducted. He refers to Del Negro and Sims (2015) arguing that interactions between monetary and fiscal authorities have to be modeled carefully; however, he models quantitative easing as an "exclusively monetary policy operation".

More empirical pieces of research look at current balance sheet compositions and the amount of asset purchases, analyzing how these factors affect monetary policy efficiency. For instance, Adler et. al. (2016) is a more recent elaboration on the fundamental conclusions made by Sargent and Wallace (1981). They argue that theoretically, there are at least two reasons why the central bank balance sheet is irrelevant for monetary policy. The first one is that central banks can always cover existing deficits via seigniorage, and the other is that if a central bank and a treasury have a joint budget constraint, the central bank will always be bailed out if its capital is low or negative. However, they find that a weak central bank balance sheet can negatively influence the conduct of monetary policy, which suggests that even if recapitalization as a within-government transaction is possible despite its potential costs for a central bank's independence, the central bank should still be concerned about loss minimization. Thus, a loss-minimizing path of interest rates has to be determined.

What is more, Fujiki and Tomura (2017) analyze the proposed exit strategy for the Bank of Japan. In turn, referring to Del Negro and Sims (2015), the authors conclude that the Bank of Japan will face significant fiscal losses by the moment it abandons the Qualitative and Quantitative Easing (QQE); however, clear recapitalization options are not suggested

2.5 Unconventional monetary policy in the Eurosystem and its implementation

In this study, we scrutinize the reaction of the ECB balance sheet on unprecedented scenarios that might disturb the Eurosystem and even lead to insolvency of the Central Bank through erosion of its balance sheet. This study does not aim to describe a primary scenario for the Eurosystem: in the data-driven model, we consider how extraordinary shocks in the economy affect the balance sheet of the European Central Bank. The black swan events might involve changes in the sentiment of consumers, disruptions in financial markets, political events, etc. (with the aim to avoid conjecturing, we are not looking to provide precise stipulations on circumstances of extraordinary shocks).

Numerous studies discuss monetary transmission mechanisms (Bowdler and Radia, 2012; Gambetti and Musso, 2017; Andrade et al. 2016) claiming that monetary policy resolutions have a significant influence on financial markets, as well as the real economy (e.g., Gambetti, Musso, 2017; Fratzscher, Lo Duca, Straub, 2016; De Santis, 2016; Altavilla, Carboni, Motto, 2015). Accordingly, disruption of the ECB's stability might have a far-reaching adverse effect on the economy and financial markets of the Eurosystem, as well as spillovers on emerging markets and developing economies. This is supported by such studies as De Santis (2016) who argues that an implicit announcement of the ECB's intentions regarding APP, which preceded the official announcement of the programme by several months, had been incorporated into the long-term bond yields long before the programme was initiated.

In their extensive study, Haitsma, Unalmis, and Haan (2016) examine stock market reactions to monetary shocks and describe two important mechanisms that allow central banks to influence asset prices. First, the influence that central banks have on interest rates allows them to adjust discount factors of future cash flows, and thus asset prices. Second, different monetary policies adjust analysts' expectations about the future performance of certain companies; for instance, expansionary monetary policy leads to more positive sales and profit forecasts, and, hence, instantly higher stock prices.

Therefore, it is reasonable to expect that due to its direct influence on financial markets, central banks can cause high turbulence if they are insolvent: analysts will have to readjust their forecasts that initially impounded the plan which cannot be carried out by the central bank anymore. Financial stability of the Eurozone strongly depends on the ECB, so it is prudent to consider different scenarios to predict the stock market reaction in case the Central Bank is suddenly insolvent, and how likely it is to happen.

Existing literature suggests that monetary policy influences the real economy mainly via financial markets through a set of transmission channels (Andrade et. al, 2016, Gambetti and Musso, 2015, Bowdler and Radia, 2012). According to these authors, the latter are presented by portfolio rebalancing, liquidity, and signaling, which we will discuss in more detail. Accounting for the current position of the central bank's balance sheet, as well as considering the range of potential impact and spillover effects of its erosion, it is crucial to keep in mind that the described course of events might be a black swan – an unexpected, previously unseen, and impactful occurrence.

It is important to highlight that this study is not a predominant scenario simulation, but rather a stress test. Such a scenario will lead to negative consequences, for example, a loss of credibility by the ECB; besides, stronger European economies will have to intervene due to the lack of a centralized fiscal authority, which will negatively affect their sovereign budgets.

2.5.1 Quantitative easing

The ECB has been adopting a range of standard and unconventional measures in order to revive the economy of the Eurozone that was hit during the 2007-2008 financial crisis. As the turmoil stroke financial markets in August 2007, the ECB initiated several strategies connected with liquidity management measures, such as liquidity injections in 2007 and 2008 (ECB, 2009) and arrangements with other major central banks to provide liquidity to foreign currencies. Besides, the ECB temporary narrowed the rate corridor between its standing facilities – the marginal lending and the deposit. Later, the ECB initiated security purchase programmes, starting with Covered Bond Purchase Programmes – CBPP1 in 2010 and CBPP2 in 2011, – and securities market programme (SMP). The aim of these programmes was to foster financial markets recovery, as well as to support the banking sector (Gambetti, Musso, 2017). These programmes have been successfully terminated as planned, and the purchased securities are held to maturity.

Besides, the ECB performed several cuts on its key interest rates, making some short-term rates negative starting from 2014. As the key European interest rates were at their historical lows, the ECB resorted to quantitative easing – the asset purchase programme (APP), announced in early 2015 and launched in the second quarter of 2015. By then, quantitative easing had been already adopted by major central banks – the Fed of the USA and the Bank of Japan – for several years already. Quantitative easing stands for a large-scale asset purchase programme performed by a central monetary institution using newly created electronic money, aiming to stimulate the economy through a reduction in long-term interest rates and cheaper borrowing.

Currently, active asset purchase programmes include Public Sector Purchase Programme (PSPP), Covered Bond Purchasing Programme 3 (CBPP3) and Asset-Backed Securities Purchase Programme (ABSPP). The ECB committed its monthly purchases of eligible marketable debt securities in the total volume of EUR 60 billion (ECB, 2015) for a year. Monthly purchases were increased to EUR 80 billion for another period spanning from April 2016 till March 2017. Afterwards, the volume of net monthly purchases was again set to EUR 60 billion per month till the end of the year, and since January 2018 to EUR 30 billion per month at least till September 2018.

Despite the prolonged unconventional monetary policy and balance sheet stockpiling globally, scholars have not yet reached a consensus on whether larger or smaller balance sheets are more benign for economies in the long run. Buiter et al. (2017) claim that the optimal size of a central bank's balance sheet is "unknown and probably unknowable" (p.1, p.7) (Goodhart, 2017). However, it is implied that a given balance sheet cannot grow indefinitely. Considering the large exposure of enormous balance sheets to shifts in interest rates, unwinding of assets hoarded by central banks might take years or even decades (Goodhart, 2017).

Presently, the Federal Reserve system of the US is on the path of shrinking its balance sheet. After a decade of quantitative easing and low interest rate environment, Fed has eventually switched to reducing its balance sheet size and started to sell the stockpiled assets as of the last quarter of 2017. Currently, the total amount of assets held on the ECB balance sheet exceeds the one of the Federal Reserve system, and the ECB has one of the largest central bank balance sheets in the world. This implies that the ECB might also start selling its assets in the nearest future.

Furthermore, there is a close link between the real economy, financial markets, and monetary policy. Research suggests three major transmission mechanisms through which monetary policy, particularly, unconventional, affects financial markets and the real economy (Andrade et. al, 2016; Bowdler and Radia, 2012). One of them is portfolio rebalancing which implies that agents selling long-term high-quality bonds obtain additional liquidity to purchase other risky securities to rebalance their portfolios. This pattern enables a rise of asset prices and a downward effect on returns and, therefore, the cost of borrowing. Another way to look at the transmission is a policy signaling channel. The channel implies that a central bank imposes expectations to investors, signaling its commitment and prolonged low interest rate policy. Yet another channel is liquidity, which is likely to act well in the context of financial distress when market participants require risk premia. However, a central bank, through providing additional liquidity to stock markets, might lower the premium required by market participants.

This altogether suggests that in the process of departing from unconventional monetary policy, the European Central Bank is additionally exposed to uncertainty, as well as it carries extra potential risks to the real economy and financial markets.

2.5.2 Uncentralized fiscal policy in the Eurozone

Many scholars have discussed the issue of the uncentralized fiscal policy of the EU (e.g., De Grauwe and Ji, 2015). As opposed to other major central banks which conduct unconventional monetary policy, the ECB is the central monetary institution of a monetary union rather than a single country. As central banks can rely on sovereign budgets in case of distress, the ECB is not supported by a central fiscal institution of the Eurozone. In other words, it is not explicit who the European Central Bank will rely on in case of heavy erosion of its balance sheet or its insolvency. The founding pact of the European Union with specific stipulations on various aspects of the ECB (and its predecessor the European Monetary Institution) – the Treaty on the European Union (also known as the Maastricht Treaty) – does not provide specific guidelines for extraordinary cases. Nevertheless, the treaty has provisions regarding the ECB capital, as well as procedures for the central bank profit distribution among the participating states.

According to the Treaty (Chapter IV, Articles 28, 29, 32, 33), balance sheet proceeds are allocated among the participating states in the proportion with the ECB capital subscription key. Namely, it is implicitly stated that in case the ECB bears substantial losses, the participating states will have to share the burden of it. However, neither clear legal procedures and rescue scenarios, nor specific guidelines are provided regarding the central bank recapitalization. Thus, it is not entirely accurate to state that the ECB has no institutions to rely on in case if its balance sheet is in jeopardy – it does, in theory. However, in practice there have not been any instances when the ECB required recapitalization, and the presence of guaranteed fiscal support is not certain.

The absence of a central fiscal institution that will support the ECB entails scattering of fiscal policies among participant countries of the EU and the EMU. Besides, as De Grauwe and Ji (2015) argue, the entire concept of QE in the Eurozone implies exposure of the largest and strongest economies of the EU, specifically Germany and France: buying out sovereign bonds which might default entails a phenomenon called *fiscal transfers* which makes the taxpayers of other countries repay the cost. The authors propose that profits and losses stemming from holding the sovereign debt should be transferred back to the National Central Banks of the Eurosystem. However, currently this is not the case, and the profit and loss are distributed among the participant states according to the capital subscription key.

Moreover, the founding treaty of the EU states that the European Central Bank is illegible of financing sovereign debts. Although purchasing sovereign public debts on the secondary market is not deemed as financing, the balance sheets of the Eurosystem are nonetheless exposed to risks associated with the default of countries to repay their debt. Therefore, the importance of a central fiscal institution of the EMU has been frequently discussed by scholars, while the largest economies of the Eurosystem have been multiple times expressing discontent with their high exposure and embroilment.

To sum up, the literature review suggests that a safe exit strategy features presence of a central fiscal institution that is able to provide support to a central bank, as well as a set of clear rules and legal acts that guarantee that all the necessary procedures will be implemented in a timely manner. It has to be clearly stated in legal documents that the central bank can rely on fiscal authorities in case of a severe balance sheet deterioration.

Thus, the absence of a central fiscal authority and clear legal guidelines is a hurdle faced by the ECB. If the ECB is to continue targeting inflation at a level of close to, but slightly below 2%, it cannot heavily rely on seigniorage or reserve deposits, since both strategies can become unsustainable at some point in the future. Therefore, it is important to accurately estimate the vulnerability of the ECB in the context of potential unforeseen scares that might take place unprecedentedly and shatteringly.

3. Methodology

3.1 The Vector Autoregression model

3.1.1 Previous Research Using General Equilibrium Models

In this study, we follow the general idea by Del Negro and Sims (2015) who look at how various shocks affect the Fed balance sheet. They develop a complex economic model to simulate changes in the short-term nominal interest rates, and, thus, bond prices. However, we apply a less complicated and a more empirical approach.

By modeling the central bank's balance sheet in the steady state, Del Negro and Sims (2015) run a set of simulations to see how the balance sheet value changes in response to different interest rate scenarios. They start with a baseline path for interest rates, assuming they would stay low for five more years, and then revert to the derived steady state at a prespecified rate, followed by a simulation of certain economic shocks. Del Negro and Sims then consider scenarios that involve multiple equilibria based on public beliefs regarding the future levels of seigniorage. Given the US data and the Federal Reserve System balance sheet composition, they conclude that fiscal support will only be required in some extreme scenarios; however, it is assumed that Fed inflation target will be backed by fiscal policy.

In Del Negro and Sims (2015), the major parameters are calibrated for the real interest rates and agents' expectation of inflation according to the US data. Further, several simulations with different interest rates are run with the aim to observe varying economic conditions and Fed balance sheet reactions. They assume different interest rate paths, as well as different scenarios of external shocks.

Del Negro and Sims (2015) use a complex general equilibrium model, which is both highly theoretical and mathematically complicated. Besides, problems might arise because of the fact that the model is created for the US rather than the Euro area: the EA is a much more open economy compared with the US, and, therefore, the original model might not account for certain transmission channels.

Due to these limitations, we simplify the methodology employed by Del Negro and Sims (2015) and refer to the classical monetary transmission analysis done by Peersman and Smets (2001): in order to estimate how interest rates are affected by shocks in macro-variables, we run a Vector Autoregression model (VAR). The first part of the analysis involves measuring how sensitive interest rates are to macroeconomic shocks, and how fast they increase if there is a sign of economic recovery. Bearing in mind the inverse relationship between bond prices and interest rates, we will later use the obtained estimates to approximate changes in bond prices. This will allow us to see how the ECB balance sheet reacts if a shock occurs, and how likely the ECB is to require fiscal support in the future.

3.1.2 The VAR model

We run a VAR model of the following form:

$$Y_t = A(L)Y_{t-1} + B(L)X_t + \mu_t \quad (1)$$

where Y_t is the vector of endogenous euro area variables, X_t is a vector of exogenous variables, and μ_t is the vector of errors. For this model, Y_t includes real GDP (y_t), monetary policy rate (s_t), Harmonized Index of Consumer Prices (HICP) (p_t), Real Effective Exchange Rate (x_t), and the spread between long-term European bond yields and the monetary policy rate (d_t). Finally, X_t includes real GDP levels in the USA. The choice of variables for the euro area is consistent with Peersman and Smets (2001), and the interest rate spread is included to measure how responsive long-term rates are to shifts in the monetary rate.

$$Y_t = [y_t \; p_t \; s_t \; x_t \; d_t] \quad (2)$$

$$X_t = [y_t^{US}] \quad (3)$$

3.1.3 Shadow Rate

An important premise of unconventional monetary policy draws a dichotomy between our model and the one presented by Peersman and Smets (2001) – current interest rates are lower globally compared with 2001. Indeed, short-term borrowing rates have been negative for the past several years; Euro Overnight Index Average (EONIA), which is the overnight lending rate for the major European banks, has been negative since 2014. This creates difficulties for observing monetary policy effects and transmission, since further central bank stimuli cannot be reflected in lower interest rates due to the so-called zero lower bound (ZLB). The idea was first proposed by Black (1995), who argues that as long as one can hold cash as a zero-return asset, short-term interest rates cannot become negative, or go below the zero lower bound. In practice, short-term rates have been slightly below zero, which is explained by the existing costs of holding a large amount of cash for commercial banks, such as storage and security costs; however, there is still the minimum short-term interest rate level that cannot be breached.

Evidently, monetary policy effects are difficult to measure using VAR-models with conventional short-term rates. Using EONIA alone as a short-term interest rate proxy is inaccurate given the continuing asset purchase programme and its impact on macro variables which cannot be reflected in short-term rates due to the zero lower bound. Thus, the model suggested by Peersman and Smets (2001) requires an adjustment to account for unconventional monetary policy measures.

Therefore, we modify our VAR regression by substituting monetary rate s_t with shadow rate estimates provided by Wu and Xia (2015). The shadow rate concept was introduced by Black (1995), and is currently used to measure monetary policy impact in the low interest rate environment. By definition, shadow rates coincide with short-term rates when the latter are positive; however, the shadow rate is a representation of what the short-term rate would be if the zero lower bound did not exist, i.e., shadow rates are not bounded from below. In other words, shadow rates reflect monetary stimuli in the low interest rate environment in a more comprehensive manner.

We use the shadow rate estimates provided by Wu and Xia (2016) who demonstrate how these estimates improve VAR models with sample periods that include negative interest rate years. Their estimates are based on the assumption by Black (1995) who argued that interest rates should be treated as options. Thus, Wu and Xia do their estimates of the interest rate term structure at the ZLB from the part that is still driven by market forces. Specifically, they assume the shadow rate is a linear function of three factors that follow a VAR(1) process (Wu and Xia, 2015).

We apply the shadow rate estimates for the period from 2004 to 2017, using EONIA for the preceding five years from 1999 till 2004. It follows that

$$EONIA = Max\{s_t, ZLB\} \tag{4}$$

where s_t is the shadow rate, and ZLB is the zero lower bound level.

Modern pieces of academic research, such as Chen et al. (2017) and Jensen et al. (2017) have extensively used shadow rates to modify VAR models when analyzing economies at the zero lower bound. Besides, shadow rates have been extensively used in recent studies on monetary policy transmission. Wu and Zhang (2017) use Wu-Xia shadow rate estimates to demonstrate the impact of QE and lending facilities; whereas, Wu and Xia (2015) demonstrate that the shadow rate is a cogent instrument to summarize information at the zero lower bound. The extensive research on shadow rate term structure in Europe has only been published since 2016, so there are few models that show the relationship between shadow rates and the yield curve. This research includes Lemke and Vladu (2017) who argue that although the shadow rate itself is not an actual investment rate faced by investors, the way interest rates behave at the ZLB is reflected in recovery expectations. Namely, positive economic shocks that lead to an increase in the shadow rate adjust investors' expectations regarding the future policy rate path and term premia.

This issue is the reason for adding the spread variable to our regression. Although we acknowledge that such shadow rate term structure models as the one suggested by Lemke and Vladu (2017) are arguably more accurate for measuring shadow rate shifts, we include the spread between European bond rate and shadow rate to empirically measure interest rate changes. Besides, a similar approach was used by Jensen et. al (2017) who include the spread between 10-year and 3-year bond yields in their VAR model for the ECB.

3.1.4 Identification

Before we can generate impulse response functions and see how interest rates react to shocks in macro-variables, we have to identify the shocks in a correct manner. Since residuals are the only source of exogeneity in VAR models (unless a vector of exogenous variables is specified), we define shocks as one standard deviation spikes in a residual, assuming it is uncorrelated with other residuals.

However, it is impossible to see the impact of these shocks without imposing additional restrictions. By construction, there is a non-zero correlation between the residuals of a reduced form VAR model, so instead of an unanticipated spike in a macro-variable (which is what we define as a *shock*), we observe several correlated spikes in different variables, i.e. in residuals from several equations in a VAR model. Thus, additional restrictions are required to overcome the so-called *identification problem* – there is more than one structural VAR model compatible with the reduced form VAR that we estimate.

A widespread means of dealing with the identification problem, which was also used in Peersman and Smets (2001) and Lombardi and Zhu (2014), is Cholesky decomposition of the covariance matrix of residuals. The covariance matrix is decomposed using a lower triangular matrix, which implies that the coefficients we are unable to estimate are set to zero. In other words, by imposing an additional set of restrictions we can recover uncorrelated residuals from the structural VAR and, hence, see the impact of a pure shock in a macro variable, rather than a mixed effect from several variables.

The issue is that we impose restrictions on contemporaneous effects of some variables on each other. From the example below, a shock related to the first variable ($\varepsilon 1t$) will have a contemporaneous effect on all the variables in our VAR model; however, this variable itself will only respond to shocks in other variables in the subsequent period.

$$\begin{bmatrix} u_{1t} \\ u_{2t} \\ u_{3t} \\ u_{4t} \\ u_{5t} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \end{bmatrix} \quad (5)$$

where u_{1t} – residual from the first equation for the real GDP (y_t) at time t, and ε_{1t} – the GDP shock at time t. Similarly, u_{2t} is the residual for the Harmonized Index of Consumer Prices equation (p_t) at time t, and ε_{2t} – is the Harmonized Index of Consumer Prices shock at time t; u_{3t} designates the residual for the Real Effective Exchange Rate equation (x_t) at time t; ε_{3t} - the Real Effective Exchange Rate shock at time t; u_{4t} – the residual for the spread between long-term European bond yields and the monetary policy rate equation (d_t) at time t, ε_{4t} – the shock of the spread between long-term European bond yields and the monetary policy rate at time t; u_{5t} denotes residual for the monetary policy rate equation (s_t) at time t, and ε_{5t} is the monetary policy rate shock at time t.

From the example above, we see that through the order of variables we determine which of them have a contemporaneous impact on each other, which, in turn, affects impulse responses. There are no clear guidelines on how the variables order is determined, and one should typically rely on economic theory. Thus, the key assumption we make in the Cholesky decomposition is that all the shocks specified in this model have a contemporaneous effect on the shadow rate, whereas interest rate and exchange rate shocks themselves only influence price and output levels in the subsequent period.

$$[y_t \; p_t \; x_t \; d_t s_t] \quad (6)$$

This is consistent with Peersman and Smets (2001), Eichenbaum and Evans (1995) who argue that prices adjust more slowly and gradually, compared with interest rates and REER, and use a similar order in their decompositions. Besides, the identification scheme that we use is also consistent with Lombardi and Zhu (2014) who use their own shadow rate estimates in a VAR model for monetary policy analysis.

3.1.5 Impulse Response Functions

The final step is to generate impulse response functions, which are a practical means to show how macroeconomic variables react to various shocks: the functions demonstrate how series change over time after a macroeconomic shock takes place, and how persistent the effect of the shock is.

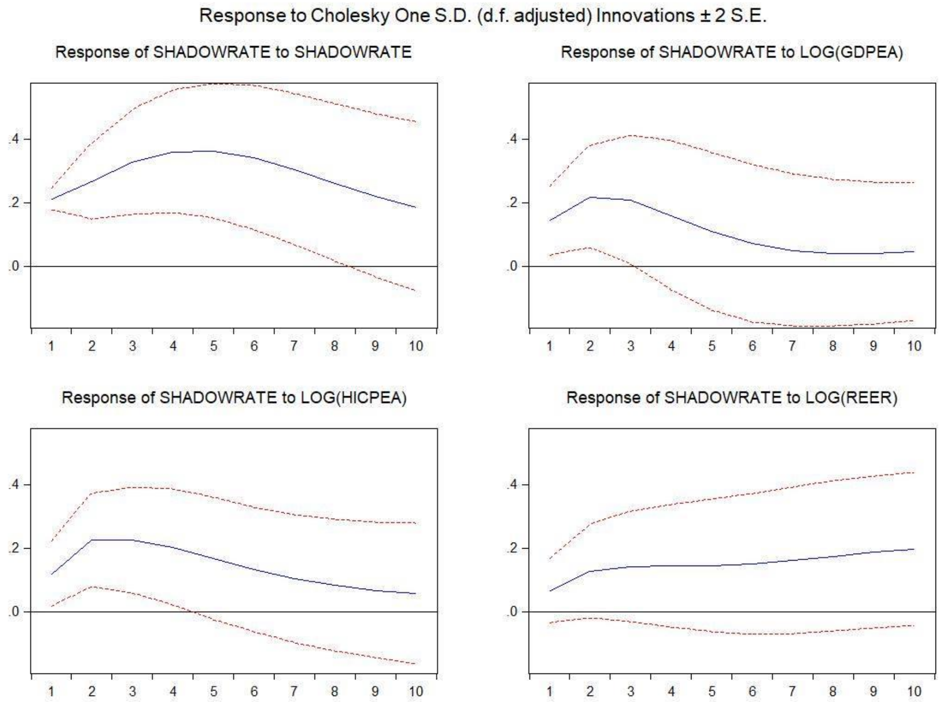

Figure 1. Impulse Responses of Shadow Rate to Various Shocks. Dotted lines denote 95% confidence intervals

The interpretation of impulse response functions is intuitive and can be explained by the example above. Figure 1 features a set of functions showing how shadow rates react to different one-standard deviation shocks in macro-variables: for instance, a one-standard-deviation shock in GDP level leads to a 0.17 percentage point rise in shadow rates in the first quarter, and a subsequent shift from 0.17 to 0.2 percentage points in the second quarter. In other words, two quarters after the shock occurs, the shadow rate will be 0.2 pp higher than what it would be if the shock never happened.

The shocks have a temporary, rather than a permanent impact on the economy, which implies that impulse responses decay as time periods increase, eventually reaching the pre-shock level. It also suggests that the solid line on the graph does not depict the accruing effect; rather, a distinct effect for every given period. Finally, if the 95% confidence band does not include zero, the macroeconomic shock has a statistically significant impact on interest rates. Most of the studies we refer to in the current thesis use 90% confidence intervals for impulse response functions, so we use a slightly higher level of significance.

3.2 Insolvency Simulation

After estimating how shadow rates react to various shocks in macro-variables, we measure the responsiveness of bond prices to these shadow rate adjustments. Since we included the interest rate spread in our model, we can estimate changes in long-term rates caused by shadow rate shifts (by adding together impulse response functions for the interest rate and the spread).

To measure the impact of a black swan event on interest rates, we implement a highly unlikely three-standard deviation shock. Assuming residuals are approximately normally distributed, the probability of such a shock is close to 0.1%, which makes this analysis a stress test, rather than a baseline scenario simulation for the ECB. We then add the impulse responses of the interest rate spread to shadow rate shifts, which allows us to see the impact of shocks in macro-variables on long-term rates. For instance, if a three-standard-deviation shock causes a 3pp shift in shadow rates, and a -1pp shift in the interest spread, the impact on the long-term rate is 2pp in the same period. We then use these shifts in long-term rates to see how shocks affect the value of assets held by the ECB.

As in Del Negro and Sims (2015), we do not make a precise estimate of the ECB balance sheet duration due to data limitations. Instead, we estimate potential losses given several predetermined duration levels. We start with looking at a low-duration balance sheet, assuming the values of five and seven years, and then proceed with an analysis of a more interest rate-sensitive asset composition (10 years). Finally, we look at a hypothetical scenario where the balance sheet duration takes the value of 15 years. Although it is unlikely to reflect the real figures, as argued by Del Negro and Sims (2017), these hypothetical scenarios are useful to consider in case a central bank is still conducting unconventional monetary policy, and its asset composition is subject to change.

From a more practical perspective, however, a low-duration balance sheet is more likely to reflect the reality: as mentioned previously, the weighted average time to maturity for the assets included in the PSPP programme is 7.65 years, and PSPP assets are more than 82% of assets held for monetary policy purposes. Since the duration of a bond cannot exceed its remaining time to maturity, we can only assume a longer duration if we believe that a) bonds purchased under the PSPP have low coupon rates, and b) bonds purchased under other asset purchase programmes have a much longer average remaining time to maturity. If these assumptions hold, it is reasonable to assume a duration value close to 10 years.

We assume that shocks have a temporary, rather than a permanent impact on the economy. Namely, we assume transitory demand shocks that will only influence the shadow rate over a certain limited period, but will not have a permanent impact on macro-variables. This implies that the impact of a macro shock will totally disappear over time, and over 10-12 quarters macro variables will return to their pre-shock levels. This assumption goes in line with the ECB policy and role as a regulating authority – the ECB smoothens the business cycle in order to meet the inflation target, but does not react to the permanent shift in supply.

To sum up, the preliminary simulation we run is the following:

1. Obtain impulse responses of the Shadow rate on three-standard deviation macro-variable shocks to approximate the impact of a “black swan”.
2. Sum the shadow rate shift and the shift in the interest rate spread to see the impact on long-term interest rates.
3. Approximate changes in bond prices assuming different balance sheet duration levels. The formula used for approximation is the following:

$$\frac{\Delta P}{P} = -D(\frac{\Delta r}{1+r}) \tag{7}$$

This is a standard duration approximation formula which is similar to the one used by Sims and Del Negro (2015) when estimating changes in bond prices for the Federal Reserve System. Thus, although we are using a different economic model to obtain the values of interest rate shifts, this part of our work is very similar to Sims and Del Negro (2015), since we are using similar ways to approximate changes in the central bank balance sheet.

3.3 Insolvency Conditions and Discussion

3.3.1 The First Insolvency Condition

Finally, we have to define insolvency conditions for the central bank. As long as these conditions are not met, the central bank requires neither seigniorage, nor fiscal support to cover the gap, and can rely on its future profits. Based on the literature review, we use two benchmarks for the central bank insolvency definitions. The first definition is the fiscal cost that is discussed by Fujiki and Tomura (2017) for the Bank of Japan. Looking at the Bank of Japan, they demonstrate that the central bank will not require a fiscal injection if its net assets are negative, as long as we assume fiscal backing of the monetary policy and a joint budget constraint with the government. If the assumptions hold, the deficit will be slowly and naturally replenished by the bank’s positive profits in the subsequent years. Thus, as the authors argue, negative net assets only demonstrate the cost of the conducted monetary policy, but not its effectiveness and overall economic impact.

However, the assumption of a joint budget constraint does not hold for the European Central Bank. The balance sheet of the European central bank is not tied to any single fiscal authority, as the Euro Area lacks a unified fiscal policy and a central fiscal institution. The founding treaty of the ECB – the Maastricht Treaty – states that balance sheet proceedings are distributed to member countries according to the ECB capital subscription key; however, it does not contain specific provisions for uncommon events, such as heavy losses of the Central Bank. Therefore, it is not apparent whether the losses will be borne by the European governments, or the ECB will have to adjust its monetary policy to increase the accounting profit (which is the definition of central bank insolvency). Since the founding and subsequent treaties on monetary policy do not specify whether negative net assets will allow sustaining the current monetary policy rule, we assume that negative net assets imply insolvency of the central bank.

Moreover, negative net assets of the ECB will have a significant impact on the European economy. According to the Maastricht Treaty, when the ECB makes a profit, up to 20% is transferred to the reserve of the ECB, whereas the rest is distributed to national central banks of the Euro Area, and subsequently to national governments as a budget contribution. If net assets turn negative, the ECB will have to cover the loss with its future profits, and national governments will face lower budgets. Net assets turn negative when the loss on the securities held for monetary policy purposes exceeds the sum of "capital and reserves" and "revaluation accounts" sections of the ECB balance sheet, which is around 19.3% of assets held for monetary policy purposes. Finally, hitting the negative net assets mark would also create requirements for a detailed set of rules for loss sharing between European governments and the ECB.

3.3.2 The Second Insolvency Condition

For the second insolvency condition, we compare the asset value with interest-bearing liabilities of the central bank. This approach is suggested by Del Negro and Sims (2015) who demonstrate that if net interest-bearing assets are negative, the private sector transversality condition is violated. In other words, the liability of the central bank is an asset of the private sector, and the asset grows at approximately the interest rate. Thus, private individuals will eventually try to turn this asset into consumption goods, which will cause growing inflation and a violation of the central bank policy rule. For the central bank insolvency to take place under this condition, assets held for monetary policy purposes have to lose around 21.14% of their value, which is close to the previous insolvency condition. Thus, either of the insolvency conditions indicates a very similar level of losses that threatens the solvency of the ECB, and further we use these conditions interchangeably.

As it was mentioned previously, in case either of these conditions is met, the central bank will either rely on seigniorage, or require support from fiscal authorities, and according to Del Negro and Sims (2015), fiscal support is only required if the seigniorage generated by a central bank is not enough to cover the gap. Looking at their statement from a practical perspective, we see that their model only considers discounted present value of seigniorage instead of an actual per year amount. Thus, it is not clear how specifically the deficit will be replenished, and how to incorporate seigniorage in an empirical model. On the other hand, Reis (2015) described fiscal support as a one-time transaction between a government and a central bank, arguing that a central bank "can never become insolvent independently of the fiscal authority" (p.12) if fiscal support is guaranteed. In other words, although a specific amount of seigniorage is currently difficult to estimate, we see that if there is not enough seigniorage to cover the gap, the ECB will have to be recapitalized by Eurozone countries.

3.4 Data and sample description

A set of macroeconomic variables that is consistent with previous academic research on monetary policy transmission is required to determine how interest rates and, thus, bond prices react to large unanticipated shocks in the European economy. The major sources of data are the ECB data warehouse, the OECD databases, the IMF, as well as central banks of the EU states.

The required variables include ***short-term and long-term interest rates, inflation, GDP levels, Real Effective Exchange Rate (REER)***, etc. Besides, the ECB does not disclose the list of assets purchased in the process of its QE programme, so available data on both active and terminated asset purchase programmes is necessary in order to approximate the composition of assets currently held by the central bank. This is required to estimate the average balance sheet duration, and approximate how vulnerable it is to sharp interest rate movements.

The balance sheet of the ECB is publicly available, and there is detailed information on assets purchased under the Public Sector Purchase Programme (PSPP), which constitutes approximately 80% of the assets purchased by the ECB through QE. However, this is not enough to accurately estimate the average duration of the balance sheet; hence, as in Del Negro and Sims (2015), we estimate the impact of interest rate shifts assuming different duration levels.

4. Results and Discussion

In this section, we present our baseline scenario output and conduct a robustness check to see whether the solvency of the European Central Bank is threatened by extreme shocks in macroeconomic variables.

4.1 VAR

4.1.1 Shadow Rate

With the aim to incorporate the full extent of the monetary stimulus effect, we have included shadow rates in our model. These rates are not observed by investors directly: whenever EONIA is positive, shadow rates coincide with it per se. However, when monetary policy rates are close to the ZLB, shadow rates better absorb the impact of monetary stimuli. The graph below illustrates how shadow rate estimates by Wu and Xia (2015) diverge from EONIA as the monetary stimulus persists: the EONIA rate has been at the zero lower bound level since 2012. Other variables used in VAR model are shown in Appendix B.

The shadow rate coincided with EONIA when the latter was above the zero lower bound, and before the ECB had recourse to unconventional monetary stimuli. However, as of 2014 we observe a clear divergence between the two rates, with the shadow rate diving more and more into the negative territory.

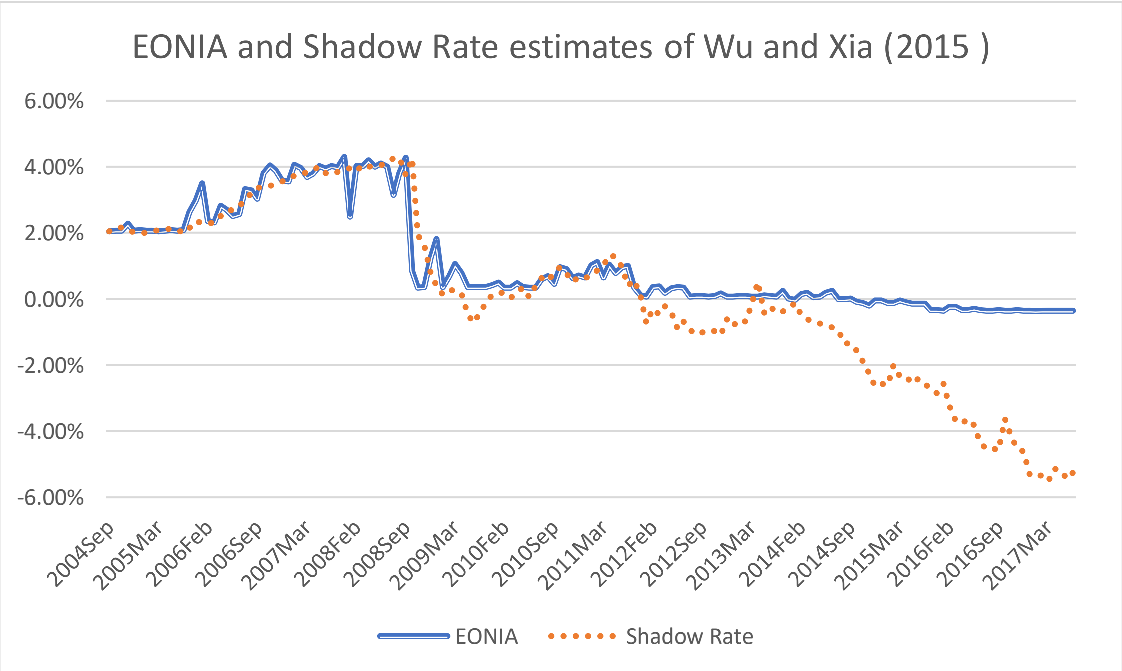

Figure 2. EONIA and Shadow Rate estimates of Wu and Xia (2015)

By 2014, the European Central Bank had already implemented measures to restore interbank liquidity and recuperate financial markets. However, the official announcement of the APP followed only in early 2015, but according to the Wu-Xia estimates (2015), the information had been incorporated in the shadow rate even earlier. As we have discussed before, the latter is consistent with findings of De Santis (2016) who claims that implicit announcement of the asset purchase programme in 2014 was immediately incorporated in bond yields preceding the official initiation of the programme.

4.1.2 Impulse Response Functions

In this section, we demonstrate the impulse response functions and define some specifications for the main VAR model. The following impulse response functions are obtained from a VAR(2) model, since using two lags minimizes both Bayes and Akaike information criteria. All variables are in log levels (except for the interest rates) – although the data is non-stationary, we run a Johansen cointegration test and reject the null hypothesis of zero cointegrating vectors at a 5% level of significance (Appendix C). Finally, the 7.65-year bond yield is constructed as the weighted average of 7- and 8-year European all-government bond yields, which reflects the remaining weighted average maturity of the assets purchased during the major programme – PSPP.

We generate responses to a one-standard deviation shock in macro variables, which has been a widespread approach in this line of research. However, in subsequent sections of the thesis, we consider three-standard deviation shocks, which is done to simulate unlikely extreme scenarios – black swans. Figures 3 and 4 below represent impulse response functions to one-standard deviation shocks, with time in quarters on the x-axis, and units of measure of a given factor (percentage points for shadow rates and the spread, and percent for other factors) on the y-axis. Figure 3 captures response functions of all the macroeconomic variables to respective shocks, whereas Figure 4 beneath concentrates on responses of shadow rates to shocks in respective macro variables.

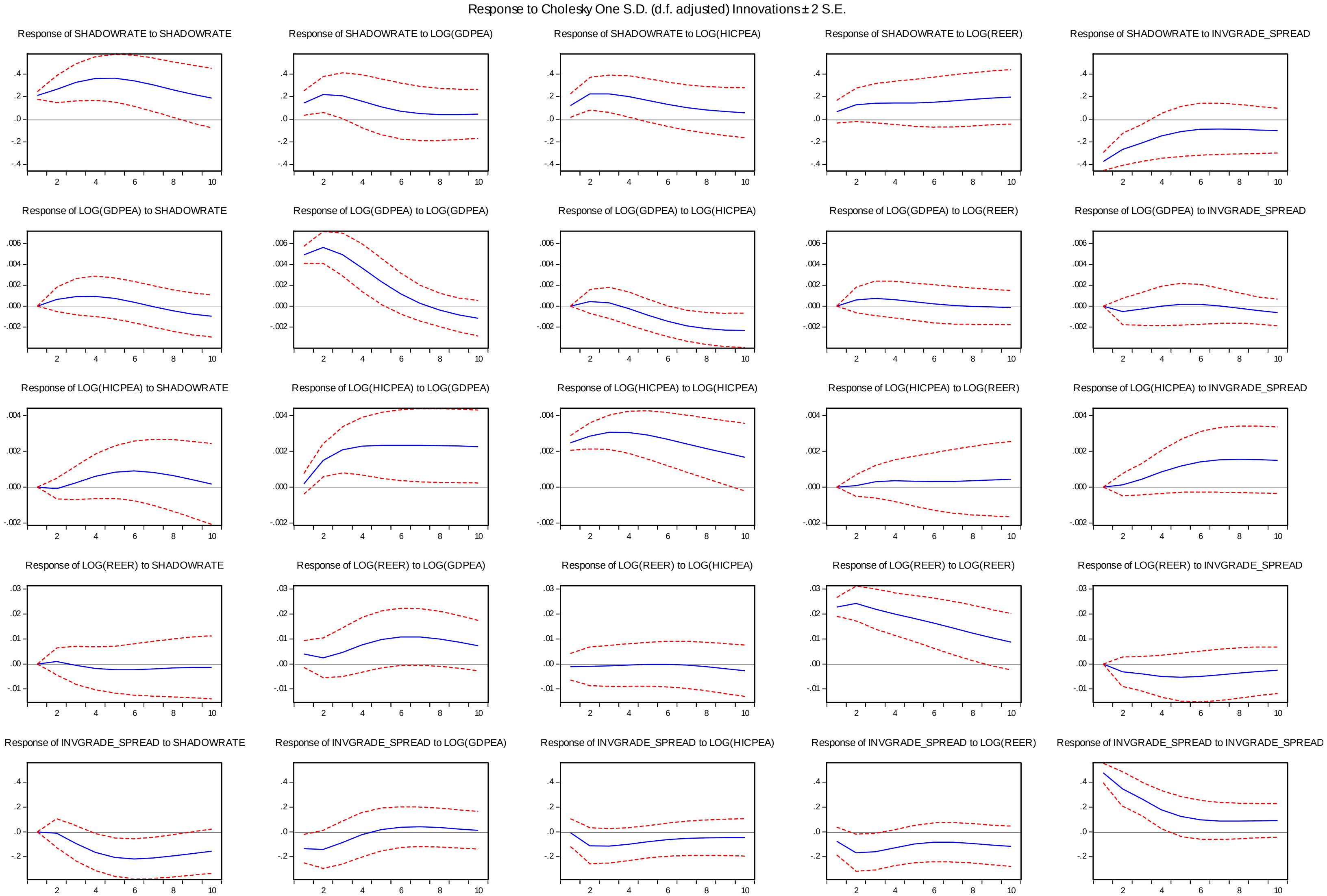

Figure 3. Impulse response of VAR(2) model. Dotted lines denote 95% confidence interval

The solid lines on the chart indicate non-accumulative responses of respective macroeconomic variables to given shocks. The dotted lines denote 95% confidence bands; the axes designate time (in quarters of a year) and units of measure (percentage points for the shadow rate).

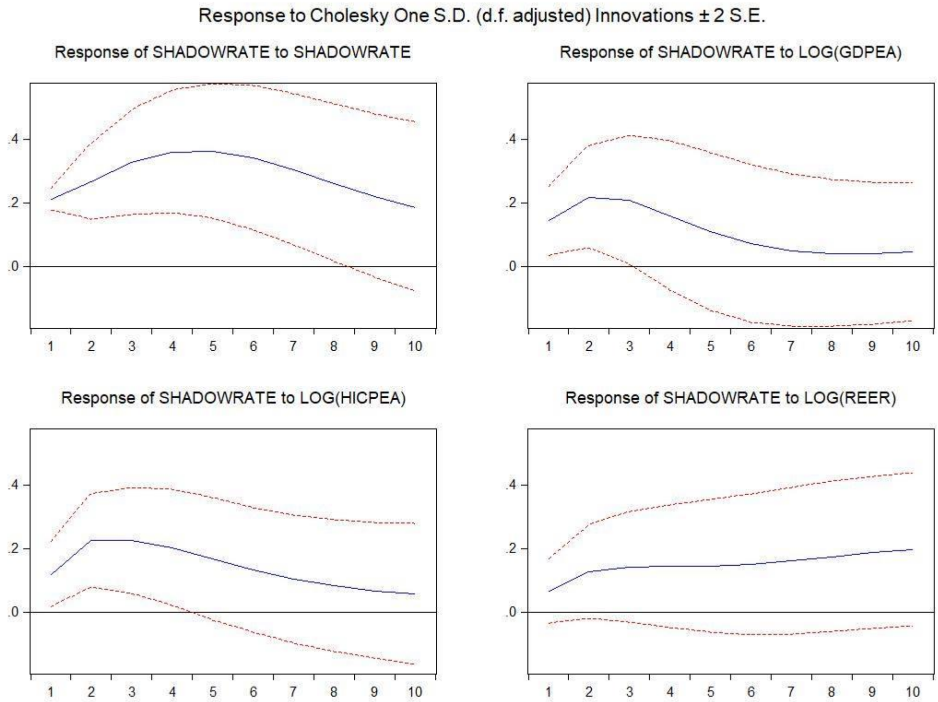

Figure 4. Impulse Responses of Shadow Rate to Various Shocks. Dotted lines denote 95% confidence interval

The obtained impulse response functions are consistent with previous research on monetary policy transmission for the ECB and the Federal Reserve System. Each of the given graphs contains a response (the solid line) and a 95% confidence band (the dotted lines). The results are deemed statistically significant when the interval is above zero. The graphs display a discrete change compared to the baseline scenario rather than a cumulative change at a given point in time.

Responses to a positive GDP shock are statistically significant and exhibit a positive reaction of all macroeconomic variables except for the interest rate spread, which has a negative response. Shadow rate response displays an upward shift by 0.17 percentage points in the first quarter, and a subsequent raise to the maximum value of 0.2 percentage points in the second quarter, followed by leveling off close to zero. We also observe a statistically significant response of the shadow rate to positive HICP shocks which reaches its peak in the second-third quarter. In the first quarter, the shadow rate response amounts 0.15 percentage points, rising to slightly over 0.2 percentage points in the second quarter. Responses to shocks in the real effective exchange rate have an expected positive sign; however, shadow rate responses are insignificant at the 95% level.

Negative responses obtained from the interest rate spread variable suggest that the shift in long-term rates is smaller in magnitude than the shadow rate shifts. Apart from interest rate responses, we see that a GDP shock has a positive and statistically significant impact on the price level, and that sudden spikes in prices lead to decreases in GDP starting from the fourth quarter after a shock.

In order to show the effect of black swan-like large shocks on bond prices, we consider three-standard deviation shocks. We multiply the shocks of Figure 3 by three, taking the average of the first four quarters; then we add the average impulse responses of shadow rates and the spread which yields three-standard deviation shocks. Estimates of long-term rate shifts caused by shocks in macro-variables under the baseline scenario are summarized in Table 1. Further, we use the duration approximation formula to see the decline in asset prices and report our baseline scenario results, as well as conduct a robustness check where we adjust the assumptions about interest rate spikes. Besides, since the baseline scenario for the Real Effective Exchange Rate resulted in a decrease in long-term interest rates, we take the closest alternative scenario in order to obtain a positive shift. Namely, for the REER baseline scenario, we assume that the spread variable response is one standard deviation higher.

Table 1. Estimates of long-term rate shifts due to three-st.d. shocks of macro variables. Baseline scenario

Long-term rate shifts, pp		
GDP	HICP	REER
0.2560	**0.3279**	**0.1672**

4.2 Insolvency Threats

Speaking of the simulation setup, for the first step we approximate the yield of the average asset on the ECB balance sheet, as well as pick different options for its average duration. In terms of the asset composition, the ECB is holding a total of around 2.3 trillion EUR in assets from its four currently active asset purchase programmes (Table 2), and around 100 million EUR from its terminated programmes.

Since PSPP is the only programme where the weighted average remaining time to maturity is publicly available (7.65 years), we assume the same time to maturity for all other assets held for monetary policy purposes. This allows us to approximate the yield of the average bond as the 7.65-year rate from the euro-area yield curve (0.795% as of March 22, 2018). For the sake of consistency, we use the all-governments yield curve instead of AAA yields in our baseline scenario simulation. The reason is that the ECB is currently holding a large number of Italian and Spanish government bonds that were purchased during PSPP, and since PSPP is used to approximate the weighted average time to maturity and overall duration of the balance sheet, we choose the yield curve consistently.

Table 2. Active asset purchase programmes of the ECB

Programme	Current Holdings	Percent of Total
ABSPP	25,306	1.09%
CBPP3	246,064	10.56%
CSPP	139,120	5.97%
PSPP	1,919,149	82.38%
Total	**2,329,639**	

Further, we demonstrate the results of our baseline scenario and discuss whether estimated losses can threaten the central bank solvency, as well as state our assumptions regarding the bond yield and duration level.

Since duration cannot exceed the remaining time to maturity, we have chosen an estimated ECB balance sheet duration of 7 years. We acknowledge that duration highly depends on coupon rates and the yield to maturity, and for the same time to maturity of 7.65 years, duration can potentially be lower. It has been decided to choose this duration estimate for the sake of prudence: since all duration levels from around four to seven years are equally possible, it is better to consider the most pessimistic scenario. However, this assumption is to be adjusted in the robustness check section.

The table below presents the effects of shocks in macroeconomic variables on the 7.65-year spot rate, as well as the effect on the total value of assets held by the ECB.

Table 3. Effect of 3 St. Dev. shocks on the total value of the Eurosystem consolidated balance sheet

Effect of shocks on the value of total assets of the Eurosystem Consolidated BS (The Baseline Scenario)				
Duration	***Spot rate: Before Shock***	***Spot rate: After Shock***	**Change in Assets Held for Monetary Policy Purposes**	**Change in Total Asset Value**
GDP shock				
7	*0.795%*	*1.0510%*	-1.78%	**-0.95%**
HICP shock				
7	*0.795%*	*1.1229%*	-2.28%	**-1.22%**
REER shock				
7	*0.795%*	*0.9622%*	-1.16%	**-0.62%**

As the results suggest, at the baseline duration level, the central bank can lose up to 2.3% of its assets held for monetary policy purposes, which is close to 58 billion euros. The obtained figure is far below the insolvency threshold of around 20%. In other words, the output from Table 3 indicates that assuming the baseline bond duration levels, macro-shocks cannot force the ECB to declare insolvency. Given the impulse responses, losses cannot exceed 2.5% percent of assets held for monetary policy purposes, which allows the ECB to gradually replenish the deficit with past and future profits. Even highly unlikely three standard deviation shocks will not force the central bank to adjust its policy rule under the baseline scenario; however, it will still suffer severe losses as interest rates increase.

Further, we conduct a robustness check where we verify yielded results by adjusting some of our assumptions and look at how larger interest rate shifts affect the ECB balance sheet.

4.3 Robustness Check

4.3.1 Interest Rate Changes

Robustness checks are a common exercise in empirical research, especially given a large number of strict assumptions which is inherent in such extensive studies. Indeed, both Del Negro and Sims (2015) and Fujiki and Tomura (2017), who analyze the Federal Reserve System and the Bank of Japan respectively, estimate all potential scenarios to make sure that the obtained results are not determined by assumptions. Such a large number of assumptions is mainly caused by data limitations: one can neither accurately model the ECB balance sheet, its duration, and bond yields, nor perfectly predict how changes in abstract and unobservable shadow rates will be reflected in long-term bond yields. In our robustness check section, we look at the most pessimistic scenarios for the ECB, considering the whole 95% confidence interval of both shadow rate and interest rate spread impulse responses. Thus, we consider all the potential long-term interest rate values, starting from our baseline scenario, and until the most pessimistic one where both the shadow rate and the interest rate spread responses are two standard deviations above the predicted values.

We take the four quarter averages for both the shadow rate response and the interest rate spread response to capture the average responses over the first year. Then we plot all potential interest rate values, starting with the baseline scenario presented in Section 4.2 to the most pessimistic one (two standard deviations above the predicted impulse response both for the shadow rate and the interest rate spread).

We also repeat the analysis for different balance sheet duration levels and plot estimated losses on three different graphs – one for each variable. We follow the approach suggested by Del Negro and Sims (2015), who argue that a wide spectrum of potential duration levels should be considered. Namely, they estimate potential losses for the balance sheet with the average duration ranging from 2 to 20 years. We take a narrower span and test the results for duration levels ranging from 5 to 15 years: given the fact that the weighted average time to maturity of the assets purchased and held during PSPP is 7.65 years, the average balance sheet duration is very unlikely to ever exceed 15 years, so we arguably capture all potential duration levels. Namely, we look at four scenarios: 5, 7, 10, and 15 years of average balance sheet duration. For the first two scenarios, we use the same 7.65-year bond yield for both 5 and 7- year balance sheet duration levels. In these cases, the assets held by the ECB are assumed to have equal-weighted average time to maturity, but different coupon rates (by definition, larger coupon rates imply lower duration levels). Since the actual coupon rates on the assets held by the ECB are unavailable, we assume two scenarios with high-coupon and low-coupon bonds (5 and 7 years, respectively).

For the other two duration levels, we re-estimate our main VAR model, changing the long-term interest rate spread variable. Since the duration of a coupon-paying bond is smaller than its remaining time to maturity, we use 12-year European government bond yields for the duration of 10 years, and 17-year yields for the duration of 15 years. Thus, the two-year discrepancy is used to take into account coupon rates.

The table below summarizes the three VAR models and different duration levels that we look at in the robustness check section, as well as current European all-government bond yields at specified maturities.

Table 4. Assumptions of the baseline model and robustness checks

		Baseline	**Robustness Check**		
		VAR#1	VAR#1	VAR#2	VAR#3
criteria	ave. maturity	7.65	7.65	12	17
	ave. duration	7	5	10	15
	yield (2018)	0.795%	0.795%	1.223%	1.560%

Further, we plot the simulated ECB losses at different interest rates and duration levels. Dotted lines show decreases in asset values at different interest rates and balance sheet duration levels; whereas, two horizontal lines demonstrate insolvency conditions. Thus, if a dotted line intersects with a horizontal one, the ECB will hit an insolvency condition. On the x-axis there are different interest rate levels (i), calculated according to the following formula:

$$i = Yield\ To\ Maturity + Shadow\ Rate\ Response + Spread\ Response \quad (8)$$

Since there is a different yield to maturity that corresponds to every assumed duration level, there are no numbers on the x-axis. However, as discussed previously, every new interest rate is calculated by simply adding one or two standard deviations to either the Shadow Rate Response or the Spread Response Components.

THE CHARTS BELOW (FIGURES 5, 6, 7) EXHIBIT SCENARIOS OF ESTIMATED LOSSES AS A PERCENT OF ASSETS HELD FOR MONETARY POLICY PURPOSES (AHMPP, Y-AXIS), ASSUMING DIFFERENT BALANCE SHEET DURATION LEVELS AND LONG-TERM RATE VALUE. EACH DOTTED LINE STANDS FOR A SPECIFIC DURATION LEVEL, AND DIFFERENT PARTS OF THE PLOTTED LINES DENOTE DIFFERENT SIZES OF INTEREST RATE SHIFTS (NUMERICAL VALUES OF THE LATTER ARE NOT DISPLAYED ON THE GRAPH, AS THEY DIFFER FOR EACH DURATION LEVEL).

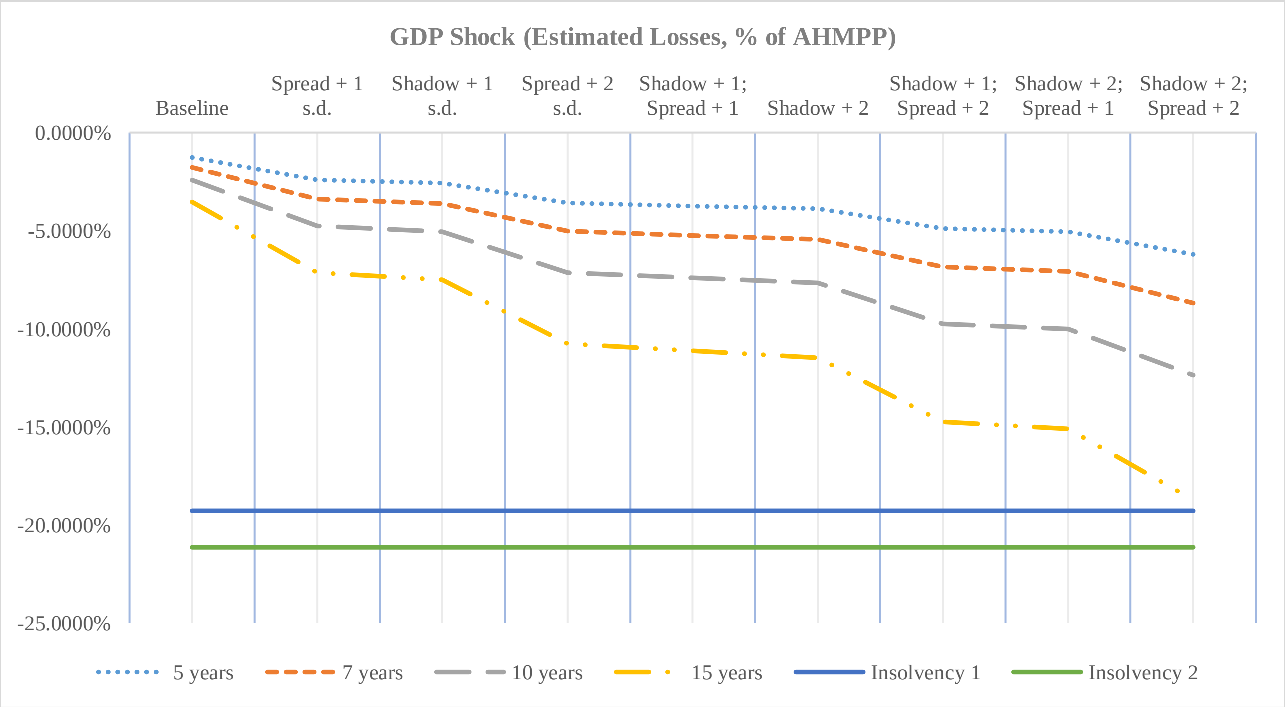

Figure 5. Effect of a GDP shock at different levels of duration

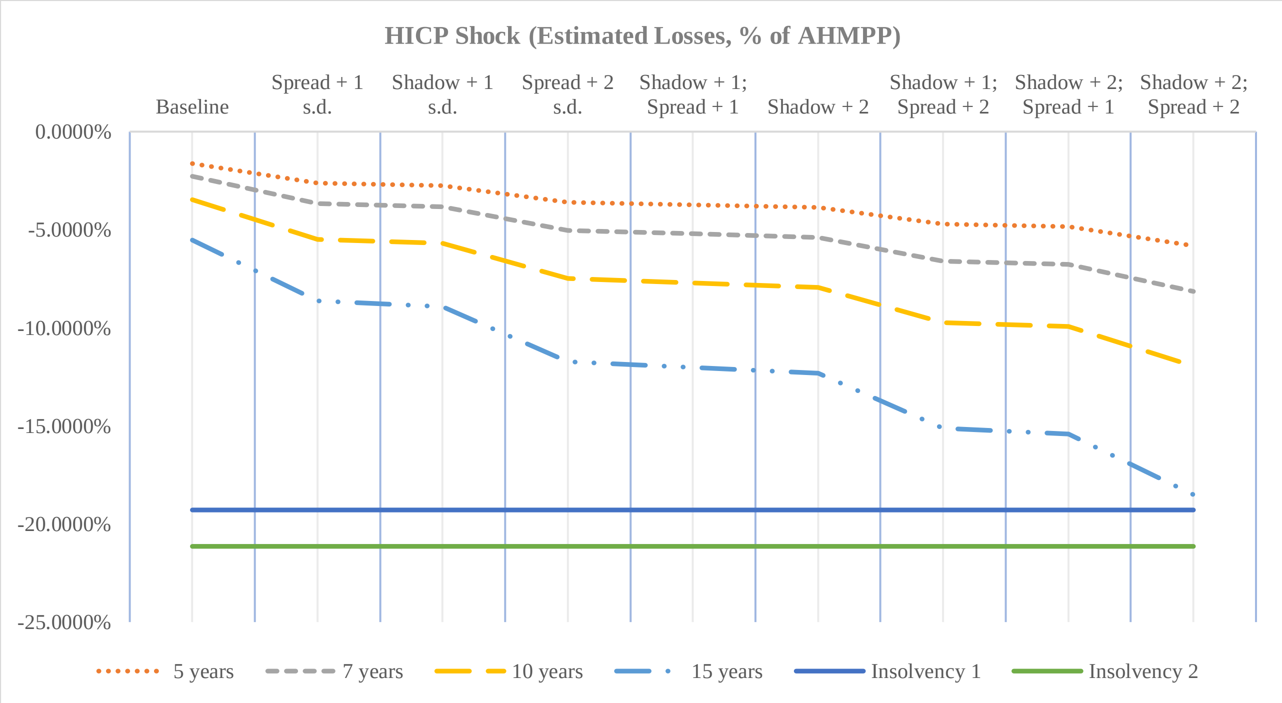

Figure 6. Effect of a REER shock at different levels of duration

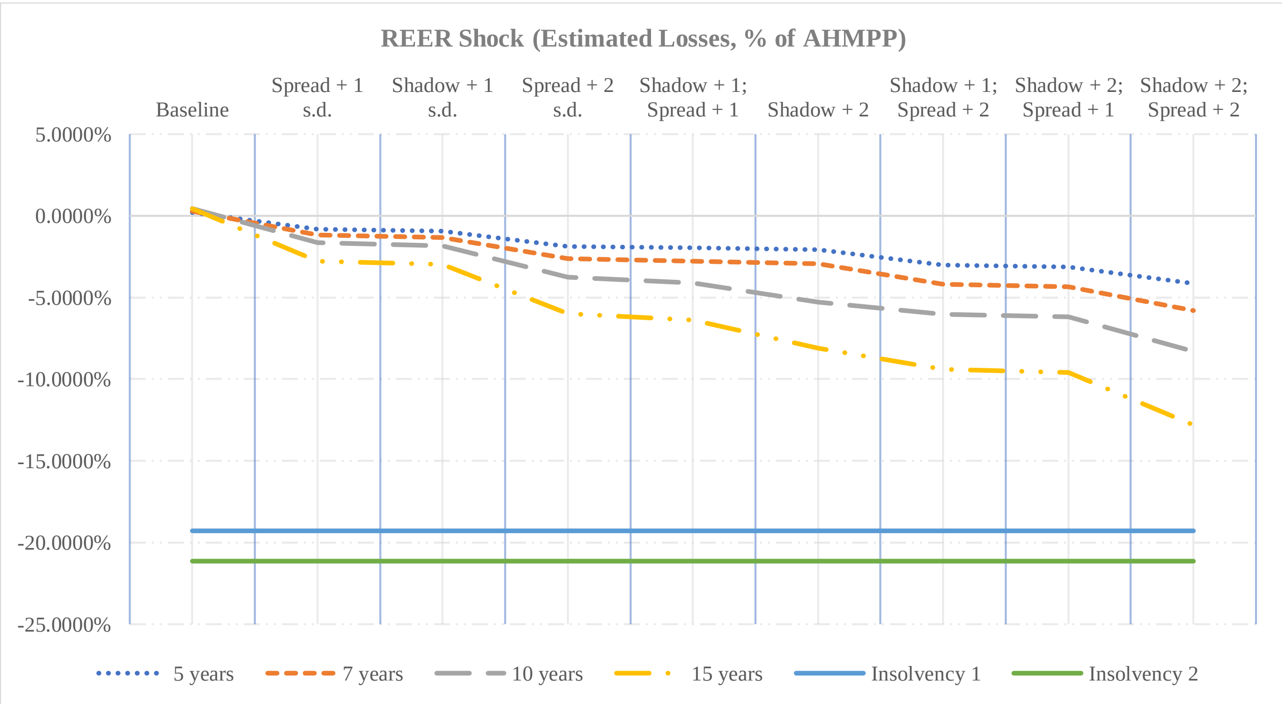

Figure 7. Effect of HICP shocks at different levels of duration

Our robustness check demonstrates that even at the most pessimistic interest rate scenarios the ECB will not hit either of the insolvency conditions. Thus, we can confirm our previous conclusion that in spite of potentially extreme losses, the ECB will not declare insolvency.

4.3.2 Cholesky Ordering

Besides, we adjust the variables order in our Cholesky decomposition to see whether it significantly influences the impulse response functions. Specifically, now the interest rate spread and the shadow rate change places – both variables reflect changes in interest rates, and, hence, there are no specific reasons to put one before the other. Adjusted impulse response functions are included in Appendix A, and they are almost identical to the ones used in our baseline scenario. Therefore, our conclusions are also robust to an ambiguous order of variables in the Cholesky decomposition

5. Conclusion

Aiming to revive economies of the Eurozone after the financial crisis, the ECB has been conducting a number of key interest rate cuts and large-scale asset purchase programmes. As the economies of the monetary union start to recover, the ECB has been considering ways to taper its stimuli. These exit strategies are difficult to implement practically because of the large balance sheet that is susceptible to interest rate spikes. Indeed, concerns were raised that drops in asset value could be so large that the ECB would need a fiscal injection to sustain its policy rule.

Similar issues have been encountered by other major central banks, such as the Federal Reserve System of the USA and the Bank of Japan which are also known for their extensive asset purchase programmes. Many scholars have conducted studies trying to predict how an interest rate rise will affect balance sheets of these banks, considering fiscal interventions to provide a smoother exit plan.

One of the key distinctions between these banks and the ECB is that latter is multinational. As it has been pointed out in our study, the Eurosystem lacks a centralized and unified fiscal policy and, therefore, a central fiscal institution. At the same time, the Fed and the BoJ are backed by the Treasury Department of the USA and the Ministry of Finance of Japan, respectively. In other words, it implies that the Federal Reserve System of the USA and the Bank of Japan have an explicit authority to step in should some unprecedented events occur, and should the banks require urgent recapitalization.

For the European Central Bank, this issue is especially important today, since most European economies are on a path of a steady recovery, so the need for loose monetary policy is diminishing. Apparently, a faster recovery pace contributes to a more agile monetary tightening which causes larger shifts in long term yields, and, thus, bond prices. In this thesis, we have estimated how the ECB balance sheet will react to such shifts in the yield curve, which can be viewed as a timely stress test for the central bank and an attempt to see how its balance sheet overcomes a rapid economic recovery.

Looking at the baseline scenario estimates, one of the main conclusions we make is that large shocks in macroeconomic variables have a significant impact on the ECB balance sheet in the same year. High magnitude demand shocks have a contemporaneous and statistically significant effect on Wu-Xia shadow rate estimates, and, according to Lemke and Vladu (2017), on the entire euro-area yield curve. This implies that the balance sheet can lose up to 2-2.5% of the asset value in a very small amount of time. Although we point out that the probability of such an event is minor, and these figures will only matter in case the ECB decides not to hold the bonds to maturity, we claim that shocks in the euro area macro variables can have a significant impact on the ECB balance sheet at all duration levels.

However, robustness checks reveal that losses only become large enough to threaten the solvency of the ECB at extraordinarily high duration levels and under scenarios that are extremely unlikely. Indeed, given the information on weighted average time to maturity of the bonds held by the ECB, the actual duration of its balance sheet is close to either five or seven years. At these duration levels, even the most pessimistic scenarios do not lead to losses that exceed 10% of the asset value. Large unrealized gains under "Revaluation account" balance sheet section, as well as a much lower value of interest-bearing liabilities compared with assets, enable the ECB to successfully replenish the loss with its own profits without relying on either seigniorage or fiscal support.

Nevertheless, it is still important to point out that our results, as well as those by Del Negro and Sims (2015), heavily rely on the assumption of fiscal backing of monetary policy. They provide clear evidence that fiscal institutions always "back" the monetary policy conducted by the Federal Reserve System, and, as stated previously, this is important for preventing explosive movements in interest rates. Thus, these results are only valid if fiscal institutions react to these shocks accordingly. Although such shocks are not likely to cause the insolvency of the central bank, it is evident that clear guidelines and legislation are required to account for potential solvency issues and provide for a rescue plan for the ECB.

A large number of scholars have discussed the lack of unity in the fiscal policy of the Eurozone, as well as warned about the importance of a central fiscal authority for the monetary union. And, indeed, the current transitions in the economic development of the Euro Area, as well as the issues faced by the European Central Bank, require cooperation between monetary and fiscal pillars of the Eurozone. Therefore, our study provides a basis for further discussion and analysis on fiscal and monetary coherence, as well as supplements the existing line of research.

Speaking of the limitations of the study, we rely on several assumptions that can cause inaccuracies in our final estimates. First, our model of the ECB balance sheet is not perfectly accurate. Although such an approach has typically been used in similar studies, the fact that it is impossible to specify the exact balance sheet duration level and the yield to maturity of every bond on the balance sheet makes our results an approximation, rather than a precise model of asset value changes. Besides, we acknowledge that there exist some more sophisticated ways to model the shadow rate term structure, so the link between shadow rates and long-term rates in our model can be estimated differently. However, a robustness check has been conducted to address potential inaccuracies, and it has confirmed that although large macroeconomic shocks are likely to lead to large accounting losses, there are no threats to the central bank solvency.

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Appendix A. Adjusted Impulse Response Function Schemes

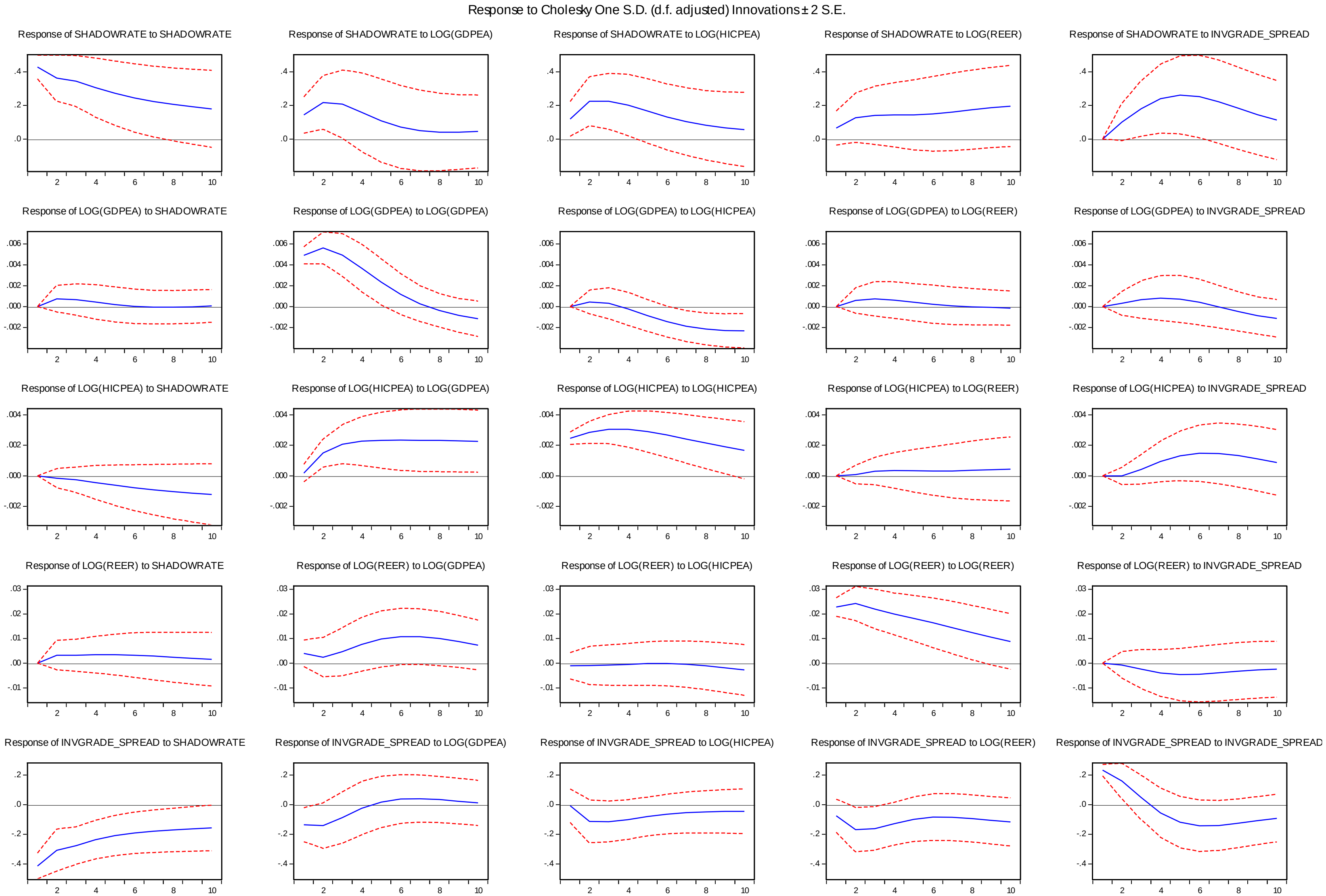

Figure 8. Adjusted Impulse Response Function Schemes

The solid lines on the chart indicate non-accumulative responses of respective macroeconomic variables to given shocks. The dotted lines denote 95% confidence bands; the axes designate time (in quarters of a year) and units of measure (percentage points for the shadow rate).

Appendix B. Variables used in VAR models

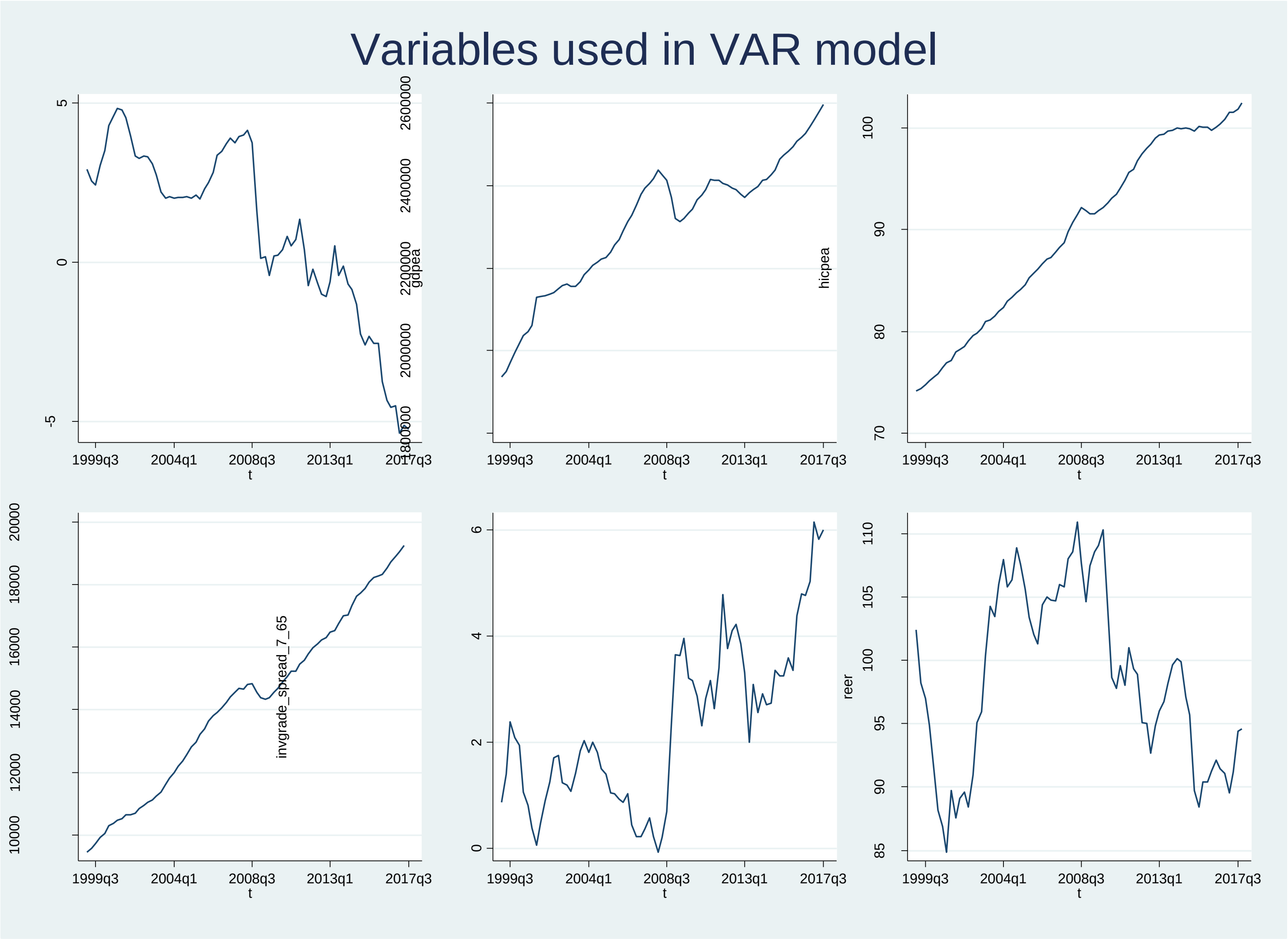

Figure 9. Chart of variables used in VAR

Appendix C. Johansen Cointegration Test

Date: 05/21/18 Time: 18:56
Sample (adjusted): 1999Q4 2017Q3
Included observations: 72 after adjustments
Trend assumption: Linear deterministic trend
Series: SHADOWRATE LOG(GDPEA) LOG(HICPEA) LOG(REER) INVGRAD...
Exogenous series: LOG(GDPUSA(-1))
Warning: Critical values assume no exogenous series
Lags interval (in first differences): 1 to 2

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.434170	86.20065	69.81889	0.0014
At most 1	0.314109	45.19936	47.85613	0.0870
At most 2	0.148284	18.05271	29.79707	0.5622
At most 3	0.073865	6.496555	15.49471	0.6368
At most 4	0.013404	0.971597	3.841466	0.3243

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.434170	41.00129	33.87687	0.0060
At most 1	0.314109	27.14665	27.58434	0.0568
At most 2	0.148284	11.55616	21.13162	0.5918
At most 3	0.073865	5.524958	14.26460	0.6746
At most 4	0.013404	0.971597	3.841466	0.3243

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values