UNIVERSITY OF LJUBLJANA
SCHOOL OF ECONOMICS AND BUSINESS

MASTER'S THESIS

AN ANALYSIS OF THE EFFECTS OF UNCONVENTIONAL MONETARY POLICY MEASURES IN THE EURO AREA WITH A SVAR MODEL

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LIST OF ABBREVIATIONS

sl. – Slovene

APP – (sl. Program nakupov vrednostnih papirjev); Assets Purchase Programme

DFR – (sl. Obrestna mera na mejni depozit); Deposit Facility Rate

ECB – (sl. Evropska Centralna Banka); European Central Bank

EU – (sl. Evropska unija); European Union

FTO – (sl. Operacije finega uravnavanja); Fine-Tuning Operations

GDP – (sl. Bruto domači proizvod); Gross Domestic Product

HICP – (sl. Harmonizirani indeks cen življenskih potrebščin); Harmonised Index of Consumer Prices

LTRO – (sl. Operacije dolgoročnejšega refinanciranja); Longer-Term Refinancing Operations

MLF – (sl. Obrestna mera na mejno posojilo); Marginal Lending Facility

MRO – (sl. Operacije glavnega refinanciranja); Main Refinancing Operations

OLS – (sl. Metoda najmanjših kvadratov); Ordinary Least Squares

SSR – (sl. Senčne obrestne mere); Shadow Short Rates

SVAR – (sl. Strukturna vektorska avto regresija); Structural Vector Auto-Regression

TLTRO – (sl. Ciljno usmerjene operacije dolgoročnejšega refinanciranja); Targeted Longer-Term Refinancig Operations

US – (sl. Združene države Amerike); United States

VAR – (sl. Vektorska avto regresija); Vector Auto-Regression

INTRODUCTION

Over the last decade, the European Central Bank (hereafter ECB) changed its operational framework by introducing several rounds of unconventional monetary policy measures. The nature of unconventional monetary policy measures depends on the market impairments that the measures are designed to address. Based on shifting economic challenges over the course of the global and euro area financial crises, unconventional monetary policy measures can be divided into three distinct phases: global financial crisis measures, euro area financial crisis measures, and measures adopted during the low inflation, low growth environment in the aftermath of the euro area crisis. The focus of this master's thesis is on the most recent phase, when the ECB struggled with increased risks of a prolonged period of low inflation and weak economic growth. As the monetary policy easing reached zero-lower bound, the ECB introduced a powerful new set of unconventional policy measures, which included large scale asset purchases, negative rates on deposit facility and targeted longer-term refinancing operations. These measures were designed to provide monetary stimulus to the broader euro area economy and to incentivise bank lending.

This master's thesis aims to empirically analyse dynamic relations between macroeconomic variables and monetary policy in times of unconventional policy measures. The main challenge in modelling the effects of unconventional policy measures is to capture the unconventional monetary policy stance, since the main policy rates become very uninformative when stuck at zero-lower bound. The recently proposed shadow short rates could be used as an alternative measure of the unconventional policy stance as suggested by Wu and Xia (2013, 2017). Damjanovic and Masten (2016) show that shadow rates affect output and inflation in a similar way as the standard policy rates in normal times. They employ shadow short rates as a monetary policy variable in a vector autoregressive model.

The purpose of this master's thesis is to investigate the unconventional monetary policy effects on euro area output and inflation by employing shadow short rates as an alternative measure of monetary policy stance in a simple three-variable structural vector autoregression. The analysis is in line with the model of Damjanovic and Masten (2016), with two notable differences. First, it includes shadow short rates proposed by Wu and Xia (2017) in their latest study on euro area that considers a time-varying lower bound on interest rates. Second, it employs a structural VAR model that imposes additional identifying assumptions to recover structural shocks. This has the advantage of imposing restrictions on contemporaneous effects between variables. In line with the economic assumption that changes in monetary policy affect macroeconomic variables only with a lag, there are zero-restrictions on contemporaneous responses of output and inflation to the monetary policy shock.

In addition to the Introduction and Conclusion, this master's thesis consists of six chapters. Chapter one introduces some basic concepts of conventional and unconventional monetary

policy of the ECB. Chapters two to four discus unconventional monetary policy measures over the three phases. The last phase (in chapter four) is covered in more detail by including the effects on the balance sheet and an overview of main transmission channels of unconventional policy measures to the real economy. Chapter five discusses unconventional policy measures impact through a literature review, and chapter six proceeds with the empirical analysis. The empirical part, firstly, outlines the shadow rates as a policy measure through relevant literature and defines the structural vector autoregression model. All necessary steps of the analysis are presented with results and comments, while the concluding remarks are discussed in conclusion.

1 CONVENTIONAL AND UNCONVENTIONAL MONETARY POLICY OF THE ECB

The aim of the first chapter is to provide the basic concepts of conventional and unconventional monetary policy of the ECB. It considers institutional principles relevant for the euro area's monetary policy, introduces the conventional monetary policy implementation and provides a short overview of the unconventional policy measures in order to form a brief classification of adopted measures over the period 2008 – 2018.

1.1 Institutional framework and financial structure of the euro area

Since January 1999, the Eurosystem has consisted of the ECB and the national central banks of EU (hereafter EU) countries that have adopted the euro. EU countries with the euro as their currency form the euro area, which currently consists of 19 countries that have transferred the responsibility for monetary policy from their national central banks to the ECB. The legal basis for the single monetary policy is the Treaty on the Functioning of the European Union (hereafter the Treaty) and the Statute of the European System of Central Banks and of the European Central Bank. The ECB has legal personality under public international law as a supranational institution of the European Union that forms the core of the Eurosystem and is responsible for conducting monetary policy for the euro area. (ECB, 2019)

The primary objective of the ECB is to maintain price stability as defined by the Article 127 of the Treaty. In addition, the ECB shall also support the general economic policies in the EU, which include balanced economic growth and full level of employment. The definition of price stability in quantitative terms is defined as a "year-on-year increase in the Harmonized Index of Consumer Prices (hereafter HICP) for the euro area of below 2 percent and is to be maintained over the medium term." (ECB, 2019). Furthermore, the Treaty consists of many other provisions relating to the economic and monetary union, including the prohibition of monetary financing by the central bank defined by the Article 123, the prohibition of privileged access by public institutions or governments to financial institutions defined by the Article 124, the "no-bailout" clause defined by the Article 125

and the fiscal provisions for avoiding excessive government deficits defined by the Article 126. Hence, the ECB is prohibited from purchasing government bonds in the primary market and has limited intervention possibilities in the secondary market. Moreover, the Treaty gives responsibility for financial stability primarily to individual governments and does not include provisions to ensure joint action in the event of euro area wide risks to financial stability. In the context of sound and stable public finances, countries in the EU shall coordinate their fiscal policies in compliance with the rules of the Stability and Growth Pact (SGP). (Cour-Thimann & Winkler, 2013)

The financial structure of euro area is significantly bank-oriented and has a multi-country context. Banks are the main source of financing of the economy, particularly households. In case of non-financial corporate sector, during the period 2002 – 2012, banks provided more than 70 percent of external financing, whereas less than 30 percent was provided by financial markets and other funding. In comparison, the proportions during the same period in the United States were just the opposite. Around 80 percent of total external financing was funded by market-based sources, while the rest was provided by the banks. Besides financial intermediation, banks are essential in the transmission of monetary policy of the ECB to the euro area economy. There are large number of counterparties that participate in regular Eurosystem refinancing operations, with decentralized implementation of monetary policy (through national central banks). Again, the opposite example of centralized policy implementation is in the States, where the Federal Reserve Bank of New York has the responsibility to implement the policy decisions on behalf of the entire Federal Reserve System. (Cour-Thimann & Winkler, 2013)

1.2 Conventional monetary policy implementation

Monetary policy is conducted by the main decision-making body, the Governing Council of the ECB, with decentralised implementation by the Eurosystem. The standard monetary policy operational framework provides liquidity to the Eurosystem through open market operations. These consist of a 1-week liquidity providing operations, known as main refinancing operations (MROs) and a 3-month longer-term refinancing operations (LTROs). Both are providing liquidity to the Eurosystem counterparties against eligible collateral. In addition, the ECB carries out fine-tuning operations (FTOs) that may be either liquidity providing or liquidity absorbing. Moreover, the ECB is responsible for setting the rates on two standing facilities. The deposit facility offers the counterparties the possibility to deposit overnight excess liquidity, while the marginal lending facility allows the counterparties to obtain overnight financing. The ECB signals its monetary policy stance through its main refinancing rate, usually referred to as the policy rate. (ECB, 2009)

The ECB implements its monetary policy through the interbank money market, which thus represents the primary channel of monetary policy transmission. In case of the euro area, the effective overnight interbank interest rate is the EONIA rate. It represents the average of all

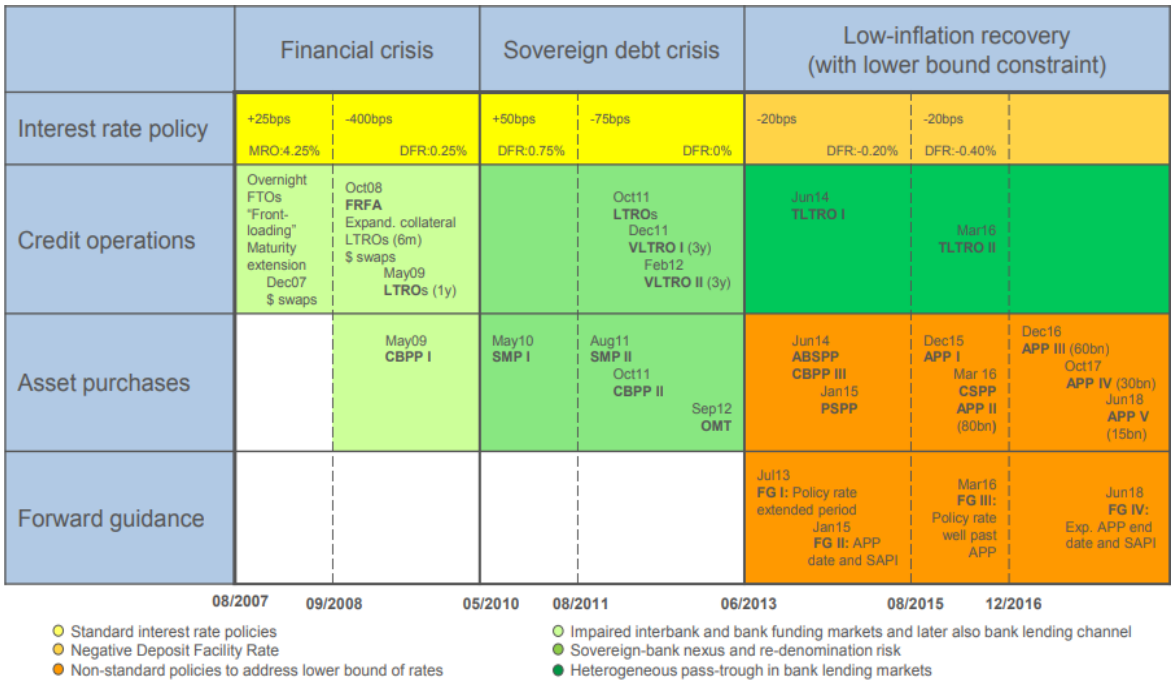
overnight lending transactions between most active credit institutions in the euro area's money market. By steering the overnight EONIA rate using the policy rate, deposit facility and marginal lending rates, the ECB provides an anchor for the term structure of interest rates. Effective steering results in EONIA rate operating closely to the policy rate, implying low positive spread between the two. Furthermore, the two facility rates form the so-called corridor system for EONIA, whereby the deposit facility rate serves as the "floor" and the marginal lending rate imposes the "ceiling". In the interbank market, counterparties lend excess liquidity in the form of reserves to one another. In this manner, liquidity supply in the banking system is distributed according to the supply and demand principles. In addition, lending reserves between banks in the interbank market also ensures that the banks fulfil reserve requirements smoothly. Banks in the Eurosystem, particularly, are required to hold a minimum level of funds in their current accounts at their respective national central bank. Minimum reserve requirements are set for 6-week's time or the so-called maintenance period in which the banks have to meet the reserve requirements on average. In pre-crisis times, the ECB has fulfilled banks' aggregate liquidity needs and banks had no incentive to keep more liquidity than necessary for satisfying the reserve requirements, as they could always address any liquidity shortcomings by borrowing in the interbank market. Conversely, banks were willingly lending excess liquidity to one another in the interbank market. Thus, short-term interbank rates stayed close to the MRO rate with a high degree of certainty. The ECB used this strategy to operate with zero excess liquidity at any point in time during the maintenance periods. (Beirne, 2010; Bech & Monnet, 2015; ECB, 2019)

1.3 Overview of unconventional monetary policy measures

Since the introduction of unconventional monetary policy measures in 2008, the ECB's guiding principles have been to maintain the price stability as its primary objective and to focus on the bank-based financial structure of the euro area. Initially, the ECB made a clear distinction between the conventional and unconventional monetary policies through the "separation principle". The use of unconventional measures in the first two phases after the crisis was rather complementary to the standard policy measures than substitutional. Standard monetary policy was focused on the primary objective of maintaining price stability, while unconventional measures were addressing the dysfunctional financial markets and impairments in policy transmission. Standard and unconventional monetary policies interact and reinforce each other, but they may take different directions as was the case in 2008 and 2011 when the standard policy was tightening and the unconventional measures were still progressing. However, as the standard monetary policy reached its limits around the zero-lower bound in the third phase of the crisis, the unconventional measures took substantial proportions and substituted the standard ones. Thus, the "separation principle" no longer existed. (Hartmann & Smets, 2018)

The nature of unconventional monetary policy measures depends on the impairments they are addressing. Hartmann and Smets (2018) classify them into four major categories and three different phases as shown in Table 1.

Table 1: Timeline of the ECB's monetary policy measures since August 2007



Source: Hartmann and Smets (2018).

In the first phase, corresponding to the outbreak and spreading of the global financial crisis in 2008 – 2009, the primary aim was to provide liquidity for the banking sector and to keep financial markets functioning. Tensions in the interbank money market were already present in August 2007, but as Lehman Brothers collapsed in autumn 2008, the crisis transformed into a systematic crisis that forced the ECB to intervene with the first round of unconventional policy measures. The so-called "enhanced credit support" package contained five distinctive elements. The most notable one was the fixed-rate full allotment procedure (FRFA) that played a major role in providing liquidity certainty.

The second phase was in the form of sovereign debt crisis that hit the euro area over the course of 2010 – 2012. As the banking sector had not yet recovered by that period, the countries were struggling with bank recapitalizations and weak fiscal fundamentals. High levels of government debt had accumulated along with increased budget deficits. Most vulnerable countries faced record high government bond yield spreads, which caused the contagion effect across the euro area markets. At the climax of the crisis, redenomination fears (to old national currencies) spread among market participants, which prompted the ECB to intervene with the "whatever it takes" strategy, accompanied by the announcement of Outright Monetary Transactions. During the second phase, the primary objective was to restore sovereign debt markets' functioning and the ECB introduced the Securities Market

Programme (SMP), Outright Monetary Transactions (OMT) programme and others that constituted the second round of unconventional monetary policy measures.

In the third phase after 2013, monetary policy struggled with a prolonged period of low inflation and weak economic growth. Markets were under external pressure, mostly caused by the rising US Treasury yields after the Federal Reserve announced tapering of its policy of quantitative easing. Increased uncertainties among market participants were reflected in rising interest rates expectations and declining inflation expectations. The ECB introduced forward guidance in 2013 and made substantial interest rate cuts. But as policy easing reached the zero-lower bound, room for further rate cuts became very limited. Moreover, the policy rate cuts were not transmitted to the financial sector effectively, which caused increased geographical fragmentation of financial markets and risks of another credit crunch. The ECB responded with more comprehensive unconventional policy measures that influenced the whole constellation of interest rates relevant for financing conditions in the euro area. The so-called "credit easing" package was introduced in June 2014 and included targeted longer-term refinancing operations (TLTROs), negative interest rate on the deposit facility and asset purchase programme (APP).

2 UNCONVENTIONAL MONETARY POLICY MEASURES IN THE FINANCIAL CRISIS

The following chapter discusses the origins of the financial crisis from the perspective of interbank money market tensions. Those started in August 2007, when the ECB had already responded with conventional policy measures in order to counteract the liquidity shortages that resulted from interbank market impairments. After the Lehman Brothers collapse in September 2008, the crisis transformed into a global systematic crisis that hit the markets around the world. The ECB introduced the first round of unconventional policy measures that were combined into the "credit enhancement support" measures.

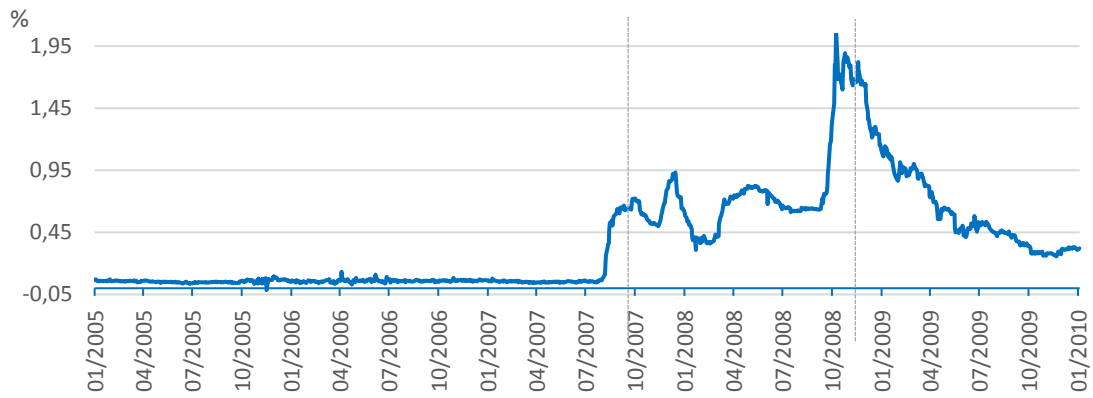
2.1 Interbank market tensions and financial crisis outbreak

Money market rates are important indicators of functionality of the interbank market. EURIBOR rates that have maturity ranges from 1 week to 12 months are especially relevant and represent a meaningful benchmark for various financial products, such as swaps, futures and options. Banks refer to EURIBOR rates when setting their rates on loans, savings and mortgages. EURIBOR rates thus form the money market yield curve, which is commonly proxied by the spread between the 3-month and 12-month EURIBOR. EURIBOR is short for Euro Interbank Offered Rate and represents the average interest rate at which the selection of European banks that form the panel lend funds to one another in the unsecured interbank market. The panel banks are those with the highest credit ratings, ethical standards, and reputation. The EURIBOR rates are calculated on a daily basis by eliminating the highest and the lowest 15 percent of all the collected quotes and averaging the remaining rates. The

interbank rate with the shortest maturity is the overnight EONIA rate. It is short for Euro Over Night Index Average, which represents the average of all unsecured overnight interbank lending transactions made by the panel banks. Thus, it is considered as a 1-day EURIBOR rate. (Euribor-rates, 2019; European Money Markets Institute, 2019)

Normally, the tensions in the interbank market are observed from the spread between the secured and unsecured money market rates or more particularly, spreads between the EURIBOR rates and the overnight index swap (OIS). The latter represents a good proxy for the secured money market rates. Usually, two parties participate in an OIS contract, where one commits to pay a fixed rate (swap rate) and the other commits to pay a variable rate (average EONIA over the maturity of the swap). Thus, it can be interpreted as an average short-term rate that the market expects to prevail over a certain period. (Abbassi & Linzert, 2011) The OIS rate is a proxy for secured money market rate, since the purely secured rate is essentially represented by the Eurepo rate in the Euro-denominated General Collateral (GC) market that has a limited use in financial instruments and contracts. The Eurepo rate is the benchmark rate at which one bank offers funds to another bank, if in exchange the former receives the best collateral from the latter, within the most actively traded European repo market. (European Money Markets Institute, 2019) In normal times, with sufficient liquidity and absence of market dislocations, EURIBOR rates evolve closely to OIS rates for the same maturities. When the spread between EURIBOR and OIS rate for corresponding maturities is widening, it reflects the worsening of liquidity risk premia and/or credit risk premia. Thus, it is considered a proxy indicator of risk in the banking sector. (Abbassi & Linzert, 2011) Figure 1 shows the EURIBOR – OIS spread for 3-month maturities. There is a notable widening in the spread with the emergence of financial market tensions in August 2007 and it is marked by the first vertical line. Moreover, the spreads escalated with the Lehman Brothers bankruptcy in September 2008, which is marked by the second vertical line.

Figure 1: EURIBOR – OIS spread at 3-month maturities



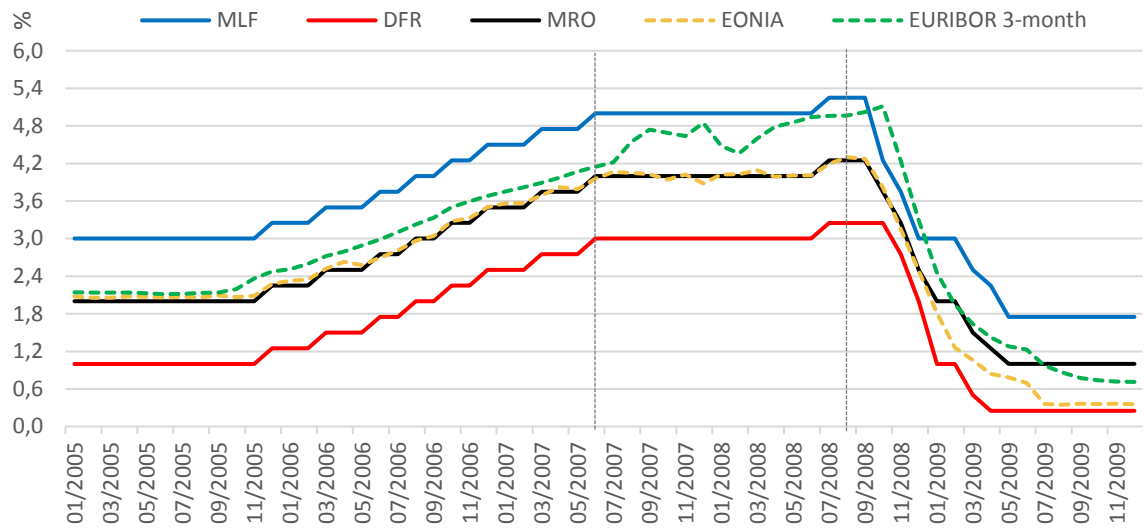
Source: Adopted from Bloomberg (2019); own work.

Abbassi and Linzert (2011) reported that the predictability of EURIBOR rates based on the market expectations about the future overnight rates diminished during the crisis. In

particular, the anticipated policy rate change of 25 basis points caused a contemporaneous increase in EURIBOR rates by roughly 3 basis points. While in pre-crisis times, the same policy rate change produced instantaneous response in EURIBOR rates by 17 – 23 basis points.

The interest rate corridor between the deposit facility rate (DFR) and the marginal lending facility rate (MLF), in which the interbank money market rates (EONIA and EURIBOR) are settled, can be clearly observed in Figure 2.

Figure 2: ECB key policy rates, EONIA and 3-month EURIBOR



Source: Adopted from ECB Statistical Warehouse (2019); own work.

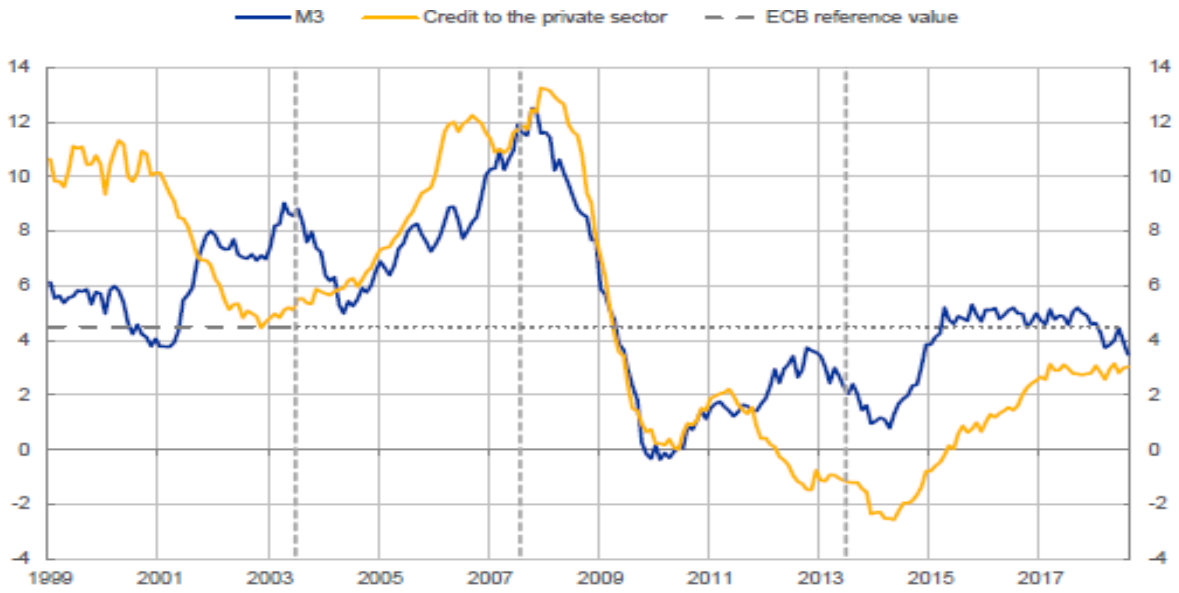
While both money market rates operated closely to the corridor mid-point before August 2007, the EURIBOR rates deviated away from the mid-point until the substantial collapse in the corridor system following the Lehman Brothers bankruptcy in September 2008.

Tensions originated in the US subprime market and spilled over into the money markets, and from there, to all the other market segments around the world. In times, when the housing bubble was still bursting both in the US and Europe, some financial institutions were already collapsing and financial health of the counterparties in the interbank market became questionable. Initially, money markets tensions caused shortages of liquidity, as banks abstained from lending in the interbank market, which resulted in a sudden increase of liquidity demands. The ECB responded with exceptional liquidity injections through fine-tuning operations (FTOs) of around 95 billion euros (Beirne, 2010). Liquidity was provided in large extent, at the beginning of the maintenance period, which is known as the liquidity "frontloading", and then absorbed towards the end with the liquidity-absorbing FTOs. Moreover, the 3-month refinancing operations (LTROs) were conducted more regularly, i.e. on a monthly basis, while the new 6-month LTROs were introduced in April 2008. In a year's time, by the middle of 2008, the total longer-term refinancing operations (with a

maturity of 3 and 6-months) almost doubled from 33 percent to 61 percent on average. (ECB, 2009)

However, after the Lehman Brothers collapse in September 2008, further drying up in the money markets and disfunctionality in other financial market segments took on extensive proportions. The euro area GDP growth dropped to historical lows, while banks tightened loan conditions, since they were uncertain about their own liquidity needs and fear of default. Figure 3 indicates the annual percentage change of Monetary Financial Institutions (MFIs) credit growth to the private sector (denoted by the yellow line) and growth of M3 monetary aggregate (denoted by the blue line). The latter is the so-called broad monetary aggregate that includes narrow (M1) and intermediate (M2) monetary aggregate. Generally, aggregates differ in regard to the degree of liquidity of the assets they include. For instance, aggregate M1 refers to the currency and overnight deposits, while M2 consists of M1 as well as the deposits with an agreed maturity of up to two years. Thus, M3 comprises of M2 and certain marketable securities issued by the resident MFI sector. (ECB, 2019) Dotted vertical line represents the ECB's reference value of 4.5 percent for M3 growth, which has been discontinued since May 2003, as the ECB reviewed its monetary policy strategy.

Figure 3: MFI's credit to the private sector and M3 growth (annual percentage changes)



Source: Hartmann and Smets (2018).

The drop in M3 aggregate and credit growth in 2008 was sizeable. The credit supply between December 2007 and January 2010 declined by 13 percent. Therefore, the risk of a credit crunch increased, together with the risk of the central bank's inability to control monetary conditions. (Collignon, Esposito & Cui, 2012)

2.2 Monetary policy responses

From conventional monetary policy side, the General Council responded with significant cuts in the MRO rate after the Lehman's bankruptcy in 2008. The MRO rate was lowered by 325 basis points in two rounds until May 2009, when it reached historically low level of 1 percent. In addition, the interest rate corridor was narrowed temporarily from 200 to 100 basis points around the MRO. The corridor was thereafter narrowed and widened many times in order to counteract the tensions in the interbank market and policy rate decisions. The magnitude of the financial crisis and distortions in financing conditions were beyond the scope of standard monetary policy responses. The ECB therefore introduced the first round of unconventional policy measures that were primarily focused on supporting the transmission of the standard monetary policy and improving funding and liquidity conditions in the banks. The following five "enhanced credit support" unconventional monetary policy measures were employed by the ECB (ECB, 2010):

- **Fixed-rate full allotment (FRFA)** – The tender procedure was changed for all open market operations from variable to fixed rate with full allotment in October 2008. Until that time, MROs were conducted in the form of variable rate tenders with minimum bid rate, which represented the MRO rate. Thus, counterparties placed their bids expressing the amount of liquidity they required and the interest rate they were willing to pay. The ECB then determined the total amount allotted to the counterparties, subject to minimum bid rate. The same rate was also applied in the regular LTROs. Instead, FRFA procedure made liquidity in all open market operations unlimited to the participating counterparties. Their only constraint was to provide eligible collateral. Thereafter, the aggregate liquidity was no longer determined by the ECB. Instead, it became completely demand driven. The procedure caused substantial increase in the volume of refinancing operations and was essential in removing allotment uncertainties.

- **Extension of collateral eligibility** - The accepted list of assets eligible as a collateral in the Eurosystem refinancing operations was expanded. Rating threshold for marketable and non-marketable assets was lowered from A- to BBB-, while the threshold for asset backed securities (ABS) remained unchanged at A-. It enabled the banks to obtain the demanded liquidity by refinancing a larger share of their balance sheets, which contained assets that became less liquid in the wake of the financial crisis.

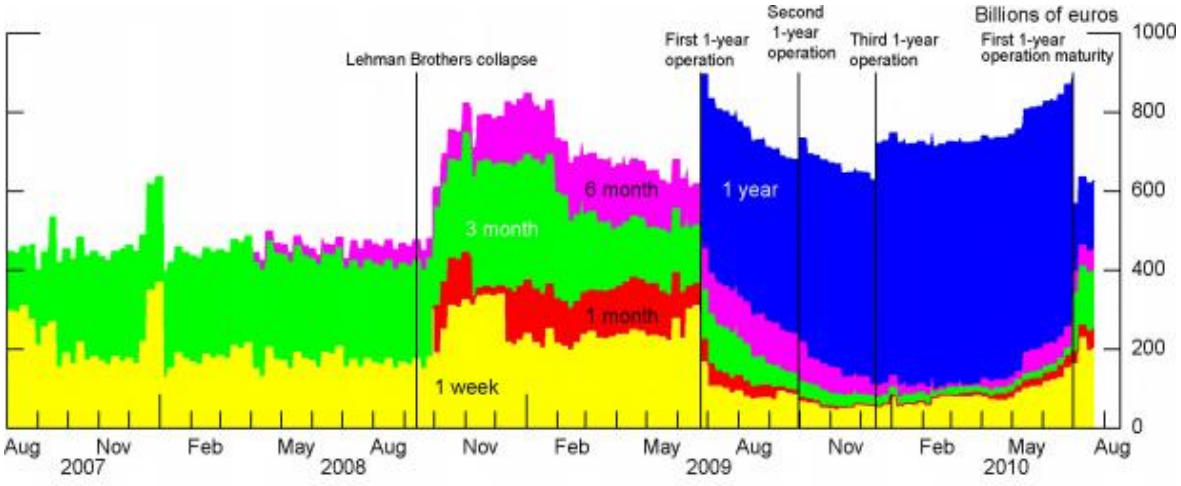
- **Extension of the maturity ranges of LTROs** – Refinancing operations were further increased and accommodated in term maturities with the purpose of loosening banks' concerns about availability of liquidity. The ECB introduced supplementary 6-month LTROs in April 2008 (even before the Lehman Brothers collapse), but most notably, it announced three series of refinancing operations with longer maturities of 12-months at a fixed-rate full allotment. Participation in the first 12-month LTRO in June 2009 was met with a very high demand, with the allotment of over 442 billion euros among 1,121

participants. The second one followed in September 2009 and attracted less attention, allotting a total of 75 billion euros, while the last one in December 2009 allotted 96 billion euros. In addition, the ECB complemented refinancing operations with 1-month LTROs carried out on a monthly basis. Below, the Figure 4 indicates developments and proportions of refinancing operations after the introduction of FRFA procedure and extensions of LTRO operations. It can be observed how LTROs and MROs increased shortly after the Lehman Brothers collapse in amount and diverse maturities. However, after the first 12-month LTRO conduction, other refinancing operations as well as MROs substantially declined. During the period between August 2007 and June 2009, the aggregate amount of outstanding refinancing operations rose on average by more than 60 percent and reached levels of 890 billion euros.

- **Currency swap agreements** - In order to overcome the disruptions in accessing US dollar funding, the ECB introduced US dollar liquidity providing operations against eligible collateral in cooperation with the US. The Federal Reserve System provided US dollars to the ECB via temporary swaps, and the Eurosystem passed US dollars to its counterparties via repo operations. This measure was first introduced without a particular announcement in December 2007, when the ECB, Bank of Canada, Bank of England and Swiss National Bank joined forces with the US in order to counter the pressures in the interbank market. Since July 2008, operations of 28-day and 84-day maturities were carried out. The risk of vast US dollar shortfall was thus avoided, since the euro area banks had significant liabilities in US dollars as they were providing funding to numerous US market segments, including real estate and subprime. In addition, the ECB provided liquidity in some other currencies as well.

- **Covered bond purchase programme (CBPP)** - Under the scope of outright purchases, the Eurosystem committed to purchasing euro-denominated covered bonds, issued in the euro area. Covered bond market is the primary source of funding for the banks in a greater part of the euro area, while also being the most attractive segment of fixed income. They are issued by banks to refinance loans made to the public and private sectors and are often backed by mortgages. As the covered bonds market almost completely dried up in terms of liquidity and issuance, the aim of the programme was to revive activity in the market. CBPP purchases were conducted in a total value of 60 billion euros in one year, from June 2009 to June 2010. Since CBPP represented roughly 2.5 percent of total outstanding amount of covered bonds, it was relatively small, and mainly adopted as a catalyst to revive the activity in this market.

Figure 4: ECB's outstanding refinancing operations since the beginning of the crisis



Source: Federal Open Market Committee (2016).

By the end of 2009, the financial markets showed signs of stabilization. Policy measures reportedly contributed to a decline in the money market rates. For instance, Abbassi and Linzert (2011) evaluated the reduction of EURIBOR rates by more than 100 basis points, while the spread between the unsecured interbank EURIBOR rate and overnight interest rate swap (OIS) gradually narrowed as well. Money market yield curve somewhat flattened and, consequently, bank lending rates declined, which resulted in a modest recovery of credit and money growth, as can be observed from Figure 3 above.

Therefore, the Governing Council announced in December 2009, that those unconventional measures, which were no longer needed, would gradually be phased out. Hence, the frequency of the 3-month LTROs was reduced, supplementary 6-month LTROs were dismissed in March 2010, as well as the currency swap agreements. In March 2010, it was even decided to return to a variable rate tender procedure in the regular 3-month LTROs. Other elements of enhanced credit support remained. (ECB, 2010)

3 UNCONVENTIONAL MONETARY POLICY MEASURES IN THE SOVEREIGN DEBT CRISIS

The second phase of the unconventional ECB monetary policy interventions concerns the period between 2010 and 2012. This chapter aims to discuss how the financial crisis transformed into a sovereign debt crisis in the euro area. On one hand, some euro area countries struggled with recapitalizations of banks with accumulated high levels of non-performing loans that resulted in increased government debt. On the other hand, the weak fiscal conditions and imbalances in some other peripheral euro area countries caused unsustainable levels of external debt and budget deficits. The most vulnerable countries faced record high yield spreads and caused contagion effect across the euro area markets. As the market participants responded with redenomination fear (to old national currencies), the

ECB responded with the "whatever it takes" strategy, accompanied by the announcement of the Outright Monetary Transactions programme. Unconventional policy measures addressed the malfunctioning sovereign debt markets and comprised of Securities Markets Programme, Outright Monetary Transactions programme and other programmes that constituted the second round of unconventional monetary policy measures.

3.1 Roots of sovereign debt crisis

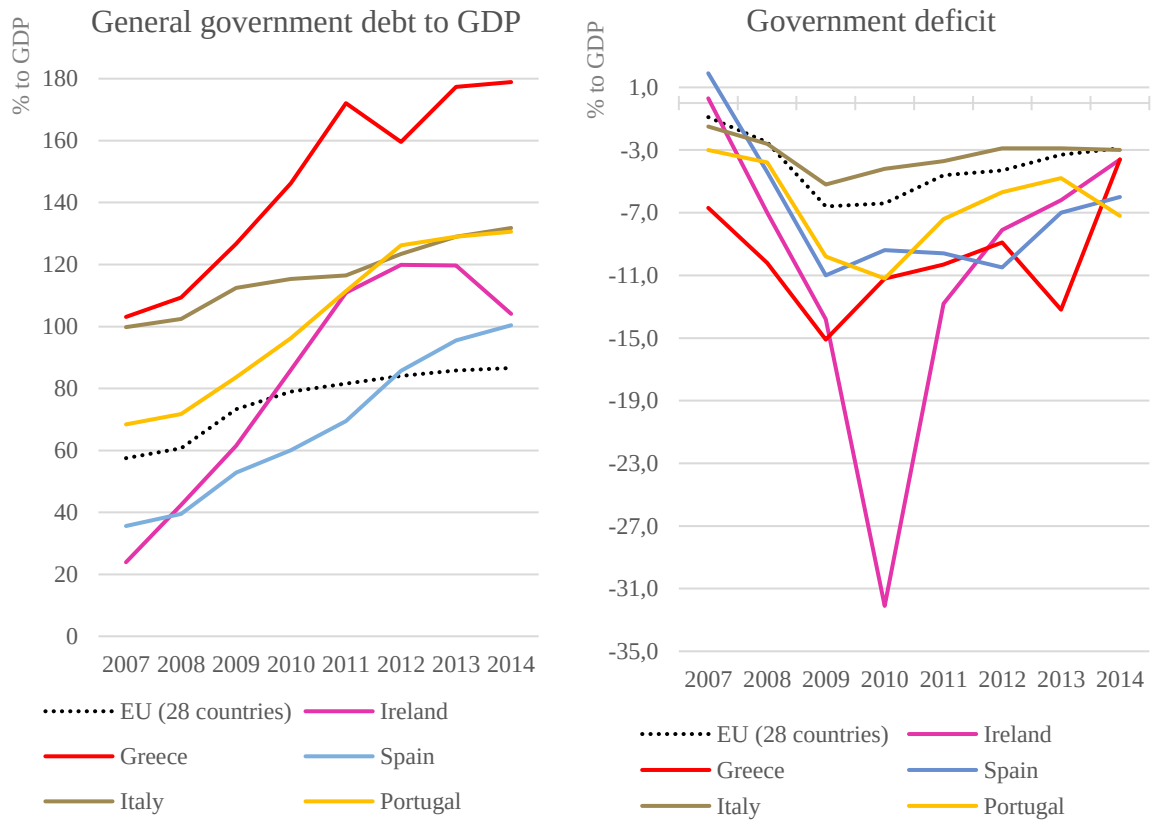
In 2010, global financial crisis transformed into the sovereign debt crisis in the euro area. Roots of the crisis were internal to the euro area, as many euro area countries have recorded large and persistent current and financial account imbalances for several years before the crisis. The integration of the banking and funding markets eased the financing constraints to a point, where the countries struggling with persistent current account deficits (associated with net imports of goods and services) could fund net cross-border payment outflows with the money provided by the interbank market. Moreover, the government bond markets were completely integrated and coherent, which was reflected in zero bond yield spreads among all sovereigns yields. (Cour-Thimann & Winkler, 2013)

Even though the financial markets showed signs of stabilization by the end of 2009, the sovereign bond markets soon started collapsing one after another. There was a remarkable event at the end of 2009, when the newly elected Greek Prime Minister Papandreou reported that the Greek fiscal deficit for the year 2009 would be 12.7 percent of GDP rather than 3.7 percent as the outgoing government had stated. Following the announcement, the confidence shock expanded around the euro area and raised concerns about sustainability of public finances in some other peripheral euro area countries. (Dell' Ariccia, Rabanal & Sandri, 2018). Moreover, the banking crisis that had evolved from high levels of non-performing loans on the back of collapsed real estate markets and private sector indebtedness, endangered solvency of some of the largest banks in the significant parts of euro area economies (Ireland, Spain). Eventually, the banking crises caused direct bailouts and emergency fiscal stimulus that resulted in increased levels of budget deficits and government debts. Figure 5 indicates levels of government deficits and general debt levels relative to the GDP for some of the euro area sovereigns. For instance, an outstandingly high level of budget deficit emerged in Ireland in 2010 on the account of government involvement in rescuing the largest Irish banks. Fiscal distress in problematic euro area countries caused significant downgrading of their fiscal and economic outlooks on the back of the fiscal imbalances and accumulated excessive debt levels. This was reflected in widening of the sovereign spreads, which in turn hit back the banks' balance sheets filled with sovereign bonds. Relationship that evolved between the banks and their sovereigns is referred to as the sovereign-bank nexus. (Dell'Ariccia and others, 2018)

Unsustainable debt levels in Greece required an Economic Adjustment Programme in May 2010, in exchange for funding Greece's borrowing needs. In October, it was followed by the

announcement of the Deauville agreement on the private sector involvement (PSI) in the resolution of the Greek sovereign debt crisis. The Greek debt restructuring was announced for July 2011, but only came into force in March 2012. Nevertheless, concerns that the PSI agreement might become a precondition for financing other vulnerable countries as well, increased sovereign spreads and produced negative effects on the banking sector across the euro area. (ECB, 2014b)

Figure 5: General government debt to GDP ratio and government deficit for selected euro area countries



Source: Adopted from Eurostat (2019); own work.

In May 2010, the ECB reintroduced some of the unconventional policy measures after the remuneration in order to avoid spillovers from sovereign bond markets to other financial markets. The ECB revived the FRFA procedure in regular 3-month LTROs, conducted additional 6-month LTROs and announced the Securities Market Programme. (Amaro, Eser, Iacobell & Rubens, 2012)

3.2 The Securities Market Programme

The ECB responded with a more powerful programme in order to mitigate the impairments in the transmission mechanism originating from dysfunctional bond markets. It announced the outright purchases of private and public debt securities in the secondary market under

the Securities Market Programme (SMP). The programme targeted mainly small peripheral euro area countries. Government bonds were potentially purchased on a daily basis by simply observing the market conditions and without any predetermined public target in terms of price or quantity. To ensure that the liquidity conditions would not be affected, purchases were fully sterilized by fine-tuning liquidity-absorbing operations (FTOs) on a weekly basis. (Fratzscher, Lo Duca & Straub, 2014)

The SMP strategy should be distinguished from the asset purchase programmes, as the main objective is focused on restoring the transmission mechanism and market functioning, instead of providing additional monetary stimulus. Besides, the injected liquidity through SMP purchases was re-absorbed on a weekly basis, in order to neutralize program's liquidity impact, which should not alter the monetary policy stance. This is very much in line with the ECB's "separation principle" between unconventional interventions and the standard ones. The SMP was terminated in the beginning of 2011, but as the sovereign tensions re-emerged, the SMP was reactivated in August 2011. (Gambetti & Musso, 2017)

In the first half of 2011, conditions appeared to be relatively stable and hardly any interventions took place. The Eurosystem even identified upside risks in headline inflation growth, since it had reached 2.6 percent in March on the back of the reported GDP growth in the first quarter of 2011. The ECB decided to intervene in its regular open market operations by increasing the MRO rate from 1 percent to 1.25 percent in April 2011 and further to 1.5 percent in July 2011. (Hartmann & Smets, 2018)

3.3 Second round of unconventional monetary policy measures

A complete reversal of conditions followed in the second half of 2011, when the financial tensions intensified yet again. Many fiscally weak countries were struggling with bank recapitalizations and resolutions, while the negative impacts were spreading from the Greek PSI agreement. Consequently, the bank-lending standards tightened again, and further reduced money and credit growth that resulted in impaired enhanced monetary credit support. The Economic Adjustment Programme was announced in May 2011 for Portugal and Cyprus, while worsening of the public finances in Italy and Spain led the ECB to reactivate the SMP in August 2011.

In October and December of 2011, the ECB intervened with another round of policy measures. The MRO rate was lowered in two steps by cumulatively 50 basis points under the new President Mario Draghi. Moreover, the following unconventional measures were activated (Amaro, Eser, Iacobell & Rubens, 2012);

- **CBPP2 (Covered Bond Purchase Programme)** – was announced to start in November 2011 and be completed in October 2012, with scheduled purchases of 40 billion euros of covered bonds. However, when the programme was completed, purchases amounted to

the total of 16.4 billion euros due to the lack of primary market covered bond issuance, along with the positive effects of 3-year VLTROs.

- **VLTROs (Very Long-Term Refinancing Operations)** – were new liquidity providing operations with 3-year maturities and with the option of early repayment after one year. The first VLTRO was scheduled for December 2011 and the second one for February 2012. The main objective was to improve the banks' funding certainty and to ease the redemptions of maturing bonds. Around 1 trillion euros were allotted in two operations (489 billion in the first and 530 billion euros in the second). The take-up was significant in volume and in number of participating banks, which was the sign that liquidity was reaching out to smaller banks, whose primary business is refinancing small and medium-sized enterprises. In addition, two LTROs of 12-month and 13-month maturities were conducted as well. The first one, in October 2011, faced very small number of tenders for allotment of 57 billion euros, while the second was conducted in December 2011 just after the first 3-year VLTRO offer and was thus scrapped. It was clear that high allotments of the 3-year VLTROs crowded out short-term refinancing operations.

- **Extension of collateral eligibility –** list of accepted collateral was further extended by allowing additional asset types to be used as collateral in refinancing operations of the Eurosystem. It was done so by reducing the rating threshold for certain asset-backed securities. Meanwhile, the national central banks were allowed to accept credit claims, in particular bank loans that satisfied specific criteria. The purpose was to improve refinancing conditions for smaller banks that have an important role in lending to small and medium-sized enterprises.

- **Fine-tuning operations were discontinued** – in order to stimulate money market activity and reduce EONIA volatility.

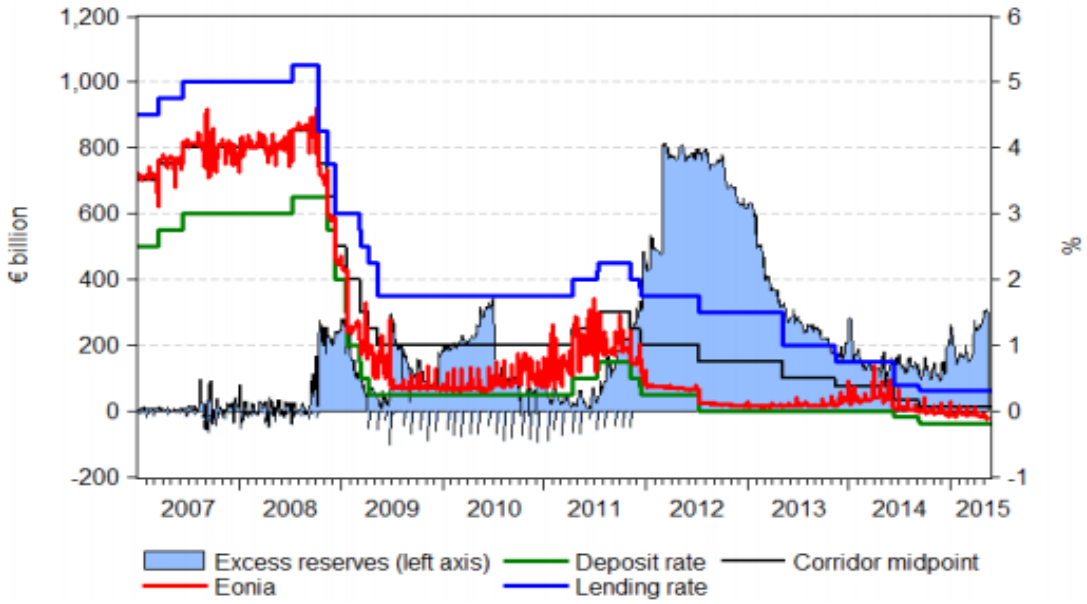
- **Reserve ratio was reduced** – from 2 percent to 1 percent in order to reduce banks' need for retaining additional liquidity with the purpose of reaching reserve requirements.

- **Foreign currency operations** – with 84-day maturities were reintroduced.

The unconventional monetary policy measures, particularly those in the form of longer-term refinancing operations and fixed rate full allotment procedure, produced high levels of excess liquidity in the banking system. The developments of excess liquidity, ECB policy rates and EONIA are presented in Figure 6 bellow. Since 2008, liquidity needs became completely demand driven, as the ECB undertook the role of interbank market intermediation. Along with policy rate cuts and liquidity providing operations, high levels of surplus liquidity started to accumulate on the deposit facility in the form of excess reserves. This created a significant downward pressure on money market rates, such as EONIA, which dropped from the interest rate corridor mid-point levels to the floor of the

corridor, represented by the deposit facility rate. Thereafter, EONIA would only slightly increase towards the MRO rate when levels of excess liquidity significantly decreased. It was mostly associated with the periods of LTROs maturities and in relative stable periods, when very few unconventional measures were in progress, especially in the mid-2009 and the first half of 2011. (Amaro, Eser, Iacobell & Rubens, 2012)

Figure 6: Developments of excess liquidity, ECB policy rates and EONIA over 2007-2015



Source: Bech and Monnet (2015).

Such developments significantly differ from the conditions before the crisis, when the ECB used zero-excess liquidity strategy. Thus, the banks were only concerned about minimal reserve requirements that had to be fulfilled on average during the maintenance period. They would lend excess liquidity to one another in the interbank market without any accumulation in the form of excess reserves in the deposit facility.

3.4 The peak of sovereign debt crisis

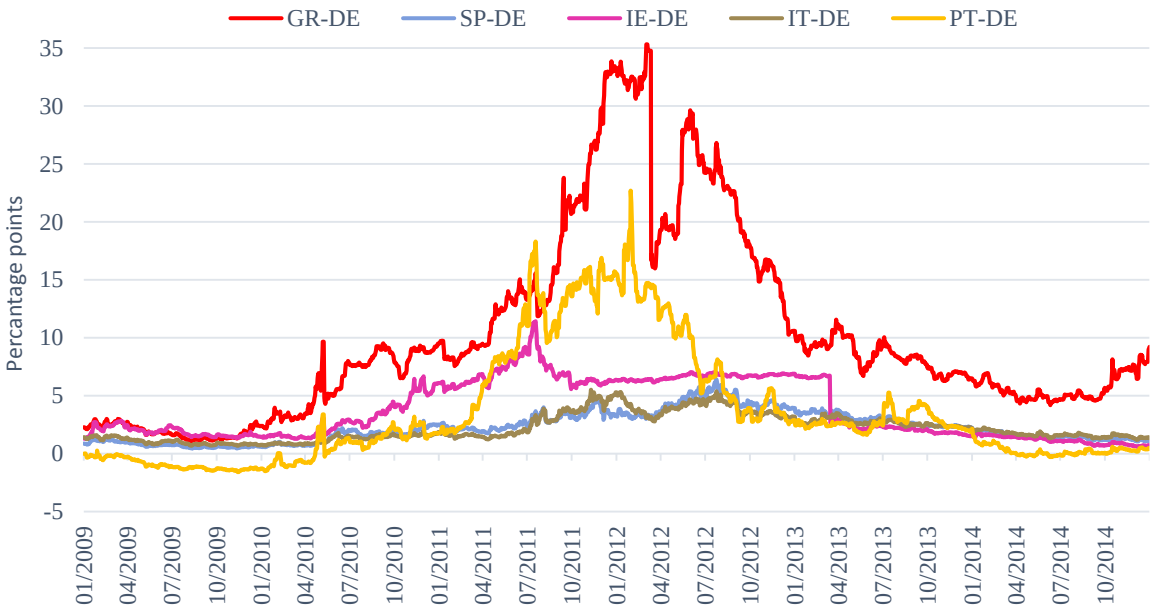
Despite efforts made by the ECB to provide credit support and to stabilize the monetary policy transmission mechanism, the underlying solvency problems of both banks and sovereigns persisted and reinforced each other. The ability of banks to provide credit was impaired, as the bank-funding costs were pushed up by the tensions in the sovereign debt markets. Bond spreads of riskier sovereigns widened due to the increased liquidity and credit risks. On the contrary, bonds that were perceived safer and more liquid started to outperform in terms of low yields, which was the case of the German debt securities (Bunds). Normally, a high level of liquidity refers to the bonds that can be traded immediately, with low transaction costs and without causing significant price changes. On the other hand, the higher

level of safety refers to a better creditworthiness of the issuer and thus a lower possibility of issuer default. Therefore, such bonds tend to have lower yields. (ECB, 2008)

Developments in the euro area sovereign bond yields reflected the concept of financial contagion. This can be defined as a transmission of instability from one market to the other markets, leading to the emergence of bad equilibria. The existence of bad equilibria refers to the phenomenon of multiple equilibria that arises because of self-fulfilling beliefs. A bad equilibrium is caused by the uncertainties regarding future fundamentals in a country due to the government's inability to commit to repaying its debt. As a result, the investors demand risk compensation. The government is then forced to default even in the case of favourable developments of the fundamentals, since the bad equilibrium has already been reached and is sustained by the self-fulfilling beliefs. Consequently, the cost of servicing a sovereign debt becomes higher and the monetary policy transmission is obstructed. (ECB, 2014b)

While the transmission of instability is propagated and amplified by financial contagion, the main driver of increased sovereign spreads towards 2012 was associated with uncertainties regarding "currency redenomination". This was reflected in a higher risk premia demanded by the market participants as a compensation for the risk of redenomination of the euro currency into the devaluated legacy (old national) currencies. As we can observe from Figure 7, in the course of 2011 and 2012, the Greek, Irish and Portuguese 10-year bond yields reached extremely high spreads relative to the German Bunds. In 2012, GR-DE spread stretched out to 35 percentage points and PT-DE to 22 percentage points, while IE-DE had already reached the levels beyond 10 percentage points in 2011. Even though Spain did not reach extremely high government bond spreads, it applied for the Financial Assistance programme in 2012.

Figure 7: 10-year government bond yield spreads relative to German Bunds



Source: Adopted from Bloomberg (2019); own work.

3.5 The Outright Monetary Transactions Programme

Dysfunctional sovereign bond markets and fears about currency redenomination put price stability at risk and forced the ECB to intervene. In July 2012, the ECB stepped in with the famous statement made by the ECB President Mario Draghi "within our mandate, the ECB is ready to do whatever it takes to preserve the euro. And believe me, it will be enough." Another round of key interest rates cuts followed this statement. The MRO rate was lowered to 0.75 percent and the deposit facility rate to 0 percent. More importantly, in August 2012, the Governing Council announced the Outright Monetary Transactions (OMT) programme that may be undertaken if needed. The modalities were presented a month later, in September 2012.

The main objective of the OMT programme was to preserve the irreversibility of the euro currency and singleness of the ECB's monetary policy. The ECB signalled its readiness to intervene in the government bond markets to prevent the forming of bad equilibria due to the self-fulfilling beliefs. The OMT operations fall into the scope of the outright transactions under the Article 18 of the Treaty and give the possibility of unlimited purchases of government bonds. The purchases were focused on the government bonds with short-term maturities of up to 3 years and holdings publicly transparent in terms of market values. (Fratzscher, Lo Duca & Straub, 2014)

The true significance of the OMT programme was the strict conditionality attached to the interventions. The reason for this were the limitations of the Treaty provisions and the institutional set-up of the monetary union for the monetary policy tools. The ECB's monetary policy itself was not able to address the underlying solvency issues of either banks or governments. Incompleteness of the euro area in banking and fiscal areas was raising concerns. Under these circumstances, decisive steps were taken at the political level. First, the "Fiscal pact" treaty was signed in March 2012, determining a balanced-budget rule. Second, in June 2012, the European Council meeting proposed comprehensive reforms of the financial, budget and economic policy frameworks of the euro area. Among the proposed reforms was the establishment of the main elements of a Banking Union with explicit reference to the need of breaking the sovereign-bank nexus. An agreement was reached on entrusting the first pillar of the Banking Union, the Single Supervisory Mechanism (SSM), to the ECB, whereas the temporary European Financial Stability Facility (EFSF) was replaced by the permanent European Stability Mechanism (ESM). The latter was an intergovernmental organization established to restore financial stability of the euro area through financial assistance to the member states with severe financing problems, against strict conditionality. In turn, eligible bonds for OMT purchases were those issued by the countries under ESM macroeconomic adjustment programme. (Hartmann & Smetz, 2018)

Conditionality of the OMT applies to four relevant parties. First, the sovereign country, the bonds of which may be subject to interventions. Second, the euro area governments collectively, which fund the ESM programmes and share responsibility of the programmes'

effectiveness. Third, the IMF, if involved in the programme. Finally, the ECB, which may suspend the OMT in case the government, the bonds of which are subject to the OMT interventions, fails to comply with the conditionality clause. However, if the government makes necessary efforts to restore the sustainability of public finances and employs appropriate economic policies, as set out in the programme conditions, the ECB defines a proper exit from the OMT. (Cour-Thimann & Wrinkler, 2013)

4 UNCONVENTIONAL MONETARY POLICY MEASURES IN THE LOW INFLATION ENVIRONMENT

In the third phase, the ECB struggled with risks of prolonged period of low inflation and weak economic growth. The following chapter first presents a brief review of developments over 2013 – 2014 that forced the ECB to intervene with the substantial policy rate cuts and to introduce the forward guidance about future interest rates. As policy easing reached the effective zero-lower bound, the ECB intervened with a more powerful set of unconventional monetary policy measures in June 2014. In addition, this chapter describes the conditions in the ECB's balance sheet after the asset purchases transition in December 2018 and discuses most common transmission channels of unconventional policy measures to the real economy.

4.1 Developments in 2013 – 2014

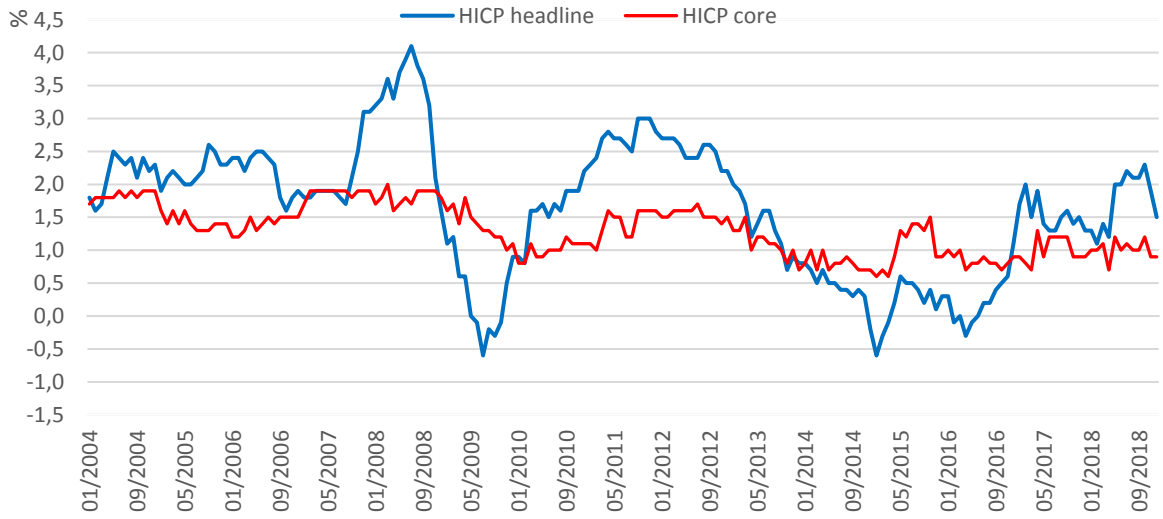
In 2013, the economic recovery and inflation rates remained fragile and subdued by the external pressures. Developments in oil and food prices dragged down the headline inflation readings, while the core components remained low due to generally weak economic growth. Negative spillovers of the US "taper tantrum"[1] resulted in rising long-term US Treasury yields that created an upward pressure on the money market rates. This obstructed the interbank lending at the same time when the general levels of liquidity in the banking-system dropped on the back of some larger amounts of LTRO repayments. In addition, the share of excess liquidity declined even more as the deposit facility rate was cut to zero. The ECB, in turn, provided an even more accommodative policy stance by cutting the MRO rate to 0.25 percent in two steps in May and November of 2013. In order to protect the euro area from the external tightening pressures, the ECB decided to introduce forward guidance on interest rates in July 2013. (Alvarez and others, 2017)

Despite the ECB's policy easing, the interest rate cuts have not been sufficiently transmitted to the real economy. High degree of financial market fragmentation along the national borders persisted and caused growing heterogeneity in financing conditions for households

[1] Taper tantrum refers to the 2013 collective panic after the Federal Reserve announced tapering of its quantitative easing policy that was introduced in response to the financial crisis. Reducing the pace of Fed's asset purchases produced a negative shock to the investor expectations and increased uncertainties of future market instability due to the lack of liquidity.

and firms across the euro area countries. Thus, the risk of a credit crunch due to the impaired bank lending channel increased. Economic recovery remained weak, while the disinflationary pressures intensified. Figure 8 indicates developments of headline and core HICP inflation components. The headline HICP inflation dropped from 2.2 percent in December 2012 to 0.5 percent in June 2014. The risks of deflation intensified a few months later, on the back of continuous fall in oil and food prices, when headline inflation reached its lowest point of -0.7 percent in January 2015. Indicators of inflation expectations, as well as the market-based measures of inflation expectations stood at their historical lows, implying increased risks of an extended period of low or even negative inflation. (Hartmann & Smets, 2018)

Figure 8: HICP headline and core inflation over 2004 – 2018



Source: Adopted from Eurostat (2019); own work.

In June 2014, the ECB announced the third round of comprehensive unconventional monetary policy measures. The so-called "credit-easing" package consisted of a negative deposit facility rate, a Targeted Longer-Term Refinancing Operations (TLTROs), and an Asset Purchase Programme (APP). The latter was substantially expanded with the asset purchases of public sector securities (PSPP) in January 2015, since the reassessment of conditions at the end of 2014 indicated a potentially prolonged period of weak economic growth and low inflation.

4.2 Forward guidance

Introduction of forward guidance in July 2013 was in the form of the following sentence: "ECB expects the key interest rates to remain at present or lower levels for an extended period of time. The expectation is based on the overall subdued outlook for inflation extending into the medium term, given the broad-based weakness of the economy and subdued monetary dynamics." (ECB, 2014a)

The Governing Council decided to present forward guidance in order to anchor market expectations about the future key interest rates. The expectations recently became extremely influenced by external shocks, which was reflected in volatile and increased money market rates. When a central bank is clear about its objective and monetary policy strategy, the market participants can better understand the central bank's response. Use of forward guidance has long been in the monetary policy a toolkit of central banks, but was only used occasionally prior to the crisis. However, as financial crises are rare and space for normal monetary policy is limited, the market participants find it difficult to infer the likely future path of policy rates from past observations. Therefore, forward guidance is considered an additional crisis management instrument. (ECB, 2014a)

- The ECB's forward guidance has been designed under the following elements (ECB, 2014a):
- Primary objective of maintaining price stability, under which the Governing Council forms decisions about key interest rates based on the desired inflation outlook in the medium term.
- Reference to "keep interest rates low for an extended period of time" applies a flexible horizon based upon the Governing Council's assessment of the outlook for price stability over the medium term.
- Approach is classified as qualitative guidance conditional on a narrative, because it is complemented by a narrative statement describing macroeconomic conditions under which the decision about the future path is based.

Evolution of forward guidance has followed the developments in the ECB's monetary policy after introducing a sizeable monetary stimulus with public sector purchases in 2015. Since then, the policy stance of the ECB became a combination of asset purchase programmes, key policy rates, and forward guidance on each of these tools. The ECB has thereafter signalled the monetary policy and price stability objective by associating the medium-term inflation outlook assessment with APP size and duration. (Praet, 2018)

Forward guidance, accompanied with key parameters of the APP helped market participants to form expectations about the future of the APP. The ECB has indicated a minimum horizon by stating the end-date until which the net monthly purchases are to be carried out, together with the possibility of extending the programme in case the "sustained adjustment in the path of inflation" has not been met. Typically, the forward guidance statement on asset purchases was announced as "ECB would continue net asset purchases at a monthly pace of X billion euros until X date, or beyond, if necessary, and in any case until the Governing Council sees a sustained adjustment in the path of inflation consistent with its inflation aim." Regarding the accumulated stock of purchases securities, the ECB added that it aims "to reinvest the principal payments from maturing securities purchased under the APP for an extended period of time after the end of its net asset purchases, and in any case for as long as necessary." Finally, forward guidance on the expected path of key policy rates was linked to the expected horizon of asset purchases in the statement that "ECB expects key interest rates

to remain at their present levels for an extended period of time, and well past the horizon of our net asset purchases." (Praet, 2018)

4.3 Negative rate on the deposit facility

4.3.1 The zero-lower bound

Accommodative stance of the ECB policy in 2013 converged towards the zero bound. This provoked numerous discussions about further capabilities of the ECB's interest rate policy. Reasons lie in the notion of the zero-lower bound, which over the last two decades became a growing concern first in Japan and then in most other developed countries. Normally, when inflation rates and output are perceived too low, the central banks cut their key policy rates to switch into an expansionary stance and to support consumption and investment, which along with other components enter the GDP growth equation. This is the basic logic, even though the whole transmission mechanism is more complex. Clearly, the scope for rate cuts becomes limited once the interest rates approach the zero-lower bound and the normal mechanism of expansionary monetary policy stance affecting the economy and inflation does not work anymore.

There are two arguments explaining the problem of the zero-lower bound. First, the zero bound is understood as a physical barrier for nominal interest rates, beyond which people would rather hold physical money (banknotes) that pays zero interest than the negative-yielding assets. It has long been believed that nominal interest rates cannot fall below zero for this reason. On the other hand, expansionary monetary policy seeks the effective lower bound, which represents a barrier beyond which further rate cuts would not be effective anymore. Thus, the effective lower bound may not correspond with the physical zero lower bound. Nevertheless, even if the effective lower bound for short-rates is reached, it does not impose a binding constraint on the effectiveness of monetary policy (Cœuré, 2016). It is important for monetary policy transmission that markets do not perceive the effectiveness of monetary policy to be constrained by the notion of zero lower bound. For instance, Lemke and Vladu (2017) illustrated in their euro area term structure model that the market perceptions of the effective lower bound decreased from positive levels to -11 basis points in September 2014, which is largely attributed to a decline in the short end of the yield curve. Thus, if the central bank manages to decrease the market's perception of the lower bound location, then the expected future rates would follow the monetary policy stance and decrease.

However, the reason why market perceptions about the lower bound are problematic lies in the monetary tightening bias that may arise. When market participants receive false signals about the monetary policy stance, they consequently form pessimistic expectations about the future policy interest rates. For instance, the appearance of a binding lower bound for monetary policy creates a gap between the actual market rates and the expected ones.

Statistically, interest rates below the perceived lower bound are "eliminated" from the set of possible outcomes and consequently, the rates above the lower bound receive higher relative weights and expected value of interest rates is pushed up. Inefficient pricing of expectations creates a tightening bias, which is reflected in rising yield curves that reinforce disinflationary pressures, even though the monetary policy is easing. (Praet, 2016)

The reason why the lower bound was reached in the euro area in the first place may be in a declining "natural interest rate". The latter is, by definition, consistent with stable inflation and output at its potential level. When key policy rate is set below that level of natural interest rate, it creates an upward pressure on the output and inflation, whereas the opposite happens if the policy rate is set above the natural rate. Long-term decline in the natural rate thus requires policy rates to be set at record low levels or even in the negative territory. However, natural rate is difficult to estimate and refers to various explanations. The broad consensus is that it has been declining in advanced economies over the past two decades and is by some estimates negative in the euro area. This could have occurred for many reasons, but particularly relevant for the euro area are low productivity and/or a slowdown in population growth. A longer period of such declining natural interest rate, as the one in Japan, for instance, is referred to as the "secular stagnation" hypothesis. (Cœuré, 2015)

4.3.2 Negative rate on the deposit facility

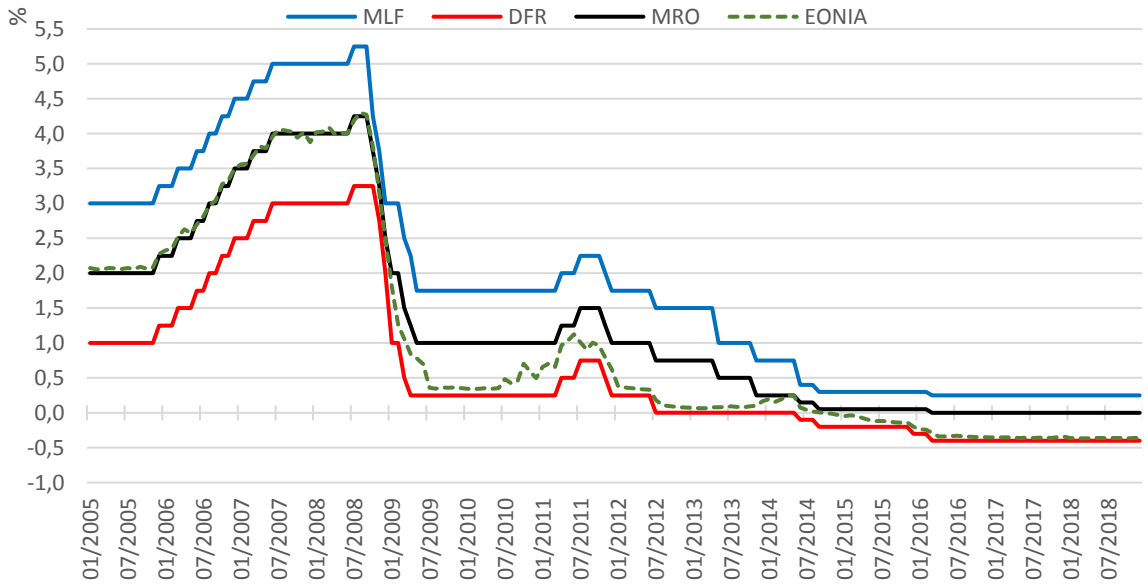
Negative rates enable loosening of the perceived lower bound about the future distribution of policy rates and strongly support the accommodative monetary policy stance. The ECB decided to go into the negative territory in June 2014, when it cut the deposit facility rate to -0.1 percent. Gradually, in steps by 10 basis points, it was lowered until left unchanged at -0.4 percent since March 2016[2]. Similarly, cuts in the marginal lending facility rate occurred three times until the rate has remained unchanged since March 2016 at 0.25 percent. Finally, the MRO rate reached 0 percent in March 2016 in five steps, since May 2013, and has also remained unchanged so far. Developments of key interest rates and EONIA rate are shown in Figure 9. (ECB, 2019)

The most important role of interest rate reductions and introduction of the negative deposit facility rate was to support the comprehensive unconventional monetary policy measures that the ECB has adopted since June 2014. The negative deposit facility rate alone strongly incentivised banks to increase lending to the economy by redistributing their excess liquidity. Any hoarding of excess liquidity in the deposit facility would be obstructing monetary policy stimulation and transmission (Praet, 2016). Moreover, the negative rates did reportedly decrease banks' lending rates but in turn caused a decline in net interest income and narrowed loan margins. The reason is that the banks that are reliant on retail deposits would be reluctant to charge negative rates to their clients. In addition, the declining key policy rates were accompanied by flattening of the yield curve that compressed the margin between

[2] The ECB cut the DFR in September 2019 by 10 basis points to the new low of -0.5 percent.

(shorter term) borrowing and (longer term) lending. Even though the loan – deposit margins are lower, banks can mitigate the negative impact on profits via two channels. First, the lower lending rates are likely to stimulate loan demand which should lead to increased lending volumes. Second, the lower lending rates together with better economic conditions should result in fewer loan defaults, which reduces banks' costs of loan losses. (ECB, 2017a)

Figure 9: ECB policy rates and overnight money market EONIA rate



Source: Adopted from ECB Statistical Warehouse (2019); own work.

4.4 Targeted longer-term refinancing operations

The motivation behind introducing the Targeted Longer-Term Refinancing Operations (TLTROs) was to reinforce the ECB's accommodative monetary policy by providing further support of bank lending to the real economy. TLTROs are operations providing financing to the credit institutions for periods of up to four years. They offer long-term funding at attractive conditions in order to ease the credit conditions and thus support the monetary policy transmission mechanism. TLTRO financing operations are targeted, because the amount that the banks were allowed to borrow was linked to their outstanding loans to non-financial firms and households. The eligible counterparties had the opportunity to participate individually or as part of a TLTRO group via lead institution, subject to certain conditions. TLTROs were conducted in two rounds. The first (TLTRO-I) started in September 2014, while the second (TLTRO-II) commenced in June 2016[3]. (ECB, 2017b)

[3] The ECB announced a new round of TLTRO-III in March 2019, starting in September 2019.

4.4.1 TLTRO-I

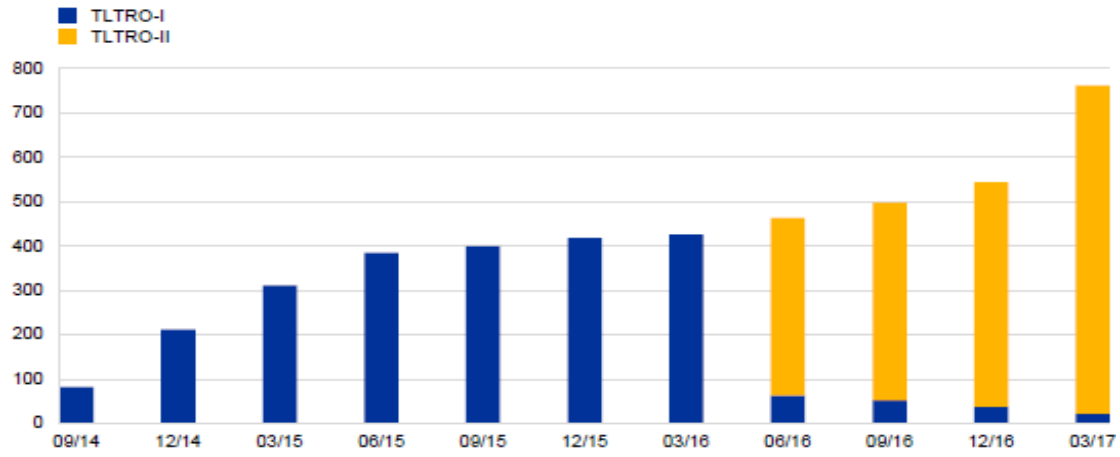
TLTRO-I programme consisted of eight open market operation series carried out at quarterly intervals between September 2014 and June 2016. The operations were conducted at the prevailing fixed interest MRO rate, plus a fixed spread of 10 basis points. The additional spread was later removed due to volatile money market rates. Amounts that banks could borrow in TLTRO-I operations were linked to the stock of their eligible loans in their balance sheets. The eligible loans are loans to the euro area non-financial corporations and households, excluding the loans to households for house purchases. In the first two operations of TLTRO-I, the banks were allowed to borrow up to 7 percent of their eligible loans reported in their balance sheets as of April 2014, the so-called "initial allowance". In the remaining six operations, borrowing allowances were linked to the evolution of eligible loans from May 2014 onwards, referred to as the "additional allowance". Meaning, that the ECB looked at the difference between bank's net lending from May 2014 until the reference date of the allotment, as well as bank's net lending in twelve months before May 2014. Thus, if a bank provided extra net lending in the first two rounds, it was "rewarded" with additional borrowings in the further six operations, amounting to three-times the amount of extra net lending. Furthermore, if the bank decreased credit supply in the first two rounds, which means net lending remained lower compared to the period before May 2014, it was "penalized" by earlier repayment of credit in September 2016. Such stimulation system in the form of "carrot and stick" was significant for TLTRO-I. (Acar, 2016; ECB, 2017b)

4.4.2 TLTRO-II

In March 2016, the Governing Council announced implementation of the second round of TLTRO (TLTRO-II). It consisted of four open market operation series that took place on a quarterly basis between June 2016 and March 2017. The operations were conducted at a fixed MRO rate prevailing at the time of allotment. The TLTRO-II was designed with similar features as the TLTRO-I, yet with some adjustments that made the new programme even more attractive for counterparties. All operations were scheduled to mature in four years, with the possibility of voluntary early repayment after two years. Every bank was able to borrow up to 30 percent of the stock of eligible loans reported in their balance sheets as of January 2016. In addition, the ECB offered banks a repayment option of TLTRO-I in June 2016, meaning that the banks could roll over their borrowings to TLTRO-II and benefit from even more accommodative terms. Stimulation in TLTRO-II was not "penalizing" banks with earlier repayment in case of a negative net lending. It was only rewarding those banks that provided extra net lending between February 2016 and January 2018 by lowering interest rate applied to the TLTRO-II, potentially to the level of the deposit facility. Since the DFR was set to -0.4 percent on March 2016, banks received payment for their TLTRO uptake. (Acar, 2016; ECB, 2016a)

Take-up of the TLTROs was significant, especially those of the TLTRO-II series. The evolution of a bank's gross TLTRO borrowing is shown in Figure 10 below. There is a clear shift from TLTRO-I into TLTRO-II that can be observed in June 2016. It is also noticeable how banks postponed the take-up towards the last allotment in March 2017, as they were expecting further cuts in key policy rates. Besides, they were consciously observing developments in their eligible loans in order to assess by how much they were likely to outperform their lending benchmarks more accurately. Finally, the outstanding amount of all TLTROs as of end of March 2017 stood at 761 billion euros. (ECB, 2017b)

Figure 10: Evolution of TLTRO's gross borrowings (EUR million)



Source: ECB (2017b).

4.5 Asset purchase programme

Asset purchase programme (APP) is the third element of credit easing measures the ECB introduced in mid-2014. Initially, it consisted of the Asset-Backed Securities Purchase Programme (ABSPP) and the third Covered Bond Purchase Programme (CBPP3). In January 2015, the programme was significantly expanded with the Public Sector Purchase Programme (PSPP) and in March 2016 with the Corporate Sector Purchase Programme (CSPP). The following two paragraphs shortly describe CBPP3 and ABSPP, while PSPP is presented into more detail, as it comprises the largest share of APP.

– **CBPP3** – Covered bond purchases were already a part of the ECB's unconventional policy responses in the first two rounds after the financial crisis and during the sovereign debt crisis. Purchases started in October 2014 with a planned duration of at least two years. In contrast to the previous CBPP programmes, the ECB did not announce any targeted volume and there were no limitations to maturity or issuance size. The purchases were conducted by a large number of national central banks and the ECB, subject to market capitalization benchmark of eligible securities. As the programme progressed, the scarcity of covered bonds in the market forced purchases to become increasingly reliant

on primary markets and on availability and liquidity of individual bonds. The main reason was that the launch of TLTRO-II increased the attractiveness of retaining covered bonds as collateral, rather than placing them in the market. Therefore, the weights attached to certain securities in the market capitalization benchmark decreased over time as some covered bond categories were becoming hard to purchase. (Alvarez and others, 2017)

- **ABSPP** – was launched with an aim to provide the incentives for counterparties to issue simple and transparent asset backed securities. The ABS were purchased in the primary and secondary markets, initially by external agents on behalf of the ECB, and since April 2017 by six national central banks[4]. The securities under ABSPP were purchased only after the approval of credit risk assessment and due diligence. The structure of purchased asset-backed securities exhibited asset types prevalent in each of the countries in the euro area. For instance, the auto ABS dominated in Germany, while residential mortgage backed securities (RMBS) were common in the Netherlands. RMBS dominated gross purchases as they would usually be actively offered to the Eurosystem and had longer maturities and lower yields. Oppositely, securities with higher yields and lower average maturity were held by hold-to maturity investors and thus not so actively offered to the Eurosystem. The contribution of ABSPP to the overall APP volume has gradually declined. The reasons for this trend were the persistent supply and demand asymmetries and the fact that the ABS were still associated with negative experience from the financial crisis. (Hammermann, Leonard, Nardelli & von Landesberger, 2019)

4.6 Public sector purchase programme

In January 2015, the ECB announced the public sector purchase programme (PSPP) that covered large-scale purchases of debt securities issued by the public entities in order to provide additional stimulus to the economy. The mechanism of large-scale asset purchases targeted the long-end of the yield curve. As central bank mechanically increases demand for the long-term securities, their relative prices increase, which in turn lowers long-term yields. Thereby, the central bank compresses the term premia and remove the interest rate risk from the market. (Alvarez and others, 2017)

Eligible bonds under PSPP purchases were those issued by the euro area governments, recognized government agencies and international organizations or multilateral development banks. Maturity of securities was limited from 2 to 30 years, while their yields should trade at least above the deposit facility rate. Eligible securities were also inflation-linked and floating-rate bonds issued by central governments. Initially, 88 percent of total purchases were allocated to government bonds and bonds of recognized government agencies, whereas the remaining 12 percent were allocated to the securities issued by international

[4] National Bank of Belgium, the Deutsche Bundesbank, the Banco de España, the Banque de France, the Banka d'Italia and De Nederlandsche Bank.

organizations or multilateral development banks. These bonds were also considered eligible for "substitute purchases" that served as complements to fulfil the intended purchase amounts, when shortage of government bonds or bonds of recognized government agencies was detected. In particular, up to 12 percent of such purchases was allowed on behalf of the national central bank. (Cœuré, 2015)

Purchases of the public sector securities were conducted by the entire Eurosystem, subject to both the market structure and the institutional set up of the euro area. For this reason, the national allocation of purchases of securities issued by the euro area governments and agencies were based on the Eurosystem national central banks' shares in the ECB's capital key. According to the Article 123 of the Treaty, purchases of the public sector securities were limited to the secondary market. The ECB carried out 8 percent of the purchases directly, whereas the 92 percent was purchased by the national central banks. (Alvarez and others, 2017) Besides, in order to preserve normal functioning of the secondary market, purchases were subject to the issue and issuer limits. The issue limit refers to the maximum share of a single PSPP-eligible security that the Eurosystem is prepared to hold. At the start of the PSPP, the issue share limit was set at 25 percent and was reviewed after six months (in September 2015) to 33 percent. On the other hand, issuer limit refers to the maximum share of an issuer's outstanding securities that the ECB is prepared to buy. It was set at 33 percent in order to prevent price formation and to mitigate the risk of the ECB becoming a dominant creditor of the euro area governments. The only exception to these two limits applies to the EU supranational bonds, whose issue and issuer limits are set at 50 percent. (ECB, 2019)

Since large-scale asset purchases result in fewer securities available in the market, the ECB introduced a procedure of securities lending. Thereby, the securities holdings were lent back to the market and used for other transactions in order to support the bond and repo market liquidity. Securities were lent to a borrower against collateral in the form of other shares, bonds or cash, plus a borrowing fee. The securities lending was available to the central banks since April 2015 for PSPP securities and later for securities under the three covered bond purchase programmes (CBPP, CBPP2 and CBPP3) and corporate sector purchase programme (CSPP). (ECB, 2019)

The Eurosystem conducted net PSPP purchases between March 2015 and December 2018[5]. Table 2 summarizes the decision dates on which the ECB provided further announcements about the APP duration, size, or made adjustments to the parameters.

[5] The ECB announced the restart of APP in September 2019. The purchases will be conducted at a monthly pace of 20 billion euros, starting in November 2019, for as long as necessary to reinforce the accommodative impact of its policy rates, and to end shortly before it starts raising the key ECB interest rates. (ECB, 2019)

Table 2: Decision dates on amounts and period of PSPP

Decision date	Period	Pace (€)
January and December 2015	March 2015 – March 2016	60 billion
March 2016	April 2016 – March 2017	80 billion
December 2016	April 2017 – December 2017	60 billion
October 2017	January 2018 – September 2018	30 billion
June 2018	October 2018 – December 2018	15 billion

Source: Adopted from ECB (2019); own work.

- **PSPP announcement –** on January 2015, the ECB made an announcement of an extended APP that will include public sector securities. The programme was scheduled to start in March 2015 until September 2015 with net monthly purchases of 60 billion euros.
- **First recalibration –** in December 2015 the ECB announced the first extension of the APP at a monthly pace of 60 billion euros until at least March 2017.
- **Second recalibration -** in March 2016, the ECB made the second recalibration of the APP and expanded combined monthly net purchases from 60 billion euros to 80 billion euros until at least March 2017. A share of purchased bonds from international organizations and multilateral development banks that served for complementary purposes on behalf of the national central banks was reduced from 12 to 10 percent. In addition, the Governing Council introduced a new programme as a part of the existing APP that concerned corporate sector securities purchases (CSPP). In particular, eligible securities for the CSPP purchases were the investment-grade euro-denominated bonds in the primary and secondary markets issued by non-bank corporations established in the euro area. The acceptable maturity range of securities was from 6 months to a maximum of 30 years. Eligible securities for the CSPP purchases first had to be eligible as collateral in the Eurosystem's regular liquidity operations, while they also had to pass credit risk assessment and due diligence. There was no minimum issuance volume for debt securities under the CSPP, which gave smaller companies that often issue limited number of bonds, the opportunity for participation. On the other hand, there was a maximum share issuance limit of 70 percent per security. Purchases under the CSPP were executed by six national central banks[6] on behalf of the Eurosystem. The main objective was to provide further monetary policy accommodation and to enhance the pass-through of asset purchases to the financing conditions of the real economy. (ECB, 2016b)
- **Third recalibration –** it was made in December 2016, when the Governing Council announced an extension of the APP until at least December 2017. Net monthly purchases of 60 billion euros started in April 2017. In addition, some parameters of the APP were changed in order to ensure smoother implementation of the APP. The maturity range was broadened by decreasing the minimum remaining maturity from 2 years to 1 year.

[6] The six specialised central banks were the National bank of Belgium, the Deutsche Bundesbank, the Banco de España, the Banque de France, the Banca d'Italia and Suomen Pankki – Finlands Bank.

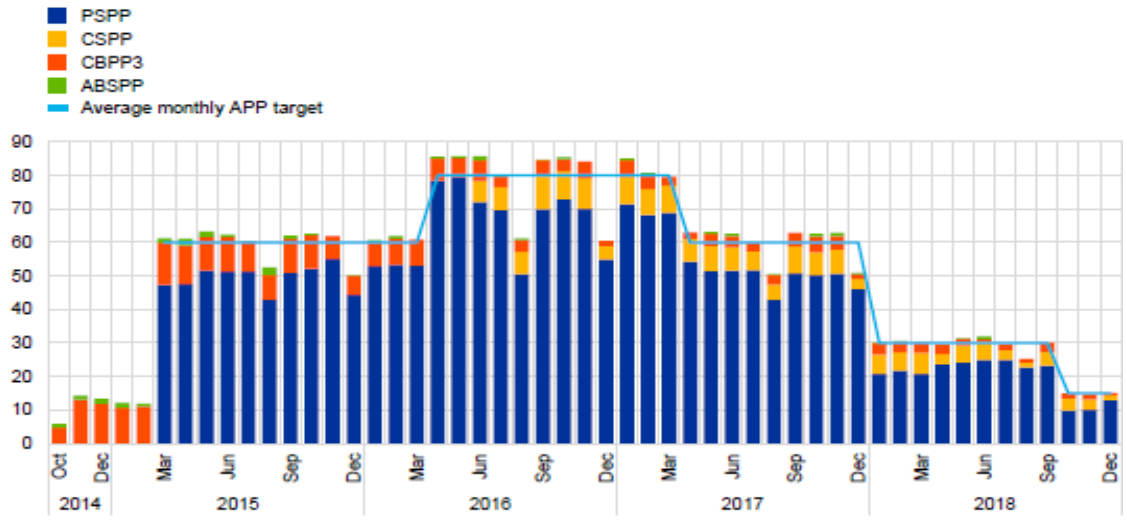
Furthermore, the purchases of bonds, the yields of which traded below the deposit facility rate, were permitted to the extent necessary. The reason was that a great deal of eligible PSPP bonds in highly rated countries traded at yields below the rate on the deposit facility, which significantly reduced the amount of available bonds for purchases, even though the ECB lowered the rate on the deposit facility in December 2015 and March 2016 down to -0,4 percent. (Bock, Cajnko & Daskalova, 2018)

- **Fourth recalibration -** was in October 2017, when the ECB announced the extension of the APP until at least September 2018 with reduced monthly pace of 30 billion euros since January 2018. As redemptions of bonds became a source of reinvestment for PSPP since March 2017, the Governing Council also adopted a decision to provide additional data on redemptions and reinvestments. The redemption dataset includes the estimated cumulative monthly redemptions for a rolling 12-month period for each of the four individual components of the APP (ABSPP, CBPP3, PSPP and CSPP). By rule, redemptions are reinvested together with the Eurosystem's asset purchases in the jurisdiction where the maturing bond was issued. (ECB, 2019)
- **APP transition -** in June 2018, net asset purchases were extended for the last time until the end of December 2018 at a reduced amount of 15 billion euros per month. With that, the period of APP net asset purchases ended in December 2018 and the ECB announced it will continue reinvesting, in full, the principal payments from maturing securities purchased under the APP for an extended period. (ECB, 2019)

4.7 Transition of asset purchases and the ECB's balance sheet at the end of 2018

Net purchases amounted in total to 2.6 trillion euros, of which the PSPP contributed by far the largest share at 82 percent, followed by the CBPP3 at 10 percent, the CSPP at 7 percent and the ABSPP at 1 percent. Figure 11 shows the composition of the net APP purchases throughout the entire period of the programme between 2014 and 2018.

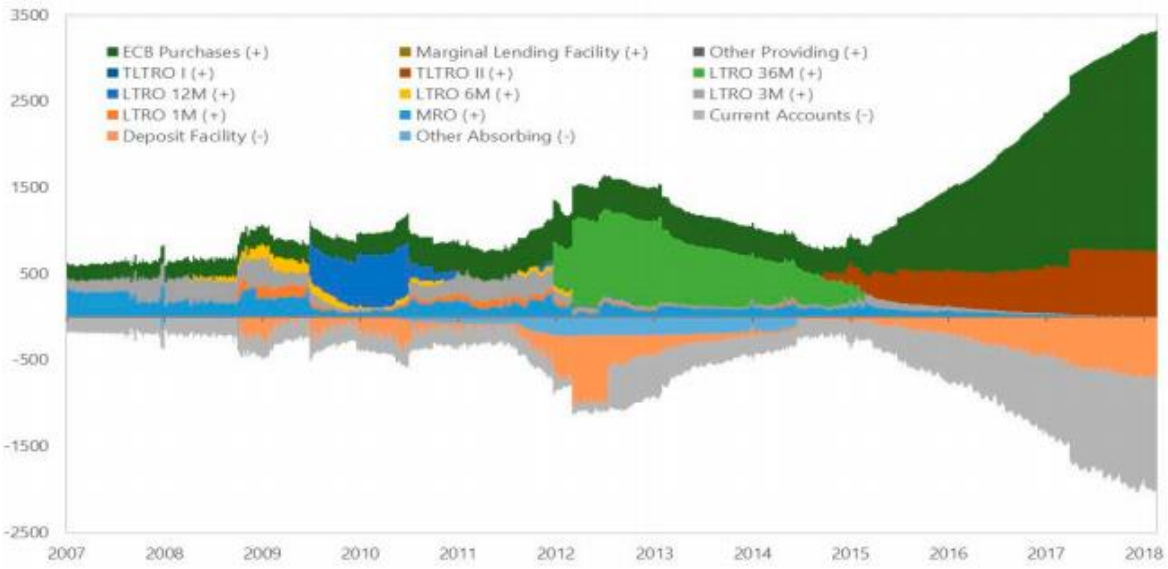
Figure 11: Pace and composition of net APP (EUR billions)



Source: Hammermann, Leonard, Nardelli and von Landesberger (2019).

Monetary policy operations are reflected in the balance sheet of the ECB, which is shown in Figure 12 below. It shows the developments in monetary policy operations since 2007 up to 2018 in million euros. Since large-scale asset purchases and refinancing operations (LTROs and TLTROs) of the ECB increased the size of the balance sheet, they are reported on the asset side. Hence, they are denoted with a positive sign (+). On the other hand, corresponding liquidity creation is reflected mainly in the increase of the central bank's reserves or deposits made by the counterparties. It is reported on the liability side of the balance sheet and denoted with a negative sign (-). Orange colour represents the deposit facility, while grey stands for current accounts of the national central banks held at the ECB. It can be observed that the use of the deposit facility as well as the use of current accounts of the national central banks increased in parallel with increases in refinancing operations provided by the ECB in its unconventional monetary policy responses. This is particularly evident when the ECB provided additional LTROs in 2009 and VLTROs in 2011. However, as the rate on the deposit facility later turned negative, the counterparties abstained from using the deposit facility and rather resorted to current accounts. Besides, the credit-easing package from June 2014 incentivised bank lending and not liquidity hoarding. Furthermore, these unconventional monetary policy measures gradually crowded out the use of standard refinancing operations of the ECB such as MROs and regular 3-month LTROs. Clearly, the demand for short-term central bank's liquidity declined. In addition, the asset side of the Eurosystem's balance sheet started to grow substantially after the introduction of the PSPP and allotments of TLTROs. By the end of 2018, the size of the Eurosystem's balance sheet reached historical high of 4.7 trillion euros. The absolute increase in the size of the balance sheet (as reported at the end of the calendar year) was around 3.2 trillion euros, compared to the size of the balance sheet at the end of the year 2007 (1.5 trillion euros). The relative increase in size was thus more than 313 percent. (ECB, 2019)

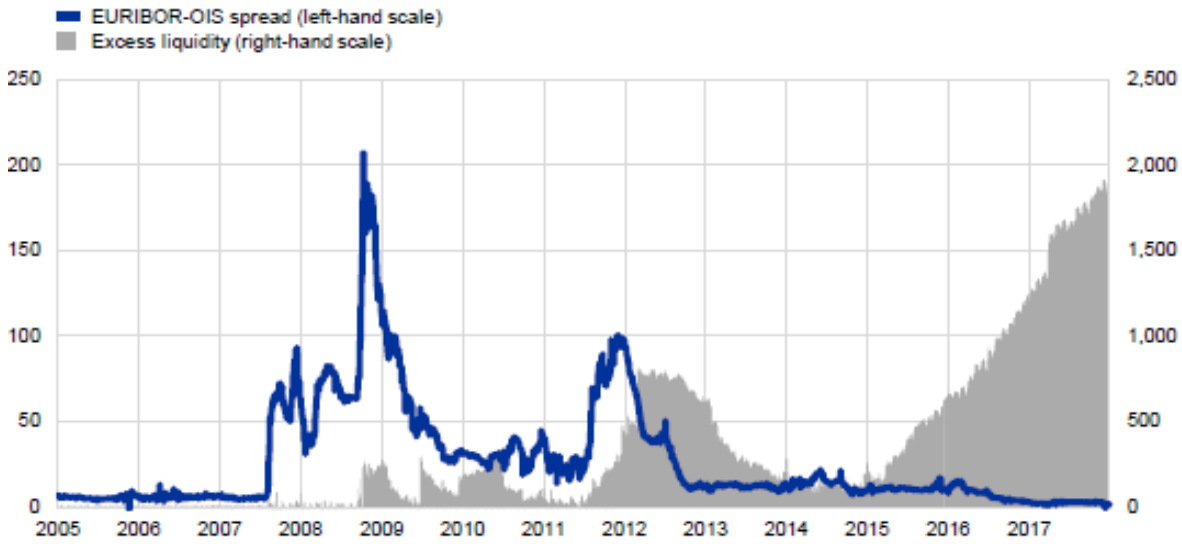
Figure 12: Eurosystem operations by type (in millions EUR)



Source: International Monetary Fund (2018).

Even though excess liquidity in the banking system created a downward pressure on the money market rates and pushed EONIA rate towards the deposit facility rate, the interbank market exhibited little stress since 2013 in the period of comprehensive unconventional policy measures. As can be observed in Figure 13, the spread between the 3-month EURIBOR and OIS rates remained close to zero, which is also close to pre-crisis levels. (Eisenschmidt, Kedan & Tietz, 2018)

Figure 13: Developments in excess liquidity and EURIBOR-OIS spread (left-hand scale: basis points; right-hand scale: EUR billions; daily data)



Source: Eisenschmidt, Kedan and Tietz (2018).

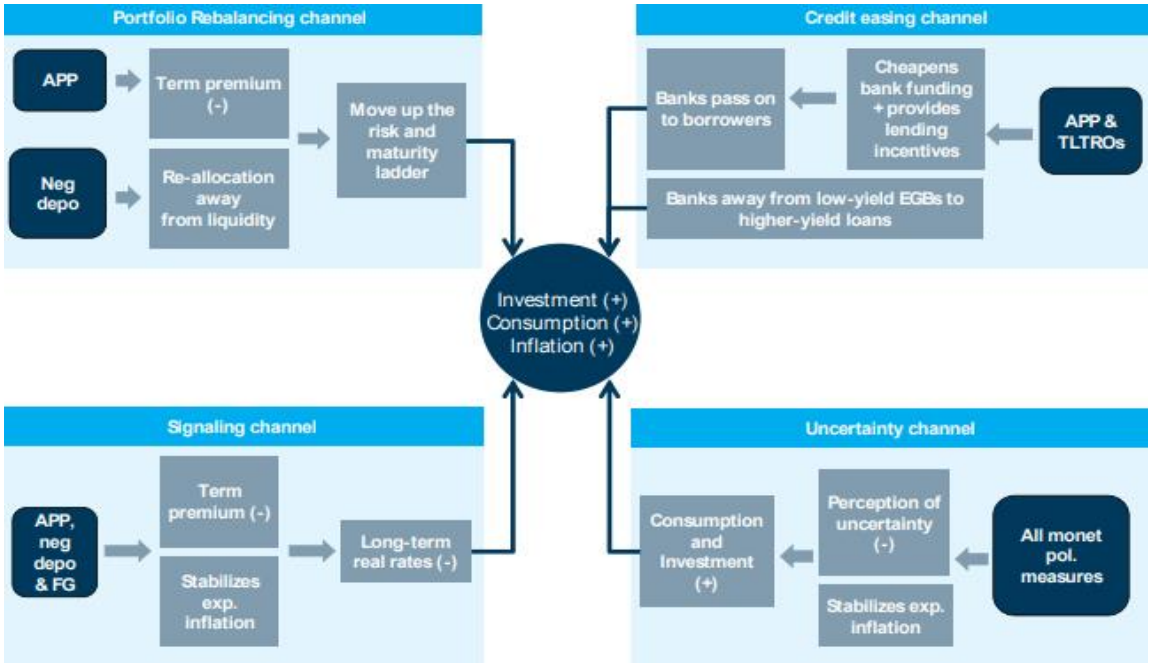
4.8 Transmission mechanisms of unconventional monetary policy measures

Comprehensive package of unconventional monetary policy measures since June 2014 was not only more forceful by nature, but it also substituted the standard monetary policy framework.[7] Thereby, the questions of transmission mechanisms of unconventional monetary policy became relevant. There is growing literature on channels of transmission, and various transmission mechanisms have been identified by different authors. In this chapter, my goal is to present the four most commonly suggested transmission channels of unconventional monetary policy measures. It is also worth mentioning that the transmission channels are sometimes difficult to separate as they usually reinforce one another, just like different unconventional policy measures operate most efficiently when considered in tandem. Even though the unconventional monetary policy measures are very diverse in nature, their transmission to the economy can be traced via a portfolio rebalancing channel, a credit easing channel, a signalling channel, and an uncertainty channel with the ultimate

[7] The question remains whether non-standard measures are becoming the new standard of monetary policy (Financial times, 2019).

goal of stimulating investment, consumption and inflation. Figure 14 represents the mechanism of the four main transmission channels.

Figure 14: Transmission channels of unconventional monetary policy



Source: Wieladek and Pascual (2016).

4.8.1 Portfolio-rebalancing channel

The portfolio-rebalancing channel is considered the most important transmission channel behind large-scale asset purchases. Mechanisms that operate behind the portfolio-rebalancing channel are caused by market imperfections, which stem from the market segmentation theories that date back to authors in the 1970s. Modern implications of these theories argue that the imperfect substitutability of long and short-term assets leads to the existence of "preferred habitat" investors, who prefer bonds with specific characteristics, typically in terms of maturity. (Boermans & Vermeulen, 2018) Moreover, in contrast to the standard new Keynesian general equilibrium model, extensive asset purchase polices in the presence of market frictions do have an effect on relative asset prices. (Tischer, 2018) When a central bank carries out extensive amounts of asset purchases, it can mechanically reduce the supply of securities available in the secondary market, which translates into higher relative prices and lower yields of the purchased securities by virtue of scarcity. "Preferred habitat" investors, though, are incentivised to rebalance their portfolios towards assets with higher expected returns by selling the lower yielding ones, owing to the fact that the liquidity received is not perceived as a perfect substitute for the assets sold. This can be referred to as the search-for yield, which enables the monetary stimulus to be passed through to the sectors that otherwise cannot directly benefit from asset purchases. (Hammermann, Leonard, Nardelli & von Landesberger, 2019)

Moreover, the presence of "preferred habitat" investors potentially causes local spillovers across financial assets with similar maturity profiles, as yields of similar maturities are compressed, as well. Hence, the effects are not limited to purchased securities. Increased demand for alternative assets eventually leads to increase in prices and decrease in interest rates in other market segments, and more importantly, to decrease in overall risk premia. Falling interest rates for domestic financial assets may also give rise to investments in foreign assets that yield higher returns. The resulting capital outflows can lead to domestic currency depreciation that lifts exports and supresses imports. (Fiedler, Jannsen, Wolters, Hanisch & Hallett, 2016)

Another aspect of portfolio-rebalancing mechanism is the following. Large-scale asset purchases increase central bank's reserves. Central bank uses new reserves to purchase long-term government debt or other long-term securities. As a result, the long-term assets are "replaced" with short-term safe central bank reserves. Meaning that the overall duration risk borne by the market participants is reduced, which affects the entire structure of the term premia, accordingly. That mitigates the riskiness of banks' portfolios and gives them an opportunity to increase riskier loans and reduce lending rates. The process is reinforced by the negative rates charged on reserves. (Hammermann, Leonard, Nardelli & von Landesberger, 2019)

The possible negative consequences of the portfolio-rebalancing channel refer to the fact that as investors rebalance their portfolios towards higher yielding assets, they also accept higher risks. Such increased risk taking might sow the seeds for future crisis. Therefore, it is important to identify for which types of investors and assets the portfolio-rebalancing takes place. (Albertazzi, Nobili & Signoretti, 2016)

4.8.2 Credit easing channel

The main function of the credit easing channel or direct pass-through channel is to pass on the lower lending rates in the banks resulting from credit-easing policy measures to the real economy. In particular, the stimulation system in TLTROs "rewarded" the banks for providing new loans by offering them greater amounts they could borrow further on, or even "charging" negative deposit rates on them. The APP compressed risk premia across a wide range of asset classes and lowered long-term yields, which incentivised lowering lending rates as well as provided the banking system with excess liquidity to be passed on by lending. Moreover, the negative interest rate policy on the deposit facility forced the banks to abstain from hoarding excess liquidity in the deposit facility, but rather redistribute it by providing new loans. Thereby, it became profitable for the banks to lower lending rates and increase lending. Since the APP included CBPP3 and ABSPP, the prices of targeted covered bonds and asset-backed securities increased. These provided incentives for the banks to increase their supply of loans, since they could securitize them and sell them on at more favourable prices. All these credit-easing measures aimed at providing various incentives for the banks

to increase their lending to the real economy, so that the unconventional policy measures reach borrowers. (ECB, 2015; ECB, 2017a)

4.8.3 Signalling channel and uncertainty channel

The signalling channel and the uncertainty channel are more qualitative in nature; hence, they can be considered together. The importance of both channels is in anchoring expectations of market participants about the future course of monetary policy and inflation. Uncertainty is connected with risk aversion of market participants that increases when there is a high level of uncertainty in the market. It is most noticeably reflected in the increased inflation expectations that stabilize when market participants believe and are confident in the ECB's measures. Expectations of both inflation and future interest rates are also a target of the signalling channel. For instance, the introduction of forward guidance about key interest rates and asset purchases directly reflects signalling that the interest rates will remain low for a long period. Moreover, the signalling effect stems from the fact that the injected liquidity, via unconventional monetary policy measures, increased the pressure on the money market rates that have since remained at levels close to the deposit facility rate. Together with the negative interest rate policy, this incentivised banks to lower the lending rates and increase their lending. Signalling and uncertainty channels thus eased the uncertainties in the markets and strengthened the signals of the ECB's accommodative monetary policy stance, which helped anchor expectations about future inflation and interest rates. (Wieladek & Pascual, 2016; Hammermann, Leonard, Nardelli & von Landesberger, 2019)

5 LITERATURE REVIEW OF THE IMPACT OF UNCONVENTIONAL MONETARY POLICY MEASURES

The following chapter provides a literature review of some relevant empirical studies about the impacts of unconventional policy measures over the three phases discussed in the previous chapters.

After the first round of unconventional monetary policy measures during the financial crisis, the financial markets, economic activity, and credit growth showed signs of stabilization. Since the financial crisis stemmed from the interbank market tensions and later evolved into a banking system crisis, the ECB's responses were primarily aiming at providing liquidity to the banks and restore the interbank market functioning. For instance, Lenza, Pill and Reichlin (2010) discussed how unconventional monetary policy measures after 2008 affected the interest rates in the interbank money market. In particular, the unconventional measures can "open up" or "close" a spread between the two money market interest rates. First, the 3-month EURIBOR-OIS spread that indicates the presence of interbank tensions substantially narrowed. Second, liquidity that the central bank injected into the market widened the spread between EONIA-MRO rate, since EONIA rate fell below the MRO rate towards the rate on the deposit facility. Finally, the unconventional measures did influence

the expectations about future monetary policy decisions as the spread between the 3-month and the 12-month EURIBOR (a proxy for the money market yield curve) flattened. Authors then further quantified the macroeconomic impact of the unconventional monetary policy measures based on the evolution of money market spreads, using a Bayesian VAR approach and counterfactual analysis of comparing the two scenarios (no-policy scenario vs. actual path of the variables in reality) since 2008. Altogether, their estimates showed a positive influence of the unconventional policy measures on economic activity resulting in a lower unemployment rate for 0.5 percentage points, had the unconventional policy measures not been employed. The positive impact of unconventional policy measures was about 1.5 percentage point on the annual growth rate of household loans after two years (since 2008), while the peak positive effect of about 3 percentage points was observed on the annual growth rate of the corporate sector loans. In conclusion, the responses the ECB employed after the Lehman Brother collapse in 2008 did significantly contribute to the stabilization of the financial sector and the economy, even though they were not enough to prevent a sizeable downfall.

After the euro area entered the sovereign debt crisis in 2010, the ECB intervened with the second round of unconventional policy measures. Most notable were the liquidity providing 3-year VLTROs that exerted more downward pressure on the money market rates (especially EONIA), which was followed by a decline in the bank lending rates. Darracq-Paries and De Santis (2013) estimated an immediate decline in the bank lending rate spread by 10-20 basis points. Moreover, they assessed the macroeconomic implications of the 3-year VLTROs in a panel VAR model over 2003-2011 in eleven largest euro area countries. VLTROs were considered as a positive credit supply shock, since they were successful in limiting the decline of loans to the real economy according to the Bank Lending Survey (BLS). The responses of GDP reached peak levels by mid-2013 at 0.5 – 0.8 percentage points, inflation by 0.15 – 0.25 percentage points in 2014, while bank loans increased in late 2014 by 1.7 – 2.5 percentage points. The results argue in favour of VLTROs contribution to easing of bank-lending standards and providing support to the economy.

In addition, the ECB responded in 2010 to the dysfunctional sovereign bond markets with securities purchases under the SMP programme. The available evidence suggests that the SMP was effective in stabilizing the distressed markets and reduced contagion across countries to some degree. Between 2010 and 2012, Greek, Irish, Portuguese, Italian and Spanish public debt securities were purchased in a total value of 211 billion euros. Several papers employ the event study approach here, as the announcement effects are particularly relevant. For instance, the economically significant announcement effects and reduction in bond yields was found by Esser and Schwaab (2013). Bond purchases of 5-years maturity contributed to a decline in bond yields per every 1 billion purchased bonds of -1 to -2 basis points (bp) for Italy, -3 bp for Ireland, -4 to -6 bp for Spain, -6 to -9 bp for Portugal and up to -17 to -21 bp for Greece. In addition, the yield volatility was lower on intervention days for most SMP countries. Similarly, lower volatility of targeted government bond yields was

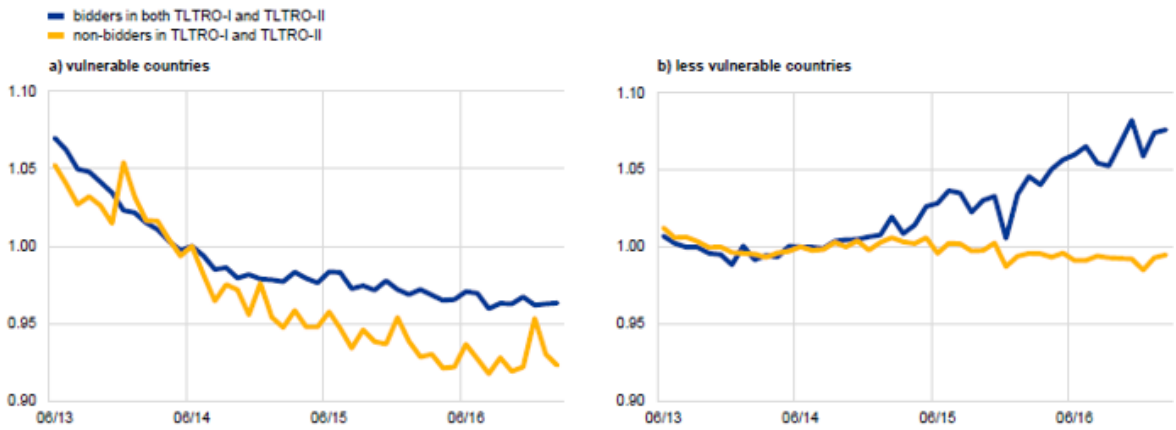
found by Ghysels, Idier, Manganelli and Vergote (2014) who investigated the impact of the SMP on bond yields considering high-frequency intraday dynamics. They reported the average immediate effect on bond yields between -0.1 and -25 bp per 100 million euros intervention. Finally, the positive effects of SMP announcements and purchases were observed in a paper by Beetsma, de Jong, Giuliodori and Widijanto (2014). In the sample period between November 2011 and April 2013, they used realized variances and covariances of intraday yield changes in the distressed countries. They reported stabilizing effect of the SMP security purchases on the yields, as well as weakening of the negative yield spillovers between Germany and the distressed countries. This means that the SMP contributed to the reduced flight-to-safety behaviour reflected in capital flows into the non-distressed countries.

Regardless of the undertaken measures, the financial contagion was spreading between distressed countries, while uncertainties were building around the fear of "currency redenomination". The ECB responded with the famous statement to do "whatever it takes" to preserve the euro and announced the OMT programme. Even though the programme was never activated in reality, the announcement impacts were significant. Financial and macroeconomic impacts were quantified by Altavilla, Giannone and Lenza (2014) who used daily frequency data on bond yields of Germany, France, Italy and Spain. They reported that the announcement had an effect of decreasing the 2-year government bond yields in Italy and Spain by 200 basis points, while leaving the German and the French bond yields unaffected. Macroeconomic effects estimated in a Bayesian VAR model over the course of 3 years were found to be statistically significant on credit and economic growth in Italy and Spain, with relatively limited spillovers in France and Germany. Furthermore, Krishnamurthy, Nagel and Vissing-Jorgensen (2017) investigated the effects of the SMP and the OMT announcements on bond yields of Greece, Italy, Ireland, Portugal and Spain using the event-study approach. The biggest announcement effects were reported for bonds with 2-year maturities, with reductions in bond yields of around 400 basis points for Italy and Spain, 500 bp for Portugal and Ireland, and more than 1,000 bp for Greece. An interesting interpretation of the OMT announcement effects on the sovereign bond yields was made by Acharya, Eisert, Eufinger and Hirsch (2017). They argued in favour of the improved health of banks in the periphery of the euro area, since sovereign bond yields did decrease in response to the announcement. As yields decreased, the relative bond prices increased, which lead to capital gains that improved the banks' capital adequacy ratios. On the aggregate, the bank health improvement translated into increased loan supply to the corporate sector. However, these loans mainly reached low-quality borrowers, which can be referred to as the "zombie firms" that misallocated credits into cash reserves. Hence, the "zombie lending" resulted in weak-recapitalization and did not translate into economic growth.

In the third phase of unconventional monetary policy measures, the ECB struggled with deflation risks, zero lower bound on its key interest rates and risks of a credit crunch. Despite the policy easing, heterogeneity of the financing conditions across national borders persisted

and caused bank lending impairments. Within the comprehensive credit-easing package, the ECB provided long-term financing to the banks at attractive conditions via rounds of TLTROs. The impacts of TLTROs cannot be effectively assessed by splitting the contributions of two rounds, however the announcement of TLTRO-I reportedly lowered bank-lending rates immediately. The ECB provided the following data on lending to non-financial corporations by TLTRO bidders and non-bidders. Figure 15 shows the aggregate evolution of lending by the group of banks that borrowed under TLTROs versus the group of banks that did not participate in any operation series. Countries are divided into vulnerable and less vulnerable. Ireland, Greece, Spain, Italy, Cyprus, Portugal and Slovenia belong to the vulnerable countries and the rest of the euro area countries represent less vulnerable countries. The number of banks that were bidders in the less vulnerable countries is 43, while the non-bidders were 91. In vulnerable countries, there were 48 bidders and 35 non-bidders. The scale on the left is indexed to June 2014. As can be noticed, the banks that participated in both TLTRO operations in less vulnerable countries have noticeably increased lending to non-financial corporations compared to the non-participating banks. On the other hand, the TLTROs for participating banks in vulnerable countries only managed to limit the downward trend in lending, whereas lending of the non-participating banks decreased significantly. (ECB, 2017b)

Figure 15: Lending to non-financial corporations by TLTRO bidders and non-bidders (index: June 2014 = 1)



Source: ECB (2017b).

Negative interest rate policy acted to amplify the APP and the TLTROs. Demiralp, Eisenschmidt and Vlassopoulos (2019) studied the adjustment of the banks' balance sheets to negative interest rate policy on a sample of 252 euro-area banks. They confirmed the presence of frictions when it comes to retail deposits that remained stuck at zero rate and did not adjust into negative territory, following the central bank rate cuts. This means that those banks, which were reliant on retail deposits, were the most affected by negative interest rates and thus more incentivised to adjust their balance sheets to reduce indirect costs. On the other hand, the banks were also charged directly for holding their excess liquidity created by

the APP in the deposit facility. The results suggest that the banks which are reliant on retail deposits significantly increased lending to households and firms by converting their excess liquidity into loans under the negative rates policy. Similarly, Altavilla, Canova and Ciccarelli (2016) provided an analysis of a large dataset containing balance sheet characteristics of the euro area banks over 2009-2015. First, they found that the capital adequacy and exposure to sovereign risk are the most important factors that cause dispersion of monetary policy pass-through. Therefore, the poorly capitalized banks that are highly exposed to sovereign risk reduced their lending rates considerably less than the banks with higher net worth and lower risk exposure. Second, the unconventional monetary policy measures, in particular the TLTROs and the APP reduced cross-sectional dispersion of interest rate pass-through and normalized lending conditions. Banks with higher level of non-performing loans and lower capital share were more responsive to the measures. Finally, they find that compression of lending margins may potentially affect profitability of those banks that have lower capital share, higher level of non-performing loans and greater exposure to sovereign risk.

In line with the bank-based financing structure of the euro area, banks played a crucial role in the transmission of large-scale asset purchases to financing conditions. The APP provided liquidity to the banking system in the form of excess reserves and compressed long-term yields, which reduced term risk premia. Thereby, the banks were incentivised to lower their lending rates and to translate excess liquidity into loans. A recent paper by Ryan and Whelan (2019) considered banks in all euro area countries (except France) in the period 2015 – 2018, when excess reserves reached the highest levels. They observed that the banks actively managed reserve holdings and reduced them at the individual bank-level on a month-to-month basis. However, not all excess reserves translated into loans. Evidently, the banks have also adjusted reserves by adding to their securities holdings through debt securities purchases and have been paying down their funding sources.

Regarding the macroeconomic implications and transmission channels, I considered the following papers. Gambetti and Musso (2017) estimated macroeconomic implications of the APP in a time-varying VAR model. The APP shock between 2009 and 2016 was identified using a combination of sign, timing and magnitude restrictions. Their results suggest that the APP contributed to real GDP growth significantly in the short-term (0.18 percentage points in the first quarter of 2015 and 0.16 percentage point by the end of 2015), whereas the effect almost vanished in 2016. On the other hand, the effect of the APP shock to the HICP increased over time (from 0.06 percentage point in the first quarter of 2015 to 0.36 percentage point in last quarter of 2016). Moreover, they identified various channels of transmission. For instance, a clearly observed increase in stock prices in response to the APP shock identifies the presence of a portfolio-rebalancing channel. Depreciation of the euro exchange rate in response to the APP shock, indicates the presence of an exchange rate channel. A positive response of the long-term inflation expectations (five years ahead by Survey of Professional Forecasters) to the APP shock activated the expectations channel.

Finally, as lending rates declined immediately after the APP shock and loan volumes to non-financial sector increased after two years from the APP shock it also confirms the existence of a credit-easing channel. Similar approach of identifying transmission channels was used by Wieladek and Pascual (2016), who estimated responses of real GDP and core consumer price index (CPI) to the APP shock. Their estimation with a Bayesian VAR model over 2012 and 2016 shows that the output and CPI are approximately 1.3 and 0.9 percent higher on the account of asset purchases. They identified a decline in the 20-year and 30-year euro area government bond yields (EGB yields) after unexpected asset purchase announcement shock, which confirms the existence of a portfolio-rebalancing channel. They confirmed the presence of a signalling channel by observing a decline in spreads between the 3-month interest rate futures 1 year ahead (3M1Y) and one-year interest rate futures 1 year ahead (1Y1Y), after the unexpected asset purchase announcement shock. Negative responses of EONIA, EURIBOR and lending rates after the unexpected asset purchase shock indicate the credit-easing channel. Finally, the indicators of volatility of interest rates (MOVE) and financial market stress (VIX) did not confirm the presence of uncertainty channel in the euro area.

The PSPP programme was the most significant part of the APP, whereas other elements (ABSPP, CBPP3 and CSPP) contributed to the APP to a lesser extent. For instance, covered bonds for CBPP3 purchases became hard to purchase as they were often retained as a collateral. On the other hand, the asset backed securities faced supply and demand asymmetries and remained unpopular because of the associated negative experiences from the financial crisis. Regarding the CSPP programme, De Santis, Geis, Juskaite and Vaz Cruz (2018) reported that it contributed to a narrowing of the bond spreads between the corporate bonds and the risk-free rates. Positive spillovers also reached corporate bonds that were not eligible for CSPP purchases. Net issuance of corporate bonds of non-financial corporations (NFCs) increased immediately after the CSPP announcement, especially in Germany, France, Italy, the Netherlands and Spain. On the other hand, banks that had access to TLTROs (unlike NFCs) reduced their bond issuance activities.

According to Hammermann, Leonard, Nardelli and von Landesberger (2019) and the calculations by the Eurosystem staff, unconventional policy measures introduced since 2014 significantly contributed to the economic recovery and inflation. Table 3 shows the estimated impacts (in percentage points) for each year.

Table 3: Impact of unconventional policy measures on euro area inflation and real GDP (percentage points)

Measures since 2014	2016	2017	2018	2019	2020	Cumulative (2016-2020)
Inflation	0.65	0.49	0.22	0.21	0.16	1.9
Real GDP	0.79	0.48	0.31	0.2	0.08	1.9

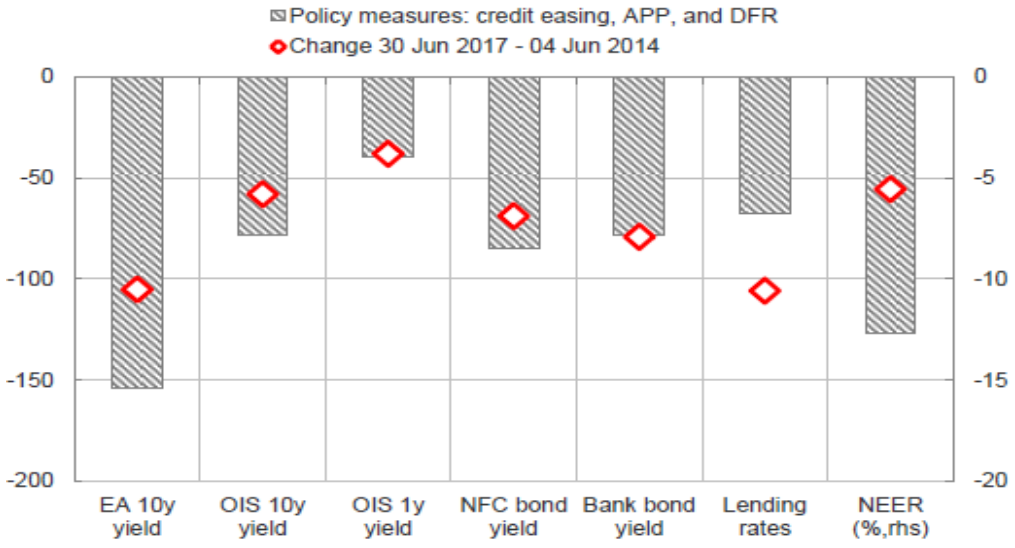
Source: Hammermann, Leonard, Nardelli and von Landesberger (2019).

Estimations were based on various modelling frameworks on behalf of the ECB and the national central banks, with the reference month being December 2018. The cumulative impact of measures on inflation and real GDP growth over 2016 – 2020 is around 1.9 percentage points. It can be observed that the strongest impact was calculated in years 2016 and 2017, when measures were at their most powerful.

A more structured decomposition of impacts of the ECB policy measures was provided by Hartmann and Smets (2018) as shown in Figure 16. In Figure 16 are reported ECB's estimated changes of key euro area financial indicators between June 2014 and June 2017 (denoted with red marks on the graph) and impacts of the ECB policy measures (denoted by shaded area). Captured impacts were based on the announcements effects and model-based counterfactual exercises. Credit easing was captured by the event-study methodology after the announcements in June – September 2014. The impact of cuts in DFR was captured after the announcement in September 2014. APP effects were based on the announcements and its further calibrations from January 2015 – December 2016, while the impacts of March 2016 and December 2016 measures were assessed via model-based counterfactual exercises. The measures contributed to;

- Approximately 150 basis points reduction in 10-year sovereign yield for the euro area GDP-weighted aggregate (EA 10y yield).
- Decrease in lending rates to non-financial corporations of around 70 basis points.
- Decrease in nominal euro effective exchange rate (NEER) of about 13 percent.
- Decline in euro area 1-year and 10-year risk-free overnight index swap yield (OIS) of around 40 basis points and 70 basis points, respectively.

Figure 16: Changes in key euro area financial indicators since June 2014 (left-handside scale: basis points; right-handside scale: percents)



Source: Hartmann and Smets (2018).

After the review of the relevant empirical analysis of unconventional policy impacts over the three phases, it is possible to conclude that the unconventional monetary policy measures were generally effective in stabilizing financial markets and restoring transmission of monetary policy. It is difficult to determine whether certain policy measures were more effective than others, since it depends on the impairments they were addressing, and it is evident that measures were evolving over time in magnitude and diversification. For instance, in the first two phases the main objective of a monetary policy was in stabilizing financial markets and monetary policy transmission. In terms of providing liquidity certainty to the banking sector and reducing volatility in money market rates, LTROs of different maturities and applied FRFA procedure played a major role. While in terms of stabilizing bond markets, the introduction of SMP and OMT significantly contributed to the sovereign bond yields reduction. However, after the introduction of credit-easing package in June 2014, unconventional monetary policy measures started to provide monetary policy stimulus to the economy and strongly incentivised bank lending. Thus, from the perspective of reducing fragmentation of the financial conditions across the euro area and positive effects on the credit supply, the comprehensive credit-easing package (APP, TLTROs and negative deposit facility rate) was the most effective. Nevertheless, the negative interest rate policy triggered concerns about future banks' profitability as loan-deposit margins reportedly decreased. But this is the subject of research beyond the empirical evidence of considered studies in this chapter. Furthermore, empirical studies generally find positive effects of unconventional policy measures on the euro area output and inflation. Most of the considered studies are focused on macroeconomic implications of the recent credit-easing package, from which APP announcements are usually taken as an unexpected shock to the economy. Positive responses of output and inflation usually come with a delay, especially those of inflation.

Methodology of capturing the effects of unconventional policy measures in the considered empirical studies is either the event-study approach or various kinds of vector autoregressions (VARs). The former is focused on the announcement effects of unconventional measures that can be observed immediately after the announcement. For instance, the SMP and OMT effects on sovereign bond yields. On the other hand, the VAR analyses consider relationships between variables of interest over longer time periods. To measure the effects of unconventional policy measures over a specific time frame, VAR analysis is often followed by a counterfactual exercise in order to determine the overall contribution of measures to the output and inflation. In the following chapter, I will proceed with the empirical analysis of the effects of unconventional monetary policy measures using a structural VAR model.

6 EMPIRICAL ANALYSIS

The aim of the empirical analysis is to investigate dynamic relations between the macroeconomic variables and monetary policy in times of unconventional monetary policy measures. A relatively flexible and commonly used models for such purposes are vector autoregression models (VARs) that offer an insight into the linear interdependencies between multiple time series. Several varieties of such models have been proposed in different papers considering the effects of monetary policy actions on different variables of interest. This analysis is focused on the unconventional monetary policy effects on the euro area output and inflation by employing "shadow short rates" as an alternative measure of the monetary policy stance in a simple three-variable structural VAR. I consider the period between 2007 and 2018 on a monthly basis and thus include all the unconventional policy measures that the ECB adopted in that period. The analysis is very much in line with the VAR model of Damjanovic and Masten (2016), although with two notable differences. First, it includes shadow short rates proposed by Wu and Xia (2017) in their latest study on the euro area that considers a time-varying lower bound on interest rates. Second, it employs a structural VAR model that imposes additional identifying assumptions to recover structural shocks. The analysis of monetary policy effects on macroeconomic variables requires an identification of monetary policy shocks, which is obtained by a recursive ordering of variables and by imposing restrictions on the contemporaneous effects between variables. In line with the economic assumption that changes in monetary policy affect macroeconomic variables only with a lag, there are zero-restrictions on the contemporaneous responses of output and inflation to the monetary policy shock. Moreover, in order to study the unconventional monetary policy effects, it is crucial to determine a monetary policy variable that would effectively capture unconventional monetary policy stance.

The empirical part proceeds in three parts. First, it introduces shadow short rates as an alternative monetary policy measure along with some evidence from literature. Second, it establishes a structural VAR model, which is followed by all necessary estimation steps, and it concludes with the main findings.

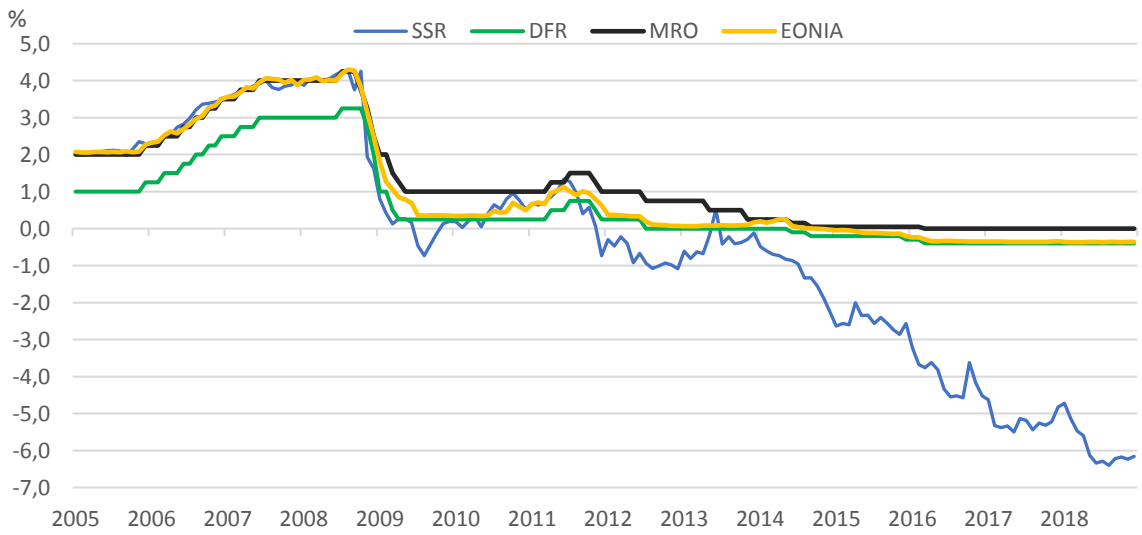
6.1 Shadow short rates as a monetary policy measure

Modelling the effects of monetary policy in times when key policy interest rates remain at zero-lower bound, is challenging. The problem stems from the fact that key policy rates do not clearly reflect monetary policy stance. In response to that, various authors proposed alternative ways of measuring monetary policy stance, for instance by introducing the shadow rate. Shadow rates are obtained by modelling the term structure of the yield curve, and represent the shortest maturity extracted from the yield curve. As they are calculated from financial data, they are determined by the movements in market yield curve. Thus, they can be considered as an indicator of how monetary policy is perceived by the markets along

with the expectations of future policy stance. Nevertheless, they are not governed by the ECB directly, which must be taken into account.

The main advantage of using shadow rates is that they are free to go into the negative territory when key policy rates are bound at zero, while at the same time they would coincide with the main policy rate under conventional policy measures in times before the zero-lower bound. Developments in shadow short rates by Wu and Xia (2017), EONIA and key policy rates are shown in Figure 17. By observing the movements of shadow rates, it can be noticed that they nicely followed the main policy rate before the crisis in 2008. After 2008, they remained downward sloping most of the time. There are two deviations from the main policy rate that can be observed in the shadow rates. The first deviation of the shadow rates can be observed in the sovereign debt crisis between 2010 and 2012, when they somewhat increased and deviated from the policy rate. Another short-term increase can be noticed in the year 2013, when market perceptions of monetary policy stance were likely influenced by spillovers from US tapper tantrum and other external pressures. However, when key policy rates reached the zero-lower bound around 2012, the shadow rates dropped into the negative territory and remained negative since then. Notable decline can be observed during the period of comprehensive unconventional policy measures since 2014, which is very much in line with the accommodative monetary policy stance of the ECB. Overall, the shadow rates do appear to be an accurate indicator of the market perceptions of the ECB's monetary policy stance. This indicator is not a pure one, due to some observable deviations from the main policy rate.

Figure 17: Developments in key interest rates of ECB, EONIA and shadow short rate by Wu and Xia 2005 – 2018



Source: Adopted from ECB Statistical Warehouse (2019) and Cynthia Wu (2019); own work.

Shadow short rates used in this analysis were obtained from Wu and Xia (2017), although they were estimated by some other authors as well. Term structure modelling at the zero

lower bound has been notably discussed by works of Krippner (2015), Wu and Xia (2013, 2017) and Lemke and Vladu (2017). The first to introduce shadow rates as a policy measure were Wu and Xia (2013) when they investigated monetary policy of the United States. They used a Shadow Rate Term Structure Model (SRTSM) originally proposed by Black (1995). They developed an analytical approximation of the forward rate in the original SRTSM model that is possible to apply directly to discrete-time data. The new policy measure was further used as a monetary policy stance when the effective Federal Funds rate reached the zero-lower bound. Wu and Xia proved usefulness of the new policy measure to study unconventional monetary policy impacts on the real economy by employing it in a simple factor-augmented vector autoregression (FAVAR). The model exhibited similar dynamic correlations with macro variables in the period after the global financial crisis, as the standard Fed Funds rate did in the data prior to the crisis. Thus, the shadow rate appears to represent a tool for measuring the effects of monetary policy at the zero-lower bound, particularly when used in VAR models to study the relationships between the monetary policy and macroeconomy. In a recent work by Wu and Xia (2017), a new SRTSM model was proposed for the euro area to describe the current environment with negative interest rates. It captures the time-varying lower bound that is particularly relevant for the euro area and Japan. The significance of their model is in the assumption that the agents are forward looking and anticipate future changes in the deposit rate that are priced into bond prices. The model is additionally customized by introducing a time-varying spread between the monetary policy lower bound and the government yield curve. Thus, their estimated forward curve better fits the yield curve. Regarding the effectiveness of the ECB's negative interest rate policy on the yield curve, they find that a 10-basis point drop in the effective lower bound lowers the short end of a yield curve by the same amount. At longer maturities, specifically for the 10-year yield, the effect amounts to between 6-8 basis points. (Wu & Xia, 2017) Similarly, shadow rates estimated by Krippner (2015) offer an approximation of instantaneous forward rates in continuous time, while Lemke and Vladu (2017) use shadow term structure modelling to study the shifts in the euro area yield curve in relation to the perceived shifts of the level of interest rate lower bound.

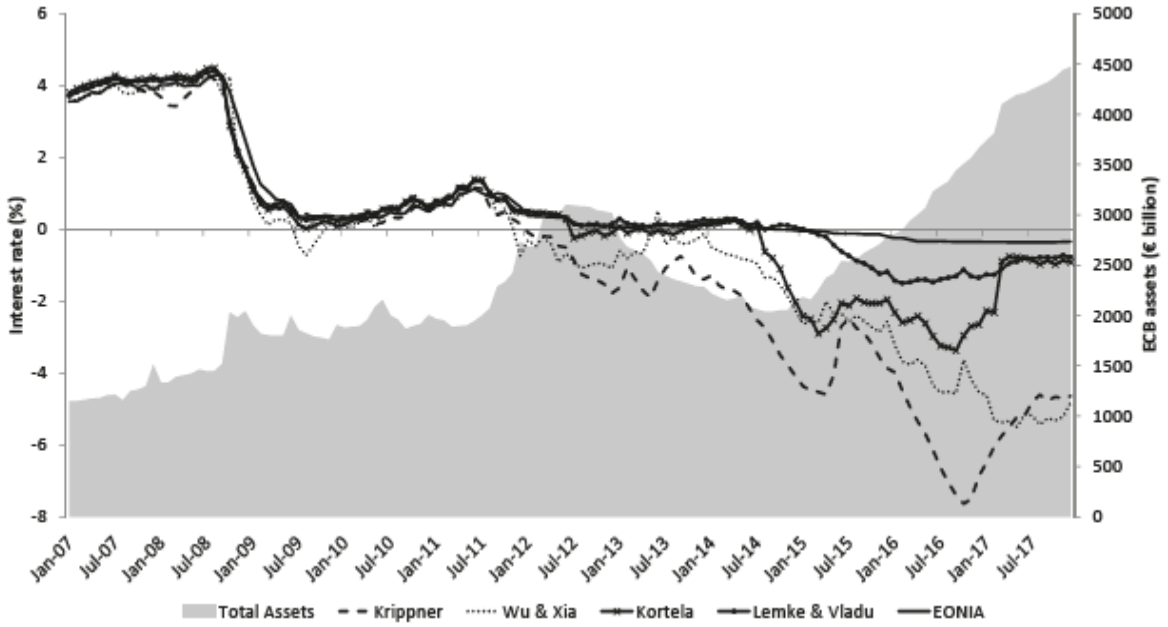
The dynamics between the shadow rates and macroeconomic variables in the case of the euro area was explored by Damjanovic and Masten (2016). They investigated the macroeconomic effects of monetary policy in the euro area using shadow short rates estimated by Krippner (2015). In a simple 3-variable VAR model with recursive ordering of variables, they argued in favour of employing the shadow rates as a measure of monetary policy stance. In their analysis of the euro area and two peripheral countries (Italy and Spain), they could also obtain cross-country heterogeneity in monetary policy transmission. In their VAR analysis for the euro area, they identified monetary policy shocks by ordering the shadow short rate variable (SSR) last, using the Cholesky decomposition of the variance-covariance matrix of reduced form residuals. An unanticipated shock to the SSR, interpreted as the monetary policy tightening, resulted in delayed declines of output and prices. Responses were broadly consistent with the economic theory and showed that the shadow

rates produce outputs in the period of zero lower bound that are similar to those of standard policy rate in normal times.

On the other hand, in order to study the effects of unconventional monetary policy, one could employ some other indicators for monetary policy stance, as well. For instance, using the size of the balance sheet was relevant especially after the introduction of asset purchases in 2014. In a paper by Boeckx, Dossche and Peersman (2017), unconventional monetary policy stance was measured by employing the size of the ECB's balance sheet in a SVAR model with identification of the shocks by a combination of zero and sign restrictions. They estimated an increase in output and prices by about 0.1 percent when the size of the balance sheet increased by 1.5 percent. Similarly, Wieladek and Pascual (2016) used the size of the ECB's balance sheet in a Bayesian VAR. In response to that, Elbourne, Ji and Duijndam (2018) and Elbourne and Ji (2019) argued that using the size of the central banks' balance sheet directly may produce biased results. The main reason for this is in the foresight problem, as changes in balance sheets are highly anticipated. For instance, the announcement of the PSPP programme was made two months prior to its implementation, making large balance sheet changes highly predictable in advance. For this reason, Elbourne, Ji and Duijndam (2018) argued in favour of using shadow rates as a measure of unconventional monetary policy stance and estimate the SVAR model with zero and sign restrictions. They found that an expansionary unconventional monetary policy shock lowers the shadow rates by 20 basis points, which causes a small response in output of 0.05 percent after 20 months, while responses of price level are negligible.

Moreover, Elbourne and Ji (2019) discussed the existence of notable differences between the estimated shadow rates by different authors. Since calculations of shadow rates result from different model specifications by authors, the movements of shadow rates at key policy announcement dates might be questionable. Figure 18 shows different shadow rates and the total size of the balance sheet. Shadow rates differ in magnitude. Those of Wu and Xia (2017) reach -6 percent at the end of 2017, whereas those of Kortela (2016) and Lemke and Vladu (2017) are as high as about -1 percent. In addition, the shadow rates appear to move in the opposite directions at key moments. The shadow rate by Krippner (2015) increases by almost 200 basis points at the time of the early stages of the PSPP in 2015, whereas those of Wu and Xia appear reasonably constant, and those of Lemke and Vladu fall for about 100 basis points. Nevertheless, shadow rates appear very coherent during the financial crisis up until the zero lower bound period. Sizeable deviations become clear after 2012 and deepen in the third phase of comprehensive unconventional policy measures.

Figure 18: Shadow rates, EONIA and total ECB assets in the period 2007 – 2017



Source: Elbourne and Ji (2019).

Elboune, Ji and Duijndam (2018) used shadow rates by Wu and Xia, as they found them to be more accurate in some key announcement moments. They also showed that shadow rates respond immediately to the news about the future changes of the central bank balance sheet and thus they do not suffer from the foresight problem that may potentially produce biased results. The instantaneous response of shadow rates to the announcements of unconventional measures has been confirmed by some other authors, as well. For instance, De Rezende and Ristiniemi (2018) used daily yield curve data to estimate the shadow rates for many developed countries, including the euro area, and concluded that they tend to fall (or rise) on the back of the perceptions about future monetary policy stance formed by the market participants that are priced into the yield curve. Thus, it is a purely market-based measure of unconventional monetary policy stance. The event-study approach also confirmed that shadow rates respond immediately after important policy announcements, in line with the responses of the government bond yields.

6.2 Structural vector auto-regression model

A vector auto regression (VAR) model is a stochastic process that captures linear interdependencies among multiple time series. Each time series variable has an equation explaining its evolution based on its own lags and lags of other model variables. Thus, the VAR models summarize the dynamic properties of the data. As they have the status of "reduced form" models, it is often difficult to draw any conclusions from the large number of coefficient estimates in a VAR system. In relation to that, a new class of econometric models has been introduced by authors such as Sims (1981), Bernanke (1986), and Shapiro

and Watson (1988), known as the structural vector auto regression (SVAR) or identified VAR models. The key significance of SVAR models is that instead of identifying the autoregressive coefficients, the identification focuses on the errors of the system, which are represented as linear combinations of exogenous shocks. Thereby, the structural shocks are not correlated, which is a desired property in studying dynamics in economic variables. (Lütkepohl & Krätzig, p 159-162, 2004)

Moreover, as SVAR models allow for contemporaneous impact between variables, they imply that OLS estimation cannot be applied. For this reason, a SVAR model cannot be identified without a priori restrictions. A standard form of a SVAR model with p-lags is given in equation 1. (Zivot, 2000)

$$AY_t = \beta_0 + \beta_1 Y_{t-1} + \cdots + \beta_p Y_{t-p} + u_t \quad (1)$$

Where A is a *n x n* matrix representing the contemporaneous relations between the endogenous variables. Y_t is a vector of endogenous variables in a *n x n* matrix, β_0 is a *n x 1* vector of constants and β_i is a *n x n* matrix for every $i = 0, \ldots p$ containing structural coefficients. The error term u_t are structural shocks.

A 2-variable SVAR (1) can be written in a matrix form as shown in equation 2. (Zivot, 2000)

$$\begin{bmatrix} 1 & a_{12} \\ a_{21} & 1 \end{bmatrix} \begin{bmatrix} Y_{1t} \\ Y_{2t} \end{bmatrix} = \begin{bmatrix} \beta_{10} \\ \beta_{20} \end{bmatrix} + \begin{bmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{bmatrix} \begin{bmatrix} Y_{1t-1} \\ Y_{2t-1} \end{bmatrix} + \begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix} \quad (2)$$

If we pre-multiply both sides of the equation 2 with A^{-1} it gives us the so-called reduced form VAR, which is shown in equation 3.

$$\begin{bmatrix} Y_{1t} \\ Y_{2t} \end{bmatrix} = \begin{bmatrix} 1 & -a_{12} \\ -a_{21} & 1 \end{bmatrix} \begin{bmatrix} \beta_{10} \\ \beta_{20} \end{bmatrix} + \begin{bmatrix} 1 & -a_{12} \\ -a_{21} & 1 \end{bmatrix} \begin{bmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{bmatrix} \begin{bmatrix} Y_{1t-1} \\ Y_{2t-1} \end{bmatrix} + \begin{bmatrix} 1 & -a_{12} \\ -a_{21} & 1 \end{bmatrix} \begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix}$$

$$Y_t = A_0 + A_1 Y_{t-1} + \varepsilon_t \quad (3)$$

Where $A_0 = A^{-1}\beta_0$, $A_1 = A^{-1}\beta_1$ and $\varepsilon_t = A^{-1}u_t$

Reduced-form VAR can be estimated using Ordinary Least Squares (hereafter OLS) method. However, in order to apply OLS, we must first restrict the number of parameters in the SVAR to be equal to those in the reduced form VAR. This is achieved by imposing restrictions on the matrix A.The minimum number of required restrictions can be calculated from the difference between the number of unknown and known elements in the SVAR. As the matrix A has unity as diagonal elements, the number of unknown elements is $n^2 - n$. Besides, there are also n unknown variances of u_t. Altogether, this implies $n^2 - n + n = n^2$ unknowns. Known elements are contained in the variance-covariance matrix of the reduced-form errors Σ_ε. Since it is symmetric, there are $(n^2 - n)/2$ distinct elements off the diagonal and n distinct elements on the diagonal. Altogether, $n + (n^2 - n)/2 = (n^2 + n)/2$ of known elements. Finally, the required number of restrictions is given by the subtraction of known

elements from unknown ones, which gives us $n^2 - (n^2 + n)/2 = (n^2 - n)/2$ restrictions required on matrix A. (Schenck, 2016)

In the example of a 2-variable SVAR, we would require one restriction to be imposed on the matrix A. For instance, requiring that $-a_{12} = 0$ gives us the equations 4 and 5. (Zivot, 2000)

$$Y_{1t} = \beta_{10} + \beta_{11} Y_{1t-1} + \beta_{12} Y_{2t-1} + u_{1t} \tag{4}$$

$$Y_{2t} + a_{21} Y_{1t} = \beta_{20} + \beta_{21} Y_{1t-1} + \beta_{22} Y_{2t-1} + u_{2t} \tag{5}$$

The imposed restriction implies that the variable Y_{2t} is contemporaneously affected by a shock to the variable Y_{1t} and by a shock to itself. On the other hand, the variable Y_{1t} is not contemporaneously affected by a shock to the variable Y_{2t}, but is affected by this variable only with a lag (Y_{2t-1}). The restriction can also be expressed in the reduced-form errors notation, which is shown in equations 6 and 7. (Zivot, 2000)

$$\varepsilon_{1t} = u_{1t} \tag{6}$$

$$\varepsilon_{2t} = -a_{21} u_{1t} + u_{2t} \tag{7}$$

Structural shocks u_t thus represent a linear combination of the reduced-form errors ε_t. Decomposition of the reduced-form errors ε_t into structural shocks is done by the process of orthogonalization. In a recursive SVAR form, the system represents the so-called Wald causal ordering of the variables. Orthogonalization is achieved by the Cholesky decomposition of variance-covariance matrix Σ_ε. If we re-write the linear relation between the structural errors and the reduced-form errors as shown in equation 8, then the identification of the structural shocks essentially means finding the unique B matrix. (Zivot, 2000)

$$\varepsilon_t = B u_t \tag{8}$$

Since structural shocks are uncorrelated, and thus it holds that $E(u_t u_t') = \Sigma_u = I$, we obtain equation 9 with a little permutation.

$$E(\varepsilon_t \varepsilon_t') = B E(u_t u_t') B'$$

$$\Sigma_\varepsilon = B \Sigma_u B'$$

$$\Sigma_\varepsilon = B I B'$$

$$\Sigma_\varepsilon = B B' \tag{9}$$

Cholesky approach requires B matrix to be lower-triangular matrix, placing zeros above the diagonal and uses an orthogonal matrix A that is a square identity matrix where $A'A = AA' = I$. The orthogonal matrix has columns and rows of orthogonal unit vectors, where the product

of vector and row is zero, and every length of row and vector is unity. Orthogonal matrix A places restrictions on the error structure of the variance-covariance matrix Σ_ε. With Cholesky identification, the structural form can be uniquely recovered from the reduced form.

There are various identification methods proposed by the authors who apply different types of restrictions to recover structural shocks. For instance, Lütkepohl (2008) outlines the following practices:

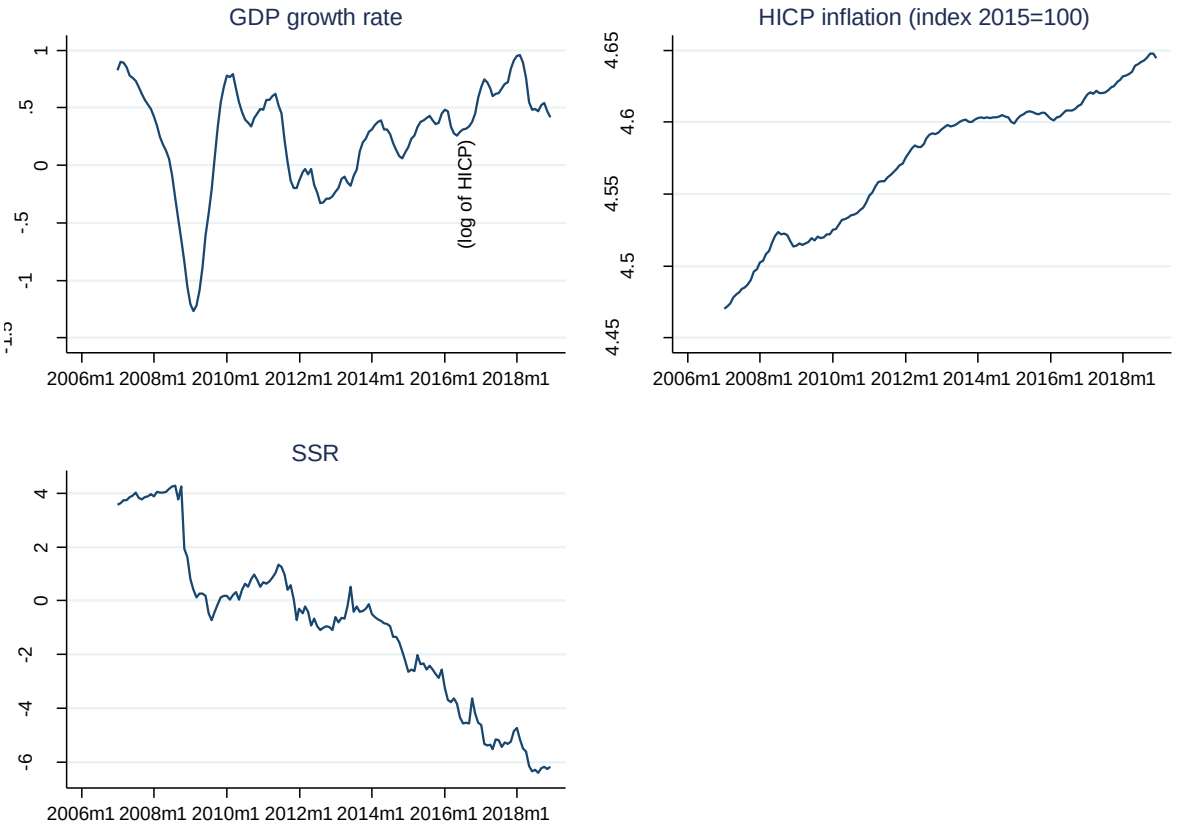
- Contemporaneous effects of shocks on certain variables may be excluded. Zero restrictions are placed on the B matrix, similar as in the Cholesky approach, yet zero restrictions do not have to form a triangular matrix B.
- Restrictions on contemporaneous relations of the variables may be imposed for the following structural form $A_0 y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + \varepsilon_t$, where typically linear restrictions are imposed on A_0. The diagonal elements of A_0 are set to unity, while other restrictions apply for $B = A_0^{-1}$, meaning that if A_0 is lower triangular, so is B.
- It is possible to set the structural model in the following form $A_0 y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + B\varepsilon_t$ and impose restrictions on both A_0 and B. It is the so-called AB-model represented by Amisano and Giannini (1997).
- Restrictions may be imposed on the long-run effects of some shocks, when one is having a prior information about those long-run effects. The structural form model was represented by Blanchard and Quah (1989), which was assuming no-long-run effects of demand shocks on the output variable.
- Finally, sign restrictions may be imposed on the impulse responses. By imposing sign restrictions, one can require certain shocks having positive or negative effects on some variables. Such structural models were proposed by Canova and De Nicoló (2003) and Uhlig (2005).

However, Cholesky approach is imposing causal ordering on the variables in the VAR since shocks to one equation contemporaneously affect variables below that equation, but only affect the variables above that equation with a lag. With this interpretation in mind, ordering of the variables reflects one's beliefs about the relationships between variables in the VAR. It is a common approach used to identify monetary policy shocks on macroeconomic variables such as GDP and inflation. The latter would be affected by monetary policy shocks with a lag, as proposed by the economic theory. Identifying monetary policy shocks is thus obtained by ordering the monetary policy variable last in the recursive SVAR form and by requiring matrix B to be lower-triangular. Thus, permuting variables in the VAR would permute the entries in Σ_ε and generate different B matrices. (Schenck, 2016)

6.2.1 Time-series data

In the SVAR model, I consider three endogenous variables: real GDP growth rate, log of HICP inflation and shadow short rates, which act as a proxy for the monetary policy stance. Figure 19 plots the time series of these three variables.

Figure 19: Time series graphs for GDP, HICP and SSR between 2007 and 2019



Source: Adopted from Banca d'Italia (2019), ECB Statistical Warehouse (2019) and Cynthia Wu (2019); own work.

- **Real GDP** is obtained from estimations by Banca d'Italia, which provides monthly calculations of €-coin data. It is defined as a real-time monthly estimate of the euro-area wide GDP growth and is calculated from a large panel of statistical data. The latter include industrial production, business surveys, stock market and financial data, demand indicators, and others. Estimations highlight the underlying trend by adjusting the growth rate for short-term fluctuations and measurement errors. Therefore, it is considered as a smoothed estimate of quarter-on-quarter euro area GDP growth and is used as an indicator of the euro area's actual growth momentum. I used data on €-coin from the official website of Banca d'Italia, following the approach as in Wieladek and Pascual (2016) in order to avoid interpolation methods suggested by many other authors.
- **HICP inflation** is obtained from the ECB Statistical Data Warehouse as seasonally adjusted overall index of consumer prices for the euro area with a monthly frequency. It

is indexed to year 2015, i.e. 2015=100 and reported in natural logarithms, denoted by lHICP.

– **Shadow short rate** is obtained from Cynthia Wu's official website that provides estimated monthly shadow rates for the US, the euro area, and the United Kingdom available for download in the excel file. Shadow rates for the euro area are available from September 2004 and up until the present month of the current year. Data correspond with those shown in the lower left panel of Figure 17 as SSR.

The sample size includes the data from January 2007 until December 2018 on a monthly basis, which gives us 144 observations. In my recursive SVAR model with the three above mentioned endogenous variables, the aim of the analysis is to obtain responses of the macroeconomic variables GDP and HICP inflation to the monetary policy shock. The SSR represents the monetary policy variable as it can be used as such on the basis of some of the studies mentioned earlier, in particular Damjanovic and Masten (2016). To identify monetary policy shock, the SSR is ordered last in the recursive SVAR that uses Cholesky procedure to recover structural shocks.

6.2.2 Pre-estimation steps

– **Stationarity**

Generally, the time series variables should be stationary before estimating a SVAR model. This means that the series process must exhibit weak stationarity or covariance stationarity, which implies constant and time invariant first two moments, mean and variance. Time-series variables are covariance stationary if the following equations from 10 to 12 hold.

$$E(y_t) = \mu \tag{10}$$

$$var\ (y_t) = \sigma^2 \tag{11}$$

$$cov(y_t, y_{t+s}) = cov(y_t, y_{t-s}) = \gamma_s \tag{12}$$

If the (weak) stationarity of variables included in a time-series regression model is not satisfied, the likely outcome is the so-called spurious regression. This produces biased coefficient estimates and misleading effects of shocks that would exhibit permanent effects instead of transitory effects. Non-stationary time series need suitable transformations to make it stationary. For instance, the data generating process is called integrated of order d, denoted $I(d)$, if first differences have to be applied d-times to make the process $I(0)$ stationary. When a process $I(1)$ is non-stationary, it has a unit root. The latter can be tested with proper statistical tests, among which the Augmented Dickey-Fuller (ADF) test is the most common one. Before running the ADF test, enough lags of Δy_t should be included, so that the disturbance term is serially uncorrelated. The number of lags to include can be determined in Stata by the DF-GLS test that uses the following methods: sequential-t method

(Ng-Perron), Schwarz criterion (SC) and modified AIC method (MAIC). If the sample size is sufficient, the SC criterion is the preferred choice. There are three versions of the ADF test (Verbič, 2018):

- No constant and no trend: $y_t = \rho y_{t-1} + v_t$ where $\Delta y_t = (\rho - 1)y_{t-1} + v_t$ which is equal to $\Delta y_t = \gamma y_{t-1} + v_t$ if the series appears to be wandering or fluctuating around a sample average of zero.
- With constant, but no trend: $\Delta y_t = \propto + \gamma y_{t-1} + v_t$ if the series appears to be wandering or fluctuating around a non-zero sample average.
- With constant and with trend: $\Delta y_t = \propto + \gamma y_{t-1} + \theta y_{t-1} + v_t$ if the series appears to be wandering or fluctuating around a linear trend.

In each of the cases, the null and the alternative hypothesis are equal to:

$$H_0: \rho = 1 \leftrightarrow H_0: \gamma = 0 \ \ implying\ y_t\ has\ a\ unit\ root$$

$$H_1: \rho < 1 \leftrightarrow H_0: \gamma < 0\ implying\ y_t\ is\ stationary$$

The ADF test results are shown in Table 4 for non-transformed variables (GDP, lHICP and SSR) and transformed variable SSR in first-differences (dSSR). All variables have 1 lag included, as suggested by the SC-criterion (preferred choice as the sample is of sufficient size) in the DF-GLS test. There are also reported test statistics $Z(t)$ and critical values at 10, 5 or 1 percent that suggest one can reject the null hypothesis and accept the conclusion from the alternative one, if the absolute value of the test statistic is greater than the critical value. Reported results of the ADF test imply that GDP (at all critical values) and lHICP (at critical values for 5 and 10 percent) variables are $I(0)$ stationary, while the SSR rate exhibits non-stationarity at $I(0)$, but after taking first-differences one time, it is $I(1)$ stationary.

Table 4: ADF test for non-transformed variables (GDP, lHICP, SSR) and transformed variable SSR (dSSR)

ADF test for a unit root	Test statistic	1%	5%	10%
. dfuller GDP, lags (1)				Nuber of obs = 142
Z(t)	**-4.075**	-3.496	-2.887	-2.577
. dfuller lHICP, lags (1)				Nuber of obs = 143
Z(t)	**-2.957**	-3.496	-2.887	-2.577
. dfuller SSR, lags (1)				Nuber of obs = 142
Z(t)	**-0.406**	-3.496	-2.887	-2.577
. dfuller dSSR, lags (1)				Nuber of obs = 142
Z(t)	**-7.408**	-3.496	-2.887	-2.577

Source: own work.

Even though the results suggest that the SSR variable should be taken in first-differences, it must be noted that the SSR variable is a result of the SRTSM model estimation. Since the estimates are obtained from financial data, they offer an indication of how different ECB

measures (including unconventional) influenced market expectations. Thus, being non-transformed, they have greater explanatory power and better capture the dynamics between the variables. Besides, in this way it is possible to observe long-term relationships between the variables, which is especially desired because the output and inflation are expected to respond with a delay to a monetary policy shock. Moreover, the OLS estimator of the equations in the SVAR model would still remain consistent. Further details of the OLS estimation method are explained in section 6.2.3 (Model estimation). However, in order to provide information on the SVAR model with all variables stationary, Appendix 3 shows the outcome of a SVAR model with transformed variable SSR in first-differences.

– **Lag-length selection**

The next step is to determine the number of lags to be included in the SVAR model. This is done by using the information criteria approach for the underlying VAR. Stata provides information criteria that are reported in Table 5.

Table 5: Lag lenght selection with information criteria up to 6 endogenous lags

Sample: 2007m7 – 2018m12 Number of obs. = 138

lag	df	p	FPE	AIC	HQIC	SBIC
0			0.000717	1.27365	1.29951	1.33728
1	9	0.000	2.8e-0.9	-11.1814	-11.0779	-10.9268
2	9	0.000	**9.2e-10***	**-12.2976***	**-12.1166***	**-11.8521***
3	9	0.840	1.0e-09	-12.2029	-11.9443	-11.5665
4	9	0.039	1.0e-09	-12.2006	-11.8644	-11.3733
5	9	0.175	1.1e-09	-12.1624	-11.7486	-11.1442
6	9	0.131	1.1e-09	-12.1317	-11.6404	-10.9227

Endogenous: GDP lHICP SSR Exogenous:_cons

Source: own work.

Most commonly used criteria in econometric studies are the Final Prediction Error (FPE), Aikaike's information criterion (AIC), Hannan-Quinn information criterion (HQIC) and Schwarz information criterion (SBIC). As suggested by most of the information criteria, I will include 2 lags in the SVAR model.

6.2.3 Model estimation

The equations in a VAR model are estimated with the OLS estimation method. If the following assumptions (1 –4) for the OLS estimator hold, then the OLS estimator is unbiased and consistent. (Wooldridge, Ch.10, 2013)

1. Linearity in parameters (the model is correctly specified)
2. Random sampling (observed data represent a random sample for the population described by the model)

3. No perfect collinearity (in the underlying time-series process no independent variable is constant or a perfect linear combination of the others)
4. Zero conditional mean: $E[u_t|X] = 0$ (expected value of the error term u_t is zero for all time periods, conditional on all values of the explanatory variable)

When assumptions from 1 – 4 hold, the OLS estimator is unbiased and asymptotically consistent. Whereas for proving consistency, assumption 4 (zero conditional mean) is sufficient. To complete the Gauss-Markov theorem that proves the OLS is best linear unbiased estimator (BLUE) the following two assumptions must hold as well (5 – 6). (Wooldridge, Ch.10, 2013)

5. Homoskedasticity: $Var(u_t|X) = \sigma_u^2$ (conditional on X, the variance u_t is the same for all time periods)
6. No autocorrelation: $Corr(u_t, u_s|X) = 0 \; for \; all \; t \neq s$ (conditional on X, the errors in two different time periods are uncorrelated)

Assumption 6 is especially relevant for the time-series regression analysis, since it is often violated. The reason lies in the fact that the value of the time-series variable in time t depends on its own lagged values. Autocorrelation is thus a consequence of a misspecification of the model due to the omitted variable bias that causes correlation between errors and its own lagged values. Therefore, it is important to test for autocorrelation and apply corrective measures if it is present. There is one additional assumption (7) that must hold to round up classical linear model assumptions. (Wooldridge, Ch.10, 2013)

7. Normality (the errors $u_t$are independent of X and are independently and identically distributed as Normal $\{0, \sigma^2\}$)

However, the violation of assumption 7 is a serious concern in small sample analysis, whereas not in large samples. (Stewart, 2016)

In order to estimate the SVAR model with the OLS estimation method, the number of parameters in the SVAR model needs to be equal to those in the underlying reduced-form VAR (assumption 1 above). This is achieved by specifying A and B matrices with restrictions. Restrictions that are reflected in matrices A_1 and B_1 below correspond to Cholesky identification, where A_1 is required to be a diagonal matrix and B_1 lower triangular. As already discussed, this method is imposing causal ordering on the variables in the VAR. In my SVAR model, I set the GDP variable first, HICP inflation variable second and SSR variable last. Thus, shocks to GDP contemporaneously affect GDP, HICP and SSR, shocks to HICP contemporaneously affect only the SSR, while they affect GDP with a lag. Shocks to SSR affect both GDP and HICP with a lag. Such ordering of the variables is in line with the economic theory that believes the monetary policy only affects other macroeconomic variables with a lag.

$$A_1 = \begin{bmatrix} . & 0 & 0 \\ 0 & . & 0 \\ 0 & 0 & . \end{bmatrix} \qquad B_1 = \begin{bmatrix} 1 & 0 & 0 \\ . & 1 & 0 \\ . & . & 1 \end{bmatrix}$$

Stata provides estimates for missing values in A_1 and B_1 matrices that are marked with dots. Results of running a SVAR model with 2 lags and restrictions imposed by A_1 and B_1 matrices are displayed in Table 6. Stata estimated six unrestricted entries in the SVAR model. Four of the six unrestricted entries are statistically significant, while coefficient on GDP in the HICP equation (/b_2_1) and coefficient on GDP in the SSR equation (/b_3_1) are statistically insignificant. How variables will respond on impact can be interpreted by Cholesky decomposition of variance-covariance matrix of underlying VAR, which is reported in matrix sig_var below the table. As the focus of the analysis is in the responses of GDP and lHICP to a SSR shock, the interpretation of other coefficients in the matrix is not relevant (that is, the contemporaneous responses of GDP to a GDP and lHICP shock, lHICP to a GDP and lHICP shock and SSR to a GDP and lHICP shock). The response of SSR to a SSR shock is positive on impact (0.322), which denotes the positive interest rate shock. The contemporaneous responses of GDP and lHICP are restricted to 0.

Table 6: SVAR model estimation

Sample: 2007m3 - 2018m12 — Number of obs = 142
Exactly identified model — Log likelihood = 898.1839

	Coef.	Std.Err.	z	P>|z|	[95% Conf.	Interval]
/a_1_1	19.79009	1.174326	16.85	0.000	17.48845	22.09172
/a_2_1	0	(constrained)				
/a_3_1	0	(constrained)				
/a_1_2	0	(constrained)				
/a_2_2	641.4133	38.06087	16.85	0.000	566.8153	716.0112
/a_3_2	0	(constrained)				
/a_1_3	0	(constrained)				
/a_2_3	0	(constrained)				
/a_3_3	3.105575	0.184282	16.85	0.000	2.744389	3.466761
/b_1_1	1	(constrained)				
/b_2_1	0.1449041	0.0847946	1.71	0.087	-0.0212902	0.3110984
/b_3_1	0.1092695	0.0860514	1.27	0.204	-0.0593882	0.2779272
/b_1_2	0	(constrained)				
/b_2_2	1	(constrained)				
/b_3_2	0.1988687	0.0855615	2.32	0.020	0.0311713	0.3665661
/b_1_3	0	(constrained)				
/b_2_3	0	(constrained)				
/b_3_3	1	(constrained)				

.matlist **chol**=e(sigma)

	GDP	lHICP	SSR
GDP	0.0025533		
lHICP	0.0000114	2.48e-06	
SSR	0.0017779	0.0001078	0.1090236

. matlist **sig_var**=cholesky(chol)

	GDP	lHICP	SSR
GDP	0.05053035	0	**0**
lHICP	0.00022591	0.00155906	**0**
SSR	0.03518495	0.06403603	**0.32200154**

Source: own work.

In order to observe long-term responses of variables to a shock, other sets of statistics for the estimated SVAR model must be studied. For instance, the bloc significance (Granger) tests, Impulse responses (IRFs) and Variance decompositions (FEVDs).

6.2.4 Post- estimation diagnostics

- **Granger causality**

Granger causality tests refer to the question whether the changes in one variable cause changes in the other. In particular, the null hypothesis for Granger causality test in my three variable SVAR model are:

- First equation: lagged values of lHICP and SSR do not cause GDP
- Second equation: lagged values of GDP and SSR do not cause lHICP
- Third equation: lagged values of GDP and lHICP do not cause SSR

Thus, if the prob. value is smaller than 0.05, the null hypothesis can be rejected. The results are reported in Table 7 and show the following:

- Lagged values of lHICP and SSR cause GDP
- Lagged values of GDP and SSR do not cause lHICP
- Lagged values of GDP cause SSR, while lagged values of lHICP do not cause SSR
- There is bidirectional Granger causality between SSR and GDP, while there is no Granger causality between lHICP and SSR

Since we are particularly interested in changes of GDP and lHICP to changes in SSR, it can be observed that the Granger causality test implies the changes in GDP variable are caused by changes in SSR, while those in lHICP might not be caused by SSR.

Table 7: Granger causality test for GDP, lHICP and SSR equations

Granger causality Wald tests

Equation	Excluded	chi2	Df	Prob > chi2
GDP	lHICP	8.2224	2	**0.016**
GDP	SSR	16.827	2	**0.000**
GDP	ALL	19.673	4	**0.001**
lHICP	GDP	4.2521	2	**0.119**
lHICP	SSR	1.065	2	**0.587**
lHICP	ALL	6.8682	4	**0.143**
SSR	GDP	10.718	2	**0.005**
SSR	lHICP	2.6973	2	**0.260**
SSR	ALL	17.869	4	**0.001**

Source: own work.

However, block significance tests cannot, by construction, explain the signs of relationships or the duration of effects in time. This is only possible by examining impulse responses and variance decompositions of a VAR model (Verbič, 2018). I will only focus on the impulse responses of the SVAR model in section 6.2.5.

– **LM test for autocorrelation in the residuals**

As mentioned in section 6.2.3 (Model estimation), the assumption of no autocorrelation in the error terms is often violated in time-series regressions. This implies an omitted variable bias and makes the OLS estimator no longer BLUE. Autocorrelation in the residuals is tested with the Lagrange-multiplier (LM) test. The null hypothesis states that there is no autocorrelation at individual lag order. Stata gives us the sequence of LM tests applied to the underlying VAR model. In the testing procedure, it first defines vectors of residuals from original VAR that contains K equations and thus gives $e_1, e_2, \dots e_K$ new variables containing residuals. Then, the original VAR is augmented with lags of these K new variables. Augmented regression is formed for each lag s in which the new residual variables are lagged s times. The formula that Stata uses for the LM statistic is given in equation 13. (StataCorp, 2019)

$$LM_s = (T - d - 0{,}5) \ln\left(\frac{|\hat{\Sigma}|}{|\widetilde{\Sigma_s}|}\right) \tag{13}$$

Where T is a number of observations in the VAR, d is the number of coefficients estimated in the augmented VAR, $\hat{\Sigma}$ is the maximum likelihood estimate of the variance-covariance matrix (Σ) of the disturbances from the VAR, and $\widetilde{\Sigma_s}$ is the maximum likelihood estimate of Σ from the augmented VAR. The results of LM tests are reported in Table 8. We can observe that there is no autocorrelation in the residuals at lag order, since the Prob. value is greater than 0.05 and we cannot reject the null hypothesis.

Table 8: LM test for autocorrelation in the residuals

Lagrange-multiplier test			
lag	chi2	df	Prob > chi2
1	4.4354	9	**0.88049**
2	13.5424	9	**0.13956**
3	9.9882	9	**0.35144**
4	7.9017	9	**0.54409**
H0: no autocorrelation at lag order			

Source: own work.

– **Normality test**

The normality test is used for testing whether disturbances in the regressions are normally distributed. The normality test gives us the reported series of three computed statistics. First is the Jarque-Bera statistic, which is followed by the skewness and kurtosis statistic. When

normality test is applied after the SVAR model estimation, it uses the estimated structural decomposition of $\hat{A}^{-1}\hat{B}$ to orthogonalize the residuals. The post-estimation statistics assume that K disturbances have K-dimensional multivariate normal distribution. The null hypothesis states that K disturbances in the model are normally distributed. (StataCorp, 2019) Results of the normality test are reported in Table 9. Reported statistics show that we cannot reject the null hypothesis of normally distributed disturbances in GDP and lHICP, while we reject the null hypothesis for SSR. However, non-normality of disturbances in SSR is in line with the empirical properties of financial time-series data, which usually do not follow normal distribution and tend to exhibit higher volatility. This is especially common for interest rates. As mentioned in section 6.2.3 (Model estimation), violation of normality is a serious concern in small samples.

Table 9: Normality test

Jarque-Bera test		chi2	df	Prob > chi2
GDP		5.476	2	0.06471
lHICP		0.956	2	0.62011
SSR		123.818	2	0.000
Skewness test	Skewness	chi2	df	Prob > chi2
GDP	-0.33127	2.597	1	0.10706
lHICP	-0.1323	0.414	1	0.51984
SSR	-0.842	8.077	1	0.00448
Kurtosis test	Kurtosis	chi2	df	Prob > chi2
GDP	3.6975	2.878	1	0.08977
lHICP	2.6975	0.541	1	0.46181
SSR	7.4229	115.741	1	0.000

Source: own work.

– **Stability of the model**

Inference after SVAR requires that the stability condition is satisfied. If a VAR is stable, it is invertible and has an infinite-order vector moving-average representation. In that manner, the impulse response functions and forecast-error variance decompositions have known interpretations. (StataCorp, 2019)

Stata forms the companion matrix A:

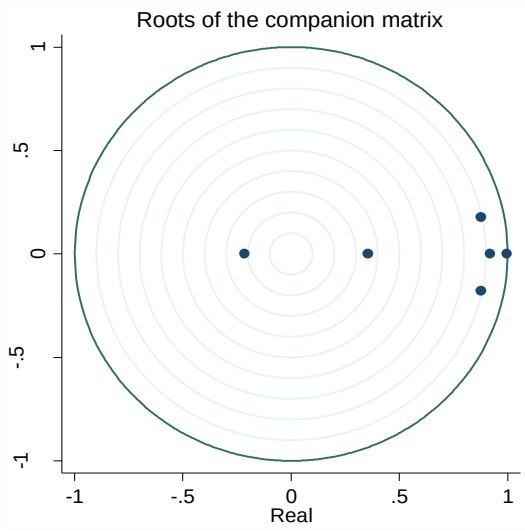
$$A = \begin{bmatrix} A_1 & A_2 & \dots & A_p \\ I_n & 0 & \dots & 0 \\ 0 & I_n & \dots & 0 \\ \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & I_n & 0 \end{bmatrix}$$

and obtains its eigenvalues and moduli. The process is stable if the moduli of each eigenvalue of A is strictly less than 1. (StataCorp, 2019)

After running the stability test for a SVAR model, Stata gives us the output presented in Table 10. The calculations of moduluses and eigenvalues are reported on the left hand-side and it can be observed that the modulus of each eigenvalue is strictly less than 1 and thus the estimates satisfy the eigenvalue stability condition. The graph on the right hand-side shows eigenvalues with the real components on the x axis and the complex components on the y axis. It can be visually observed that these eigenvalues are well inside the unit circle.

Table 10: Stability of the SVAR model

Eigenvalue stability condition	
Eigenvalue	Modulus
0.995679	0.995658
0.9194048	0.919405
0.8749292 + 0.178025i	0.892953
0.749292 – 0.178025i	0.892953
0.3543475	0.354347
0.2152399	0.21524
All the eigenvalues lie inside the unit circle.	
VAR satisfies stability condition	



Source: own work.

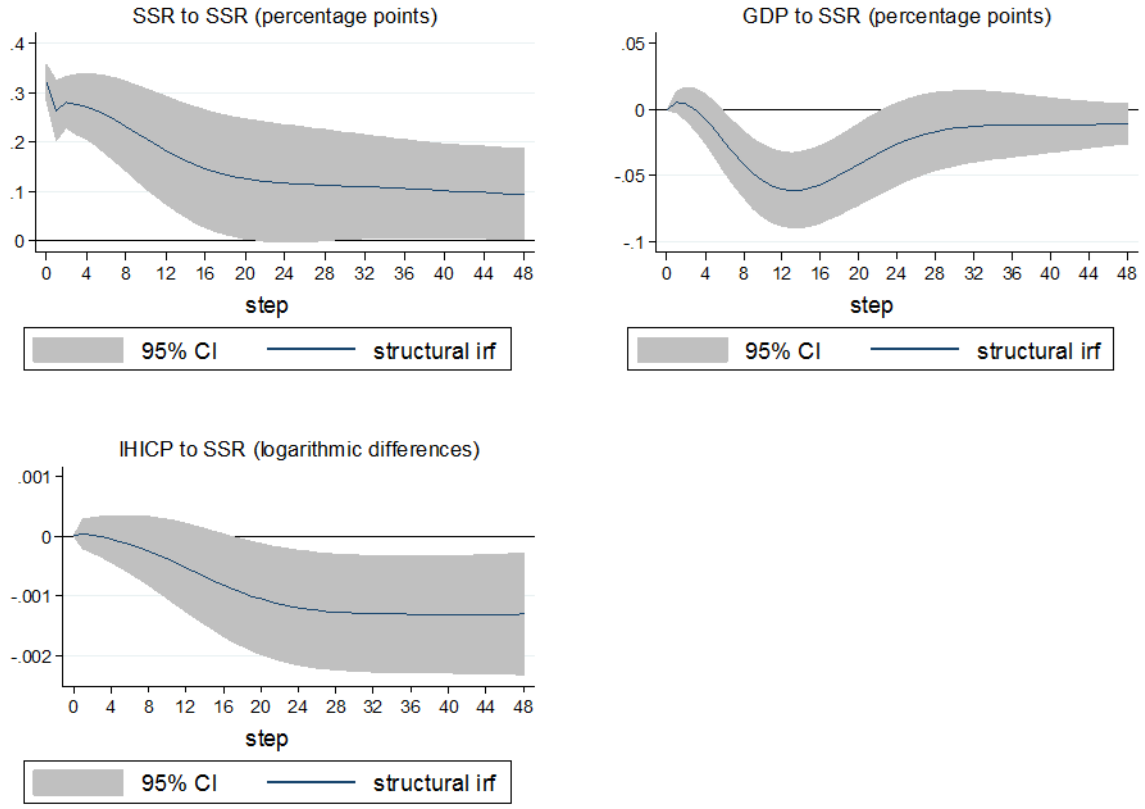
6.2.5 Impulse responses

Impulse responses trace out the responsiveness of the dependent variables in the SVAR model to shocks to the disturbance term. In particular, a one-time unit increase (shock) is applied to the disturbance term of the respective equation separately for each variable. Normally, the impulse responses are presented graphically for a given number of periods as impulse response functions (IRFs). In case of Cholesky decomposition, they are orthogonalized impulse response functions (OIRFs), while the structural impulse response functions (SIRFs) are derived from the constraints imposed on the SVAR model. For g variables in a system, g^2 impulse responses are generated (Verbič, 2018).

Figure 20 shows graphs of structural impulse responses of the three variables to a SSR shock. The first variable written above each graph represents the impulse variable, while the second variable is the response variable. The magnitude of the shock corresponds to one-unit standard deviation, while the response is measured in the units of the response variables that are shown on the vertical axis. The horizontal axis for each graph shows the time units (in months), over which the SVAR is estimated in. In this case, the impulse response graphs show the effect of a shock over a 48-month period. The table of structural impulse response

functions with 95 % upper and lower bounds for SSR, GDP and lHICP responses to a SSR shock is reported in Appendix 2.

Figure 20: Structural impulse responses



Source: own work.

A one-unit standard deviation shock to a SSR increases SSR for a 0.32 percentage point. A positive response of SSR, denoted as a positive interest shock (monetary policy tightening) causes lagged negative responses of both GDP rate and HICP inflation rate. Maximum GDP response to a 0.32 percentage point increase in SSR is a drop of -0.06 percentage point after 12 months. The effect gradually dies away after about 32 months. Since the response of the lHICP to a SSR shock is measured in logarithmic changes (differences), it could be interpreted as an approximation of a monthly HICP growth rate or monthly inflation rate. In response to a positive SSR shock, HICP rate gradually declines for -0.001 percentage point after 19 months in response to a SSR shock. A lagged negative response of a HICP rate is highly persistent and of very small magnitude.

Since SSR represents an alternative measure of unconventional monetary policy stance, a positive SSR shock could be interpreted as an unexpected positive unconventional monetary policy shock. Thus, positive unconventional monetary policy shock (as a 0.32 percentage point increase in SSR) lowers GDP growth rate for 0.06 percentage point (after 12 months) and inflation rate for 0.001 percentage point (after 19 months). This would proportionally

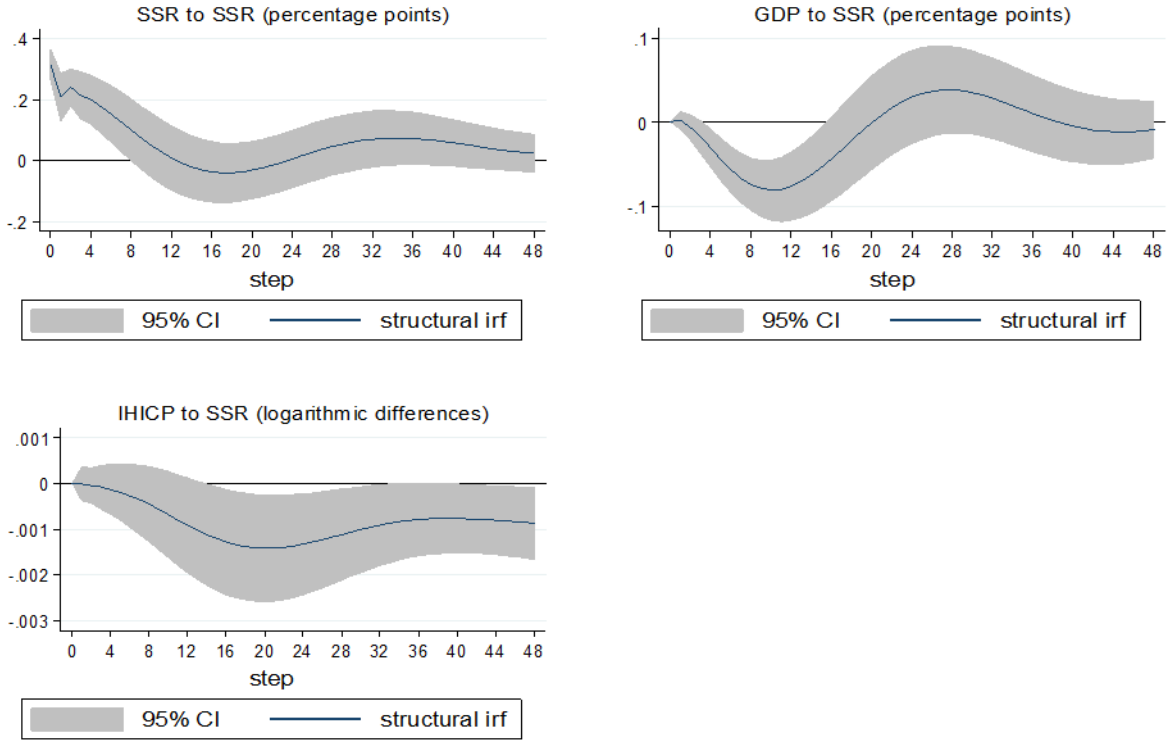
mean that a 1 percentage point increase in SSR lowers real GDP rate for around 0.19 percentage point and lowers inflation rate for 0.003 percentage point.

The results are very much in line with the expectations on the basis of the economic theory. An unanticipated monetary policy tightening lowers GDP rate and inflation rate with a delay. In terms of magnitude, the responses of GDP are more significant compared to those of inflation, which are quite negligible and more delayed. The observed responses of GDP rate and inflation rate imply that SSR could be used as an alternative measure of monetary policy stance, when key interest rates are stuck at the zero-lower bound. In other words, SSR could be used as a measure of unconventional monetary policy stance that reflects the market perceptions of all the ECB's policy measures (including unconventional, which dominate over the course 2014 – 2018). From this perspective, the results provide evidence of the effects of unconventional monetary policy, which in the form of a positive shock decreases GDP and inflation rate.

6.2.6 Robustness check

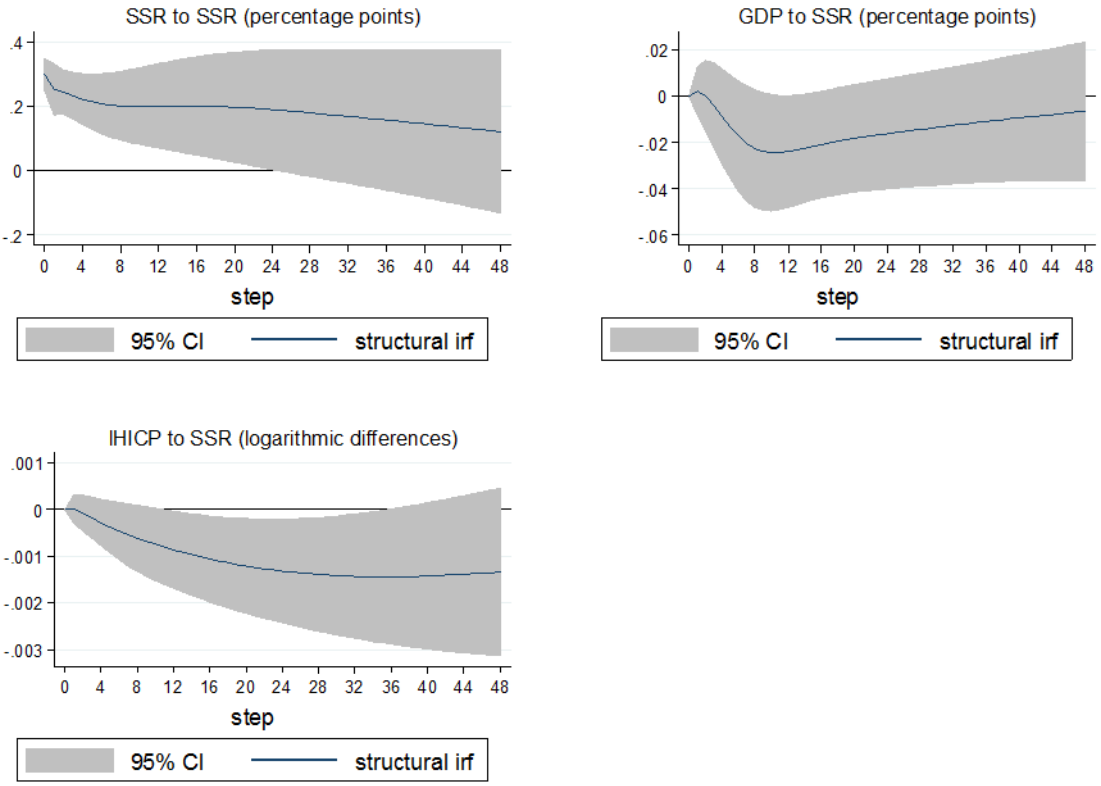
There are many ways for checking the robustness of a SVAR model. I checked robustness by dividing the time period into two sub-periods in order to check whether the responses of the variables remain consistent. First sub-period covers 2007–2013 (month 5) and the second sub-period covers 2013–2018. The impulse responses of the first sub-period are reported in Figure 21 and impulse responses of the second sub-period are reported in Figure 22.

Figure 21: Structural impulse responses sub-period 1



Source: own work.

Figure 22: Structural impulse responses sub-period 2



Source: own work.

As can be observed from Figure 21, the shock to SSR dies away earlier but SSR response is of the same magnitude. GDP rate declines in response to a positive SSR shock and reaches its peak level earlier, which is after 10 months before it starts growing. The response of lHICP rate is negative over the entire period, although the drop is of very small magnitude and persistent. In Figure 22, which indicates the second sub-period, the shock to SSR is only gradually dying away and is not very significant. The responses of GDP rate and lHICP rate are exhibiting similar dynamics as they both decrease in response to a positive SSR shock. However, it can be observed that GDP rate drops a little more than 0.02 percentage point already after 8 months. The insignificance of the responses to a SSR shock is very likely due to a small sample. The test shows the model remains robust as the variables in general exhibit similar dynamics and do not change the sign in response to a shock.

Furthermore, I checked robustness by using different ordering of the variables. For instance, in first version I set the lHICP first, then GDP, and SSR last, while in the second version I set SSR first, then lHICP, and GDP last. The first version showed almost no change in responses of the variables, while in the second version response of lHICP was different. After a positive SSR shock lHICP increased on impact before it started to decline, and it became negative only after about 12 months. This is not consistent with the economic theory after a positive interest rate shock. The test confirms the robustness of the SVAR model and

the Cholesky ordering of the variables, which is in line with the identification of monetary policy shock.

6.2.7 Findings of the empirical analysis in the context of other empirical research

The results of the empirical analysis show that the unexpected positive unconventional monetary policy shock lowers GDP and inflation rate with a delay. The effect is more significant in the case of GDP response, while the effects on the inflation rate are relatively small and more delayed. The impulse responses show that shadow short rates could be used as an alternative measure of monetary policy stance in times when the key interest rates are bounded at zero. These findings are very much in line with those of Damjanovic and Masten (2016) and Elbourne, Ji and Duijndam (2018).

Damjanovic and Masten (2016) provide evidence of usefulness of shadow short rates in studying responses of macroeconomic variables. Their impulse responses of a three-variable VAR model with SSR by Krippner (2015) exhibit similar dynamics to this empirical analysis, with observable differences in responses of inflation that are more significant in terms of magnitude. In addition, their impulse responses of both GDP and inflation are even more delayed (after 9 and 16 quarters). On the other hand, Elbourne, Ji and Duijndam (2018) employ SVAR model with six variables and combination of a zero and sign restrictions. They use SSR by Wu and Xia (2016) and provide evidence that the unconventional monetary policy shock has a relatively small effect on the output and inflation, which is very much in line with the findings of this empirical analysis. Their impulse responses show that an expansionary unconventional monetary policy shock increases output growth (0.05 percent to GDP after 10 months), whereas the responses of inflation are rather negligible and economically insignificant. In terms of magnitude, the responses are quite comparable to those in this empirical analysis.

To quantify an overall effect of the unconventional monetary policy measures on the output and inflation, other analyses, such as the SVAR model with long-run restrictions or counterfactual exercises that compare the two scenarios (with and without policy measures), should be employed. The latter is a very often used approach that can be found in many empirical researches of the effects of unconventional monetary policy measures with different methodology. For instance, Lenza, Pill and Reichlin (2010) in a Bayesian VAR, Boeckx, Dossche and Peersman (2017) in a SVAR model with zero and sign restrictions, Mouabbi and Sahuc (2018) in a DSGE model, Garabedian (2018) in a time-varying VAR or Damjanovic and Masten (2016), who use historical decomposition of the stochastic component of the SSR series to determine the effect of the ECB's unconventional policy measures on the euro area output and inflation in the sovereign debt crisis. However, these are additional steps that go beyond the scope of the empirical analysis of this master's thesis and remain open for further research.

CONCLUSION

Responses of the ECB to the global financial crisis and its aftermath over the last decade faced many challenges. Soon after the outbreak of the global financial crisis, the standard monetary policy framework proved to be inadequate in coping with the extensive proportions and severe impairments that the crisis caused to the financial markets. The ECB responded with rounds of unconventional monetary policy measures that can be analysed by dividing them into three distinct phases. In the first phase, the primary aim was to provide liquidity to the banking sector and to keep the financial markets functioning. In 2008, the ECB introduced the so-called "enhanced credit support" package, within which the fixed-rate full allotment procedure (FRFA) played a major role in providing liquidity certainty. The second phase came in the form of a sovereign debt crisis that hit the euro area over the course of 2010 – 2012. The ECB pledged to do "whatever it takes" in order to restore the sovereign debt markets' functioning. In the third phase, the monetary policy struggled with a prolonged period of low inflation and weak economic growth. Policy easing was not sufficiently transmitted to the financial sector and key interest rates reached the zero-lower bound. In June 2014, the ECB introduced the so-called "credit easing" package that included targeted longer-term refinancing operations (TLTROs), negative interest rate on the deposit facility and asset purchase programme (APP).

Net purchases amounted to a total of 2.6 trillion euros, of which the PSPP contributed by far the largest share at 82 percent, followed by the CBPP3 at 10 percent, the CSPP at 7 percent and the ABSPP at 1 percent. The PSPP purchases were conducted in the period between March 2015 and December 2018, during which it was calibrated four times. Net monthly purchases were carried out at monthly paces of 60-80-60-30-15 billion euros before the transition in December 2018. Large scale asset purchases significantly changed the ECB's balance sheet, where a clear substitution of regular liquidity providing operations with unconventional policy measures can be observed. By the end of 2018, the size of the Eurosystem's balance sheet reached historical high of 4.7 trillion euros. The absolute increase in size of the balance sheet (as reported at the end of the calendar year) was around 3.2 trillion euros (a relative increase by more than 313 percent), compared to the size of the balance sheet before the financial crisis at the end of the year 2007 (1.5 trillion euros).

The credit-easing package raised many theories on the transmission of significant monetary policy stimulus to the real economy. Large-scale asset purchases managed to lower long-term bond yields and absorb a part of the overall term premia risk, while providing extensive amounts of liquidity to the banking sector. The banking sector was on the one hand exposed to liquidity certainty, and on other hand to incentives to increase lending to the economy. These incentives were further enhanced by a "rewarding" system of TLTROs in case of the banks' increased level of loans to non-financial sector, whereas the negative deposit facility rates were designed to mitigate liquidity hoarding. Transmission mechanisms of non-conventional monetary policy measures are described by portfolio-rebalancing, direct pass-thorough, or credit-easing and signalling channel.

In the empirical part, I investigated the dynamic relations between the macroeconomic variables and monetary policy in times of the unconventional policy measures. Since key policy rates remain at zero lower bound, they become very uninformative about the monetary policy stance. Thus, shadow short rates offer an alternative for measuring unconventional policy stance as argued by many authors; Wu and Xia (2013, 2017), Damjanovic and Masten (2016), Elbourne, Ji and Duijndam (2018). The main advantage of using shadow rates is that they are free to go into the negative territory when key policy rates are bound at zero, while at the same time they coincide with the main policy rate in times before the zero lower bound. In the analysis, I employed econometric modelling to study the effects of the unconventional monetary policy on the euro area output and inflation. Using shadow short rates by Wu and Xia (2017) as an alternative measure of monetary policy stance, I set up a simple three-variable SVAR that imposes additional identifying assumptions to recover the structural shocks. To recover monetary policy shocks, variables in the SVAR model were ordered recursively with the shadow rates ordered last and the Cholesky decomposition applied.

The impulse responses show that a one-unit standard deviation shock to a SSR increases SSR for 0.32 percentage point. Since the SSR represents an alternative measure of unconventional monetary policy stance, a positive SSR shock could be interpreted as an unexpected positive unconventional monetary policy shock. This results in lagged negative responses of both the GDP rate and the HICP inflation rate. Maximum GDP response to 0.32 percentage point increase in the SSR is a drop to -0.06 percentage point after 12 months, while the HICP rate gradually declines for -0.001 percentage point after 19 months. A lagged negative response of the HICP rate is highly persistent and of very small magnitude. The results are very much in line with the expectations based on the economic theory. An unanticipated monetary policy tightening lowers GDP rate and inflation rate with a delay. The observed responses of GDP rate and inflation rate imply that SSR could be used as an alternative measure of monetary policy stance, when key interest rates are stuck at the zero-lower bound. In other words, the SSR could be used as a measure of unconventional monetary policy stance that reflects market perceptions of all the ECB's policy measures (including unconventional, which dominated over the course 2014 – 2018). From this perspective, the results provide evidence of the effects of unconventional monetary policy, which in the form of a positive shock decrease GDP and inflation rate. To quantify an overall effect of the unconventional monetary policy measures on the output and inflation, other types of analysis, such as SVAR model with long-run restrictions or counterfactual exercises that compare the two scenarios (with and without policy measures), should be employed. However, these are additional steps that go beyond the scope of the empirical analysis of this master's thesis and remain open for further research.

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APPENDICES

Appendix 1: Povzetek (Summary in Slovene language)

Denarna politika Evropske Centralne Banke (v nadaljevanju ECB) se je v zadnjem desetletju občutno spremenila. Kmalu po izbruhu globalne finančne krize se je standardni okvir denarne politike izkazal za nezadostnega pri reševanju njenih razsežnosti in posledic, ki jih je pustila na finančnih trgih. ECB je vpeljala več nizov nestandardnih ukrepov, ki jih je moč razdeliti na tri različne faze. V prvi je bil primarni cilj zagotavljanje likvidnosti bančnemu sektorju in ohranjanje funkcionalnosti finančnih trgov. V letu 2008 je ECB uvedla paket nestandardnih ukrepov, ki je predstavljal "okrepljeno podporo kreditiranju" v sklopu katerega je znatno vlogo odigrala vpeljava operacij odprtega trga prek avkcij s fiksno obrestno mero in popolno dodelitvijo. Druga faza je v obdobju 2010 – 2012 zaznamovala evro območje v obliki dolžniške krize. ECB je obljubila, da bo naredila »whatever it takes« in nestandardne ukrepe usmerila v reševanje trgov obveznic. V tretji fazi se je denarna politika soočala s povečanim tveganjem daljšega obdobja nizke rasti inflacije in šibke gospodarske rasti. Sproščanje denarne politike v obliki znižanja obrestnih mer ni v celoti doseglo vseh finančnih sektorjev, kar je povzročalo velika neskladja med finančnimi trgi in povečanim tveganjem pojava kreditnega krča. Ker so ključne obrestne mere dosegle tako imenovano spodnjo ničelno mejo, kjer je prostor za nadaljnja zniževanja zelo omejen, se je na to ECB odzvala z intenzivnejšimi nestandardnimi ukrepi. Junija 2014 je uvedla sklop ukrepov med katere sodi program nakupov vrednostnih papirjev (APP), ciljno usmerjene operacije dolgoročnejšega refinanciranja (TLTROs) in negativna obrestna mera na mejni depozit.

Neto nakupi vrednostnih papirjev programa APP so skupaj znašali 2,6 trilijone evrov, pri čemer nakupi programa PSPP predstavljajo največji delež (82 odstotkov), sledijo nakupi programa CBPP3 (10 odstotkov), nakupi programa CSPP (7 odstotkov) in nakupi programa ABSPP (1 odstotek). Nakupi vrednostnih papirjev programa PSPP so potekali v obdobju med marcem 2015 in decembrom 2018, parametri pa so bili v tem obdobju štirikrat spremenjeni. Tako so neto mesečni nakupi potekali v zneskih 60-80-60-30-15 milijarde evrov, z zaključkom v decembru 2018. Do konca leta 2018 se je bilanca ECB občutno spremenila. Standardne operacije refinanciranja so skoraj v celoti nadomestili nestandardni ukrepi, medtem ko je stopnja preseženih rezerv v obliki presežne likvidnosti v bančnem sistemu, dosegla nekatere rekordno visoke vrednosti. Bilanca ECB je dosegla rekordno visoko vrednost 4,7 trilijone evrov, kar kaže na absolutno povečanje v višini 3,2 trilijona evrov (oziroma več kot 313 odstotno relativno povečanje) v primerjavi z vrednostjo pred začetkom finančne krize konec leta 2007 (1,5 trilijone evrov).

Sklop nestandardnih paketov vpeljan junija 2014 je spodbudil številne teorije o kanalih po katerih presežena likvidnost in preostali nestandardni ukrepi denarne politike dosegajo realni sektor. Obsežni nakupi vrednostnih papirjev so vplivali na znižanje krivulje donosnosti na daljših ročnostih in absorbirali del celotne premije za tveganja ter hkrati sprostili znatno količino likvidnosti v bančni sistem. S tem se je sprostila likvidna nesigurnost v bančnem sektorju in okrepile so se spodbude za povečanje kreditiranja gospodarstva. Slednje je bilo

dodatno podkrepljeno s sistemom »nagrajevanja« bank za povečan nivo novih posojil nefinančnemu sektorju preko operacij dolgoročnejšega refinanciranja (TLTRO), po drugi strani pa je negativna obrestna mera na mejni depozit zmanjšala kopičenje presežene likvidnosti znotraj bančnega sistema. Celoten transmisijski mehanizem podrobneje opisujejo kanal uravnoteženja portfelja, kanal bančnega posojanja in kanal signaliziranja.

V empiričnem delu sem preučila dinamične povezave med makroekonomskimi spremenljivkami in denarno politiko v času nestandardnih ukrepov. Ker se ključne obrestne mere nahajajo pri ničelni meji, ne predstavljajo jasne slike naravnanosti denarne politike. Iz tega razloga mnogi avtorji; Wu in Xia (2013 in 2017), Damjanovič in Masten (2016), Elbourne, Ji in Duijndam (2018) zagovarjajo vpeljavo senčnih obrestnih mer kot alternativno merilo naravnanosti denarne politike v času nestandardnih ukrepov. Prednost vpeljave senčnih obrestnih mer je v tem, da le-te preidejo v negativno območje takrat, ko so ključne obrestne mere na ničelnih ravneh. Hkrati pa sledijo ključnim obrestnim meram v obdobju pred ničelno mejo. V tej empirični analizi sem uporabila ekonometrično metodologijo preučevanja učinkov nestandardnih ukrepov na rast BDP in HICP inflacije v evro območju. Uporabila sem senčne obrestne mere Wu in Xie (2017) kot alternativno merilo naravnanosti denarne politike in uporabila enostaven model strukturne vektorske avto regresije (nadaljnje model SVAR), ki omogoča vpeljavo dodatnih omejitev za identificiranje strukturnih šokov. Z namenom identificiranja denarnih šokov na spremenljivke v modelu, sem uporabila rekurzivni vrstni red spremenljivk pri čemer so senčne obrestne mere razvrščene zadnje ter aplicirano Cholesky dekompozicijo variančne-kovariančne matrike ostankov.

Impulzivni odzivi kažejo, da šok v velikosti enega standardnega odklona na senčne obrestne mere, le-te poveča za 0,32 odstotne točke. Ker senčne obrestne mere prestavljajo alternativno mero naravnanosti denarne politike v času nestandardnih ukrepov, lahko pozitivni šok v senčnih obrestnih merah interpretiramo kot nepričakovan šok nestandardne denarne politike. Slednje se odrazi v negativnih odzivih rasti BDP in inflacije z zamikom. Stopnja rasti BDP doseže maksimalen padec za -0,06 odstotne točke po 12 mesecih v odziv na povečanje v senčni obrestni meri za 0,32 odstotne točke. Po drugi strani pa se stopnja inflacije na pozitiven šok v senčnih obrestnih merah odzove s padcem za -0,001 odstotne točke po 19 mesecih. Kasnejši odziv inflacije je dolgotrajen in zelo majhen. Rezultati so v skladu s pričakovanji na podlagi ekonomske teorije. Nepričakovan šok zategovanja denarne politike vpliva na zmanjšanje rasti BDP in inflacije z zamikom. Odzivi BDP in inflacije potrjujejo uporabo senčnih obrestnih mer kot indikator naravnanosti denarne politike v času ničelnih ključnih obrestnih mer ECB. Z drugimi besedami, senčne obrestne mere predstavljajo naravnanost denarne politike kot jo zaznavajo trgi (tudi v času nestandardnih ukrepov, ki prevladujejo v obdobju 2014-2018). S tem rezultati kažejo na učinke nestandardnih ukrepov, ki v obliki pozitivnega šoka zmanjšajo rast BDP in inflacije. Za določitev kvalitativnega učinka nestandardnih ukrepov na BDP in inflacijo pa je potrebna razširitev analize v obliki SVAR modela z dolgoročnimi omejitvami ali pa »counterfactual« analize, ki primerja dva

scenarija (z in brez ukrepov). Te razširitve sodijo med nadaljnje korake, ki sežejo izven obsega tega magistrskega dela in ostajajo predmet nadaljnjih raziskav.

Appendix 2: Table of structural impulse response functions (Figure 20)

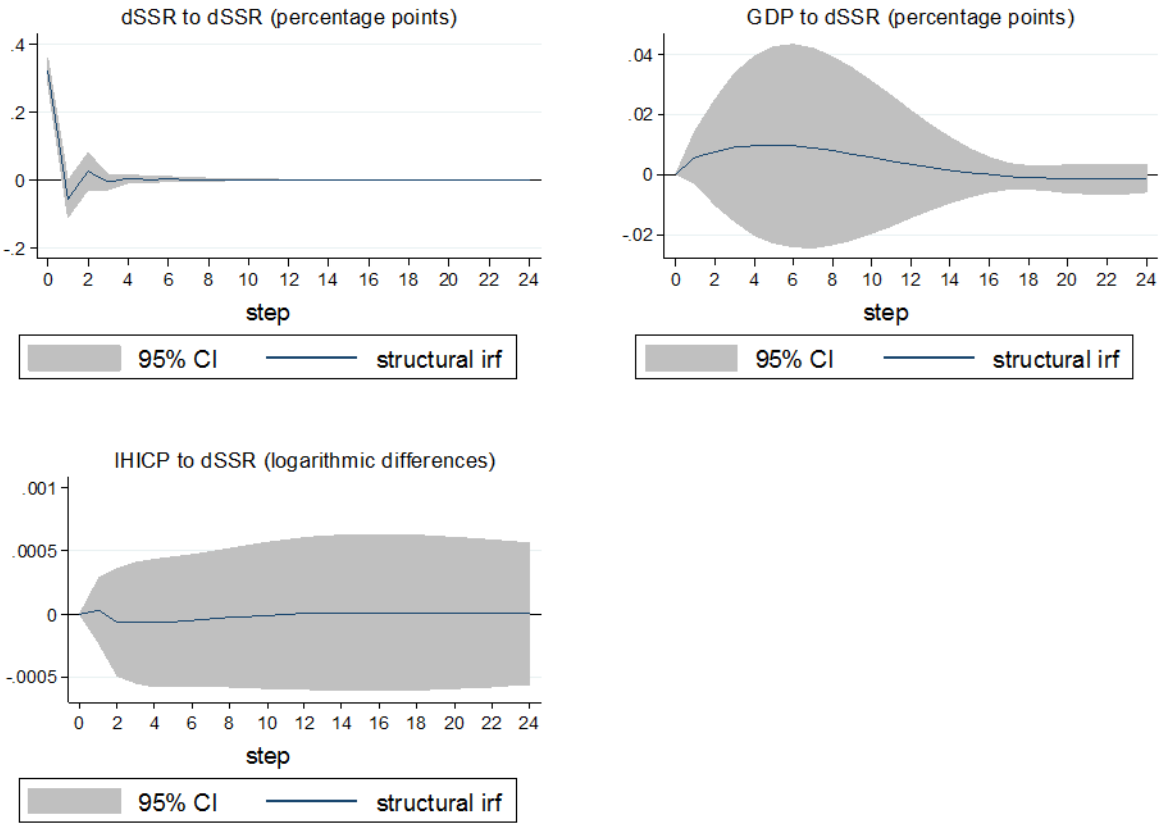
Table of structural impulse response functions (sirf) with 95 % upper and lower bounds for SSR, GDP and lHICP responses to a SSR shock (Figure 20)

SSR to SSR				GDP to SSR				lHICP to SSR			
step	**sirf**	**lower**	**upper**	**step**	**sirf**	**lower**	**upper**	**step**	**sirf**	**lower**	**upper**
0	**.322002**	.284552	.359451	0	0	0	0	0	0	0	0
1	.263906	.202407	.325405	1	.005719	-.002464	.013901	1	.000045	-.00021	.000299
2	.28043	.228601	.332259	2	.004411	-.008102	.016924	2	.000017	-.000278	.000313
3	.275791	.21468	.336902	3	-.000035	-.016131	.016062	3	-.000013	-.000355	.000329
4	.27166	.205344	.337976	4	-.007098	-.025871	.011676	4	-.000049	-.000434	.000336
5	.264126	.191163	.33709	5	-.015589	-.036532	.005355	5	-.000089	-.000522	.000343
6	.254714	.175341	.334087	6	-.024624	-.047381	-.001867	6	-.000135	-.000616	.000346
7	.243756	.158083	.329429	7	-.033455	-.057754	-.009157	7	-.000187	-.000716	.000343
8	.231819	.140188	.323449	8	-.041516	-.067107	-.015926	8	-.000244	-.000822	.000333
9	.219374	.122241	.316506	9	-.048405	-.075034	-.021775	9	-.000308	-.000931	.000315
10	.206852	.104767	.308937	10	-.05387	-.081285	-.026455	10	-.000377	-.001043	.000289
11	.194619	.088186	.301052	11	-.057791	-.085757	-.029826	11	-.000449	-.001155	.000256
12	.182969	.072812	.293126	12	**-.060159**	-.088485	-.031834	12	-.000524	-.001266	.000218
13	.172127	.058858	.285395	13	-.06105	-.089609	-.032491	13	-.0006	-.001375	.000176
14	.162248	.046447	.278048	14	-.060605	-.089347	-.031862	14	-.000675	-.001481	.000131
15	.153425	.035624	.271226	15	-.059008	-.087952	-.030065	15	-.000748	-.001581	.000085
16	.145695	.026371	.265019	16	-.056472	-.085681	-.027262	16	-.000818	-.001675	.000039
17	.139047	.018625	.25947	17	-.053215	-.082772	-.023658	17	-.000884	-.001763	-4.9e-06
18	.133432	.012289	.254575	18	-.049456	-.079426	-.019486	18	-.000945	-.001843	-.000047
19	.128773	.007251	.250294	19	-.045398	-.075805	-.014991	19	**-.001001**	-.001915	-.000086
20	.124969	.003383	.246556	20	-.041224	-.072038	-.01041	20	-.001051	-.001979	-.000122
21	.121912	.000558	.243267	21	-.03709	-.068228	-.005952	21	-.001095	-.002035	-.000155
22	.119486	-.001355	.240327	22	-.033125	-.064461	-.001789	22	-.001134	-.002084	-.000184
23	.117575	-.002483	.237634	23	-.029427	-.060807	.001954	23	-.001167	-.002125	-.00021
24	.116071	-.002951	.235092	24	-.026066	-.05733	.005197	24	-.001196	-.002159	-.000232
25	.114871	-.00288	.232623	25	-.023088	-.05408	.007905	25	-.001219	-.002187	-.000252
26	.113889	-.002385	.230163	26	-.020512	-.051099	.010076	26	-.001239	-.002209	-.000269
27	.113047	-.001577	.227671	27	-.018339	-.048416	.011738	27	-.001255	-.002227	-.000283
28	.112284	-.00056	.225127	28	-.016554	-.046045	.012936	28	-.001267	-.00224	-.000295
29	.111549	.000572	.222527	29	-.01513	-.043986	.013727	29	-.001277	-.00225	-.000304
30	.110807	.001733	.219881	30	-.014028	-.042224	.014169	30	-.001285	-.002257	-.000312
31	.110033	.002851	.217214	31	-.013207	-.04073	.014317	31	-.001291	-.002263	-.000319
32	.109211	.003868	.214554	32	-.012622	-.039465	.014221	32	-.001295	-.002267	-.000324
33	.108335	.004738	.211932	33	-.012228	-.038381	.013926	33	-.001299	-.00227	-.000327
34	.107405	.005432	.209379	34	-.011982	-.037431	.013467	34	-.001301	-.002273	-.00033
35	.106428	.005934	.206922	35	-.011845	-.036567	.012878	35	-.001303	-.002275	-.000331
36	.105411	.006239	.204583	36	-.011781	-.035748	.012187	36	-.001305	-.002277	-.000332
37	.104367	.006357	.202377	37	-.01176	-.034941	.011421	37	-.001306	-.00228	-.000331
38	.103308	.006302	.200314	38	-.011758	-.034123	.010607	38	-.001306	-.002283	-.00033
39	.102246	.006097	.198396	39	-.011755	-.03328	.00977	39	-.001307	-.002286	-.000328
40	.101195	.005767	.196622	40	-.011737	-.032408	.008935	40	-.001307	-.00229	-.000325
41	.100163	.00534	.194987	41	-.011694	-.031513	.008125	41	-.001307	-.002293	-.000321
42	.099162	.00484	.193484	42	-.011621	-.030604	.007362	42	-.001307	-.002297	-.000318
43	.098197	.004291	.192103	43	-.011516	-.029694	.006663	43	-.001307	-.002301	-.000313
44	.097275	.003716	.190834	44	-.011379	-.028801	.006043	44	-.001307	-.002305	-.000308
45	.096398	.003131	.189665	45	-.011213	-.027937	.005511	45	-.001306	-.002309	-.000303
46	.095569	.002551	.188588	46	-.011023	-.027117	.005071	46	-.001305	-.002313	-.000297
47	.094788	.001985	.18759	47	-.010814	-.02635	.004723	47	-.001304	-.002316	-.000292
48	.094053	.001442	.186663	48	-.01059	-.025642	.004461	48	-.001303	-.00232	-.000285

Appendix 3: Structural impulse responses on transformed variable SSR (dSSR)

The following impulse responses are obtained after running a SVAR model with transformed variable SSR in first-differences. The information criteria (FPE, AIC, HQIC and SBIC) suggest 2 lags and restrictions on matrices A and B remain the same. The impulse responses are in this case calculated over 24 months.

Structural impulse responses on transformed variable SSR (dSSR)



Source: own work.

The responses show that SSR in response to a one-unit standard deviation shock increases on impact. The response is significant. In response to a positive SSR shock, GDP rate increases and HICP rate slightly decreases. The positive response of GDP rate is very insignificant and of small magnitude. The increase in GDP rate in not in line with the expectations of the economic theory. The drop in HICP rate is very small and insignificant. Based on the impulse responses, no conclusions regarding the effects of the unconventional monetary policy could be made.