QUANTITATIVE EASING OF MONETARY POLICY AND ITS MANIFESTATIONS IN THE FIXED INCOME SEGMENT

A Dissertation Presented for the

Doctor of Philosophy

Degree

The University of Economics, Prague

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July 2019

"Then I saw that wisdom excelleth folly,
as far as light excelleth darkness."

Ecclesiastes 2:13

Acknowledgments

Personal Gratitude

I would like to thank, above all, my supervisor doc. Ing. Karel Brůna, Ph.D. for his help and numerous consultations through the writing of this thesis. I would also like to thank my colleagues for help with data and providing of professional expertises, namely (in alphabetical order) to RNDr. Martin Koc, Ph.D., Mgr. Martin Michálek, Ph.D., Ing. Ladislav Mochán, MSc, CFA and Ing. Jan Vojtěch, Ph.D. My personal gratitude also goes to Mrs. Elizabeth Crombie, B.Sc. and Mr. Matthew Buckland, M.T.S. for technical help.

Funding Acknowledgments

I would further like to acknowledge the support from the grant project IGS F1/5/2014 "Finanční a hospodářský cyklus" and the project IGA F1/18/2017 "Makrofinanční stabilita a finanční cyklus v zemích s negativní čistou investiční pozicí".

Affidavit

I hereby affirm that this Doctoral thesis named "Quantitative Easing of Monetary Policy and its manifestations in the Fixed Income Segment" represents my own written work and that I have used no sources and aids other than those indicated. All passages quoted from publications or paraphrased from these sources are properly cited and attributed. This thesis has not been submitted in the same or in a substantially similar version to another examination board and was not published elsewhere, except for the journal papers (sections 2-5) that were published and are together constituting this thesis.

In Prague on 4th of July 2019

Jakub Jakl

Abstract

This dissertation thesis is devoted to the topic of Quantitative Easing (QE) of monetary policy and consists from four academic papers that deal with the quantitative easing and its manifestations, mainly in the fixed income segment, in the U.S. and the Eurozone economy.

The first paper focuses on the QE episode undertaken by the Federal Reserve System in the U.S. and its effects on assets prices, mainly on QE-targeted assets and its investment alternatives using event study and VAR analysis. In this paper a non-negligible impact of QE on purchased assets was found in both models through all waves of QE and time persistency patterns in VAR impulse-response functions (IRFs) part. Furthermore, some evidence for portfolio-balance and other related effects was found.

The second paper focuses on analysis of possible effects of the ECB's Public sector purchase programme (PSPP) on portfolios of the Eurozone investors. This paper incorporates the counterfactual analysis approach and uses sectoral data regression analysis of asset holdings of different investors in the Eurozone. The series of obtained regression estimates and counterfactual analysis graphic representation identified a nonnegligible effect of the PSPP on the rebalancing of government bond portfolios towards riskier corporate bonds and equities across investor types in major Eurozone countries.

The third paper focuses on the effects of the ECB's Corporate sector purchase programme (CSPP) on yields of corporate sector bonds and its impact on corporate sector debt markets. Detailed regression-controlled event study focused on relevant events and impulse-response analysis of constructed VAR models were used to obtain series of sector-specific and country-specific results. Results showed non-negligible impact of the CSPP on purchased bonds in both models. Size and persistency of stock and flow effects of ECB's actions were considerably different in various segments of the Eurozone corporate bond market. Furthermore, detailed representative-company based analysis in main Eurozone countries gives us microeconomic quantification of the real change of funding costs induced by the CSPP.

The fourth, and final, paper focuses on the identification and quantification of possible effects of the ECB's asset purchase programmes (APPs) on the SER spread, while the main focus is given to detailed intraday analysis of the implementation of the Public Sector Purchase Programme (PSPP). High frequency intraday approach analysis was also implemented in order to identify which leg of the SER spread was decisive in determining

the SER spread change in the first three years of the PSPP implementation. Whether it was the "sovereign bond-based leg" directly affected by the ECB's PSPP purchases or the "interbank lending / STIR-based leg". The central finding is that the bond-based leg was the SER spread determining leg since the beginning (or even since the anchoring of market anticipation) of the PSPP programme and this role even intensified later on in 2016/2017 when the squeeze on prime bond markets hit hard its yields.

The introductory chapter summarizes the theoretical background of QE monetary policy and put papers constituent to this thesis into a wider context. The final chapter summarizes the papers results and overall benefits of this dissertation thesis for monetary theory and practice.

Keywords: Monetary Policy, Quantitative Easing, Credit Easing, ECB, FED

JEL classification: E43, E44, E52, E58, E61, E65, G11, G12, G21

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Chapter 1

Introduction

1.1 A new paradigm of monetary policy

The Great Recession in late 2000s accompanied by deflationary pressures and natural limitation of conventional monetary policy stemming from zero-bound frontier led to major transformation of monetary policies of leading central banks around the world. Many central banks have adopted unconventional monetary policy in the form of so-called Quantitative easing (QE) and other accompanying measures in order to reach its lawful goals.[1] They followed the example of the Bank of Japan (BOJ) which has already begun its QE policy in 2001, long before the 2007-12 credit crunch. The BOJ maintained short-term interest rates close to zero-bound since 1999 and QE was a viable option of how to continue expansionary policy and how to face domestic deflation, see e.g. Fujuki, Okina and Shiratsuka (2001). Other central banks were not limited by zero-bound till the Great Recession rates cutting and in order to battle its aftermath they were forced to redesign monetary policies to make them work even in the state of liquidity trap. Liquidity trap is defined as a state of the economy and monetary policy, when the central bank is not able to influence the economy by conventional monetary policy and is forced to use unconventional measures that allow them to bypass short-term interest rates to decrease in negative numbers even more, as argued e.g. by Krugman (2000) or (2011). Eggertsson and Woodford (2003) claim that unconventional monetary policy may work through lowering long-term interest rates however only under the condition of credible commitment of the central bank that interest rates will stay accommodative even after partial economic recovery, which could mean to deviate from the so-called Taylor rule (or its country-specific alternatives) for some time.

[1] For the FED it is the dual mandate of maximum employment and low and stable inflation (price stability). In broader meaning, anchored in the Employment Act (1946), Federal Reserve Reform Act (1977) and Full Employment and Balanced Growth Act (1978), it also covers the following four general goals except its dual mandate: stability in the financial system, economic growth, interest rate stability and currency stability.

In November 2008 the U.S. Federal Reserve System (FED) was the first that followed the BOJ by introducing the first wave of its QE (QE1), in March 2009 followed by the Bank of England (BOE), the European Central Bank (ECB)[2] in May 2009 and the Swiss National Bank (SNB) and the Sveriges Riksbank (SRB) in following years. The universe of applicable monetary policy instruments was expanded for unsterilized, in some cases partially unsterilized, asset purchases and soon after, the balance sheets of the above listed central banks started to swell on account of securities held for monetary policy purposes. Central banks simply reduced their monetary policy interest rates to exceptionally low levels and needed them to be even lower to battle the financial crisis that emerged, which is easier said than done. The concept of negative interest rates used in monetary policy framework, that goes beyond the costs of cash-to-asset conversion, is still not perceived as a viable option and QE policy together with other additional measures were chosen as less controversial measures. Newly implemented measures across the main central banks can be according to Mishkin (2011) divided into three categories: (1.) providing liquidity to MFIs and newly also to other subjects (e.g. longer-term refinancing operations – LTROs of the ECB), (2.) management of economic subject's expectations regarding the future path of monetary policy rate (e.g. for the FED it is called Open mouth operations) and (3.) Quantitative easing characterized by purchases of selected assets. In a broader meaning, the exchange rate interventions, which are usually realized by small open economies, also fall into this category under certain circumstances.

At a time of QE introduction, a fruitful academic discussion about the implementation of the QE emerged and a broad discussion also started on a number of issues that accompany this unorthodox monetary policy. It was unclear, especially back then, what the long-run effects and disadvantages of the QE policy are and how QE will actually work – what transmission channels will play major roles and how different subjects in the economy will react on QE. This unorthodox monetary policy has been supported by new Keynesians, traditional Keynesians and Post Keynesians – see e.g. opinions of economists Krugman (2010), DeLong (2009) and Farmer (2009). The theoretical opposition of this monetary policy is formed by monetarists, e.g. Meltzer (2011), and new classical macroeconomists e.g. Taylor (2011). While new Keynesians advocated the necessity of the FED's new QE policy and even proposed the direct intervention on equity markets (see Farmer, 2009), while e.g. Taylor (2011) saw in 2011 discretionary government interventions and the FED's QE programme guilty of extraordinary high and prolonged unemployment. He argues that these actions had a small temporary effect that dissipated quickly, leaving a legacy of higher debt, and bloated the FED's balance sheet and elevated uncertainty. He argues that the

[2]In the whole thesis, the ECB often stands for the Eurosystem and not necessarily only for the ECB per se. The Eurosystem comprises the ECB and the National Central Banks (NCBs) of those countries that have adopted the euro.

best way to reduce unemployment is to restore sound fiscal and monetary policies.[3] New classical economists in general reject QE monetary policy arguing that unemployment is of the structural mismatch type that loosened monetary policy cannot fix and can only bring a risk of elevated inflation. Keynesians reject the unemployment mismatch argument arguing that more or less all geographic regions and economy sectors of the labor market (as for the U.S. in the Great Recession) have experienced higher unemployment with no evidence of significant sector-specific excess demand and rising wages (DeLong, 2009).

Assessments of the overall costs and benefits of QE monetary policy were in the first place presented by central bank researchers, mainly by those, who were preparing to walk upon that unconventional path of asset purchases. The FED's chairman Bernanke was the first from western central bank chairmen that implemented QE after the period of theoretical advocation of this policy, when he argued since 2002 (Bernanke, 2002) to 2008 (Bernanke, 2008) about future possibility of QE implementation with following assessments of undertaken monetary policy measures, see e.g. Bernanke (2012) and (2013). The fundamental critique of this new FED unorthodox policy by Meltzer (2013) or Taylor (2012) and many others emerged soon after and focused mainly on the short-term orientation, reliance on the Phillips curve and disregard for money, credit and asset prices. Also, other aspects are relevant regarding the QE implementation and are mentioned e.g. in Issing (2013), one of them is the potential undermining of fiscal discipline by boosting the demand for sovereign debt obligations, and the other is the redistributive or rather discriminatory effects of purchasing only targeted assets. These are general issues that go along with QE monetary policy since the beginning and are the main source of criticism of this policy.

The story of QE has not reached its end and extensive asset holdings of central banks containing mainly assets from QE programmes will be an issue for a long time until they completely dissolve. QE tapering and reinvestments of maturing bonds held by the FED and the ECB is still underway and this rather cooling phase is good for assessment of undertaken programmes and to form recommendations and suggestions regarding possible future reestablishing of QE purchases facing possible economic downturn, which is not so unlikely given the weak recent economic data and still very low monetary policy rates.

[3] In that time the unemployment was circa 9%.

1.2 Doctoral thesis goals

The main goal of this doctoral thesis is to contribute in an original way to the vast existing research done on the theme of quantitative easing of monetary policy and to shed more light on this new unconventional praxis of central banks. It is necessary to better understand the behavior of market participants facing changing market conditions under QE policy and to uncover possible relations between different assets in the economy, those who were purchased under QE programmes and those who were not. The role of different theoretic transmission channels in reality is also not fully known and quantified and needs to be analyzed from different perspectives. The shift of monetary policy paradigm towards QE also naturally heavily affected the whole financial framework of concerned economies, starting with directly affected asset markets to other markets and its financial indicators.

In order to reach the above stated goals of this doctoral thesis, several specific questions were raised and are answered in following sections, where the following sections 2 to 5 represent each academic paper published in economic or financial journal forming together this doctoral thesis and answering these questions:

Question 1

In what way exerted and what was the intensity of possible effects of asset purchases realized under the QE programmes by the FED and the ECB on targeted assets? What was the time distribution of these effects and what asset segments exhibit the biggest change in yields?

The FED realized three waves of QE and the Maturity Extension Program (MEP) in years 2008-2014 and its holding of purchased assets reached its highs of roughly $4.5 trillion in 2014, of which more than half accounts for government bonds and the other half consists almost entirely from Government-Sponsored Enterprise-related (GSE-related) securities. The ECB realized several programmes where the main part was given to the Public Sector Purchase Programme (PSPP), which started in 2015 and was targeted on the Eurozone sovereign bonds. Later in 2016 the Corporate Sector Purchase Programme (CSPP) followed, targeted this time on corporate sector bonds. Together with smaller asset purchase programmes the overall ECB holdings of assets purchased via these programmes reached almost €3 trillion in 2019. Anticipation, introduction and realization of these monetary policy programmes of the FED and the ECB must have had significant impact on price creation on concerned markets and quantification of this impact and its persistence over time is essential in order to better understand QE and its transmission.

Question 2

If the QE monetary policy worked and caused targeted assets prices to rise and yields to be lowered, was this effect also transferred onto other similar assets or to other asset segments?

Asset purchase programmes of the FED and the ECB led to equilibrium impairment on prime sovereign bond markets, while the FED and the ECB bought vast amounts of sovereign debt in the U.S. and the Eurozone and crowded out, at least partially, other market participants. This was officially claimed to be a desired effect that was supposed to lead via various transmission channels (described in section 1.2) to change in prices and yields in other, less prime markets and consequently ease financial conditions in the economy, mainly for the small and medium-sized enterprises (SMEs) and households. Unofficially, exactly in a way that it was criticized for by QE opponents, asset purchases targeted at sovereign bonds could be perceived as a government debt-monetizing action, when purchases of the central bank on the secondary market caused the significant decrease in funding costs of sovereign bond issuers. This applies especially for the ECB's PSPP and the aftermath of the European debt crisis, while the FED was criticized as well for the same reason. The key element of transmission of the QE policy is the magnitude and spread of such a policy to other markets that are not directly the subject of asset purchases – whether the effect of price increase and yield decrease of targeted assets was transferred into other markets as well and if so, to what extent?

Question 3

What were the transmission channels that played the main role during the QE announcements and implementations of the ECB's and the FED's asset purchases and how did they manifest?

QE policy could theoretically work through many transmission channels, while some are considered crucial and some are insignificant and hard to separate from other effects. Both groups of transmission channels are described in detail in section 1.3 of this thesis. The primary role is however being assigned to the portfolio rebalancing channel and the signalling channel that work each in their own different way and both were to some extent present during the asset purchase programmes (APPs) life cycle of the FED and the ECB. Both main transmission channels have different prerequisite conditions to work in reality and its identification and separation from each other on data covering the FED's and the ECB's APPs is necessary to better understand its mechanism and impact of different states / conditions of the economy on its functionality.

Question 4

Did QE monetary policy of the ECB have some real impact on the microlevel on preferences of corporate funding? Were the costs of funding of companies and households reduced thanks to the ECB's asset purchases or not?

The ECB established the CSPP as a more direct way to support the corporate sector in the Eurozone by directly purchasing corporate debt obligations and consequently lowering the funding costs in this segment. There are several funding alternatives for private companies, by acquiring a loan from a commercial bank or by issuing their own debt obligations. The ECB by its APPs influenced both funding alternatives – while the CSPP directly caused price rise and yield reduction in segment of corporate bonds, the PSPP and APPs as a whole led to the reduction of corporate loans interest rates set by commercial banks. The investigation of funding costs reduction, possibly caused by the CSPP, of the whole segment of corporate debt obligations and individual companies in the Eurozone could provide valuable insight into QE mechanics on micro level. In what Eurozone countries and in what sectors were corporate bonds affected the most and how was the yield decrease in the eligible bond universe transferred to the ineligible universe? Uncovering the above mentioned relationships would certainly provide valuable information on how to form and aim possible future APPs of monetary policy.

Question 5

Did QE monetary policy of the ECB have impact on financial distress indicators, mainly on the SER spread? And how markets for prime sovereign bonds changed due to QE implementation in the Eurozone?

The SER spread is an Eurozone alternative to the TED spread, the indicator of banking distress as well as the indicator of credit risk and global systemic risk. Implementation of the QE monetary policy by the ECB certainly influenced both its constituent legs, bond-based leg and interbank lending-based leg, and its ability to act as a financial indicator may have been seriously impaired. The analysis on detailed intraday data could provide the picture about changes in time of the SER spread caused by the ECB's APPs, mainly by the PSPP, which is the largest APP programme. The change in relationship between the SER spread constituent to legs could also uncover QE-induced changing nature of both underlying markets – the German federal bond market and the Eurozone uncollateralized interbank market (Euribor). Both markets are of primary interest to the ECB's monetary policy and better understanding of QE-induced changes on these markets is necessary in order to develop more robust QE monetary policy apparatus and to extend its operational radius in the future.

1.3 QE transmission mechanism and its specifics

Quantitative easing has its theoretic origins in the Quantity theory of money of monetary economics, respectively in the new Quantity theory of money developed by Milton Friedman, whose cornerstone is the statement that inflation is always and everywhere exclusively a monetary phenomenon. According to Friedman, the supply of money is exogenously determined by the central bank, which via its changes (unexpected changes) in money supply, shock the economy.[4] The simplified implication of Friedman's theory states that if the central bank would begin to "print" money and distribute it to economic subjects (that would spend it), the final effect will be increase in price levels. Real economic stimulation may however occur during the transmission from creation of the new money to rising of price levels. The problem in applying the monetary policies based on this principle is that the real effect on the economy may not occur at all, and the newly created money will only spill over into inflation or inflation expectations. This parallel between the quantitative easing of large central banks such as the FED or the ECB and the quantitative theory of money is only spurious. Endogenous money theories represent the opposition to Friedman's Quantity theory of money – they claim that supply of money is determined endogenously and autonomously via interactions of economic agents and real variables of the economy rather than by a central bank. Money comes into existence through the demands of the real economy and the banking system liquidity (in form of reserves at the central bank) corresponds to a current need for accommodation of loan demand in the current interest rates environment. The money supply then reacts to all demand changes and accommodates the resulting money demand.

The current QE monetary policy of major central banks caused an increase in liquidity on the interbank market – it is not about "printing" new money and distributing it to the general public after all, but rather about increasing total liquidity of the banking system. In the first phase of QE, the liquidity of the banking system will increase and a part of this liquidity is subsequently either traded on the interbank market or not. The part that is not being traded may be either sterilized by the central bank or remain as a non-sterilized liquidity. This liquidity is practically the equivalent of money, but only on the interbank market – commercial banks (respectively Monetary Financial Institutions – MFIs) cannot easily transfer it from this market to somewhere else. The total amount of liquidity on the interbank market can only be influenced (withdrawn) by the central bank acting as a counterpart to MFIs having this excess liquidity. The quantitative theory of money also assumes that the creation of new money under standard conditions will temporarily lead to higher demand of individuals for goods and services and to stimulate aggregate demand. In

[4] Friedman clearly significantly neglected the way, how the money is created outside the central bank, and the fact that central banks do not distribute money directly to final consumers (households, companies and other subjects), but usually rather exclusively to the banking sector.

other words, the newly created money/funds will not be saved or used to repay consumer's debts (households etc.), instead it will be accumulated on company accounts or used to reduce their debt. This has not been a reality to a large extent so far. The central banks have purchased securities mostly in the form of government bonds and Asset Backed Securities (ABS) from MFIs or other institutions and these subjects currently usually hold this liquidity received from the central bank on their reserve accounts.

Frequently mentioned possible effect of the QE was that it could increase willingness of commercial banks to provide loans to firms and households, however, the extent to which commercial banks and other financial institutions are motivated to provide additional loans through the newly delivered liquidity is not large. This is mainly due to the fact that demand for new loans is determined on the demand side by the expectations of households and corporations and their real creditworthiness, and on the supply side by stable sources of bank credit funding and not by excess liquidity on the interbank market. Also, the regulatory framework and its requirements for covering the credit risk of banks increased significantly, while the economic reality objectively exerted increased credit risk. For instance, the U.S. economy is currently in a state of high debt, forcing it to reduce its debt, rather than in a favorable position to generate new loans. The FED's quantitative easing is therefore rather a continuation of interest rate policy by other means to reduce long-term interest rates rather than genuine quantitative easing in terms of classic economic theories.

Nowadays, new directions of monetary policy are characterized by affecting assets prices, e. g. in the case of the Bank of Japan (BOJ) it is setting the desired yield level for benchmark government 10-year bond. The BOJ naturally intervene on the bond markets to achieve this yield target. The consequence is the spreading of asset price changes on other assets and ultimately via a complex system of relations affecting the unemployment, inflation, GDP and other macroeconomic variables. Monetary policy of other central banks undertaking the QE is in principle very similar – in the case of APPs targeting the sovereign and corporate bonds and other assets like ABS to change their prices and yields. This process of assets purchases is due to its significant size accompanied by wealth effects and by crowding out of traditional market participants by the central bank. The range of assets purchased during APPs of the FED, the ECB and other central banks is quite wide while each central bank undertakes the QE monetary policy in its own way, purchasing different assets, handling asset holdings differently and above all pursuing differently defined goals via specifically designed purchase programmes. The FED started its own extensive asset purchases in 2008 as a measure to ease deteriorated conditions on the mortgage-backed securities (MBS) markets, by buying the MBS and agency bonds of Government-Sponsored Enterprises (GSEs), and to foster growth and maximum employment through lowering yields in the economy by purchasing the U.S. Treasuries. Lowered yields of targeted assets would consequently transfer to yield decline in other markets and indirectly lower the costs of long term investments of the U.S. firms and individuals. The ECB started its QE purchases in rather small fashion in 2009

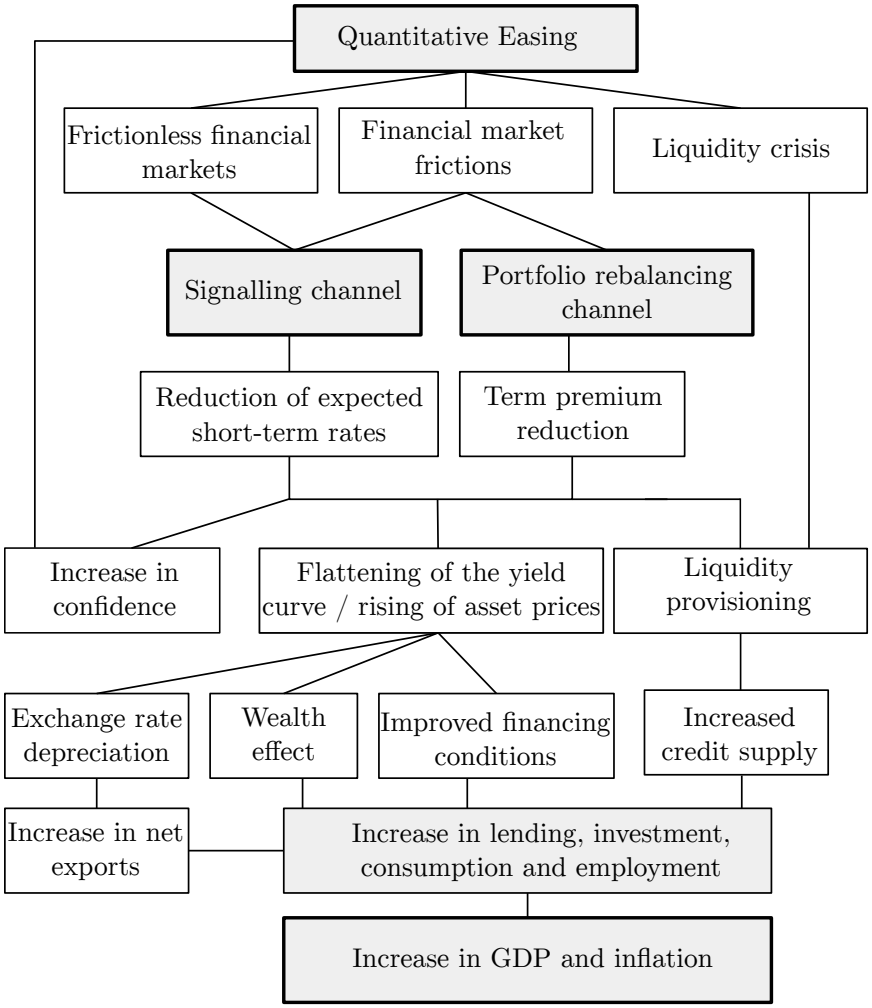
by the introduction of several programmes (Securities Markets Programme[5] and Covered bond purchase programme) and its main Public sector purchase programme (PSPP) was introduced in 2015. The Corporate Sector Purchase Programme (CSPP) was introduced as so far the last APP programme of the ECB targeting corporate bonds in the Eurozone in 2016.

Composition of purchased assets, its average maturity, overall liquidity, riskiness and other characteristics of purchased assets together with central bank communication framework and nature of purchases implementation predestine the transmission, respectively these are QE monetary policy parameters that can be directly changed by the central bank. Different communication about the intended monetary policy or the different emphasis on asset purchases as for maturity for instance set in motion processes that can be very different for each set of settings and each set of these settings can be characterized by a slightly different transmission mechanism. In Figure 1.1, there is a simplified transmission mechanism diagram with the two most pronounced QE transmission channels and associated processes that can be used for explaining the QE transmission mechanism. The first is the signalling channel and the second is the portfolio rebalancing channel. Both channels were numerously described in many academic papers regarding QE, see e.g. Gern et al. (2015), and both are targeted mainly on lowering mid-term and long-term interest rates in the economy.

The signalling channel is inseparably connected with central bank communication regarding monetary policy as a whole and especially its QE intentions. The signalling channel in the world of New Keynesian economics and Ricardian equivalence works only to extent of how much the central bank is able to influence the expectations of an average economic agent regarding the expected future path of its rates or expected effects of asset purchases. This channel is examined in detail for instance in Clouse et al. (2003). The signalling channel works only under the circumstances that the central bank is credible enough to change expectations of economic subjects in the economy about the future path of short-term interest rates. By announcing the QE policy, which is by nature considerable as for purchased amounts, and signalling that the central bank intends to keep short-term interest rates low for an extended period of time, even beyond the horizon of picking up economic recovery, and is willing to undertake significant effort to reach and maintain this state. The primary interest of the central bank lies in the growth of consumption in the period sufficient to overcome the deflationary and debt effects of crises aftermaths including negative effects on the labor market and real investment markets. This necessarily means to maintain interest rates low for longer despite the economic recovery and avoid high accelerating inflation at the same time. If economic subjects (market participants) believe in the credibility of QE announcements, they could immediately change their behavior and expectations about the future accordingly.

[5]The SMP was designed to purchase government debt in the secondary market and is not generally perceived as a QE because the non-preannounced size of purchases and the sterilization of the purchases, which did not affect monetary base.

Figure 1.1: Quantitative easing transmission mechanism diagram



Source: Intereconomics

And markets are usually being repriced very quickly after the announcements, depending on the level of market imperfections. The signalling channel has however the higher impact on medium-term rather than long-term rates while it is unlikely that the central bank would keep its rates low in the case of full economic recovery and therefore risk economic overheating as mentioned by Krishnamurthy and Vissing-Jorgensen (2011).

Mainly mentioned transmission channel, with connection to asset prices, is the portfolio rebalancing channel, formally described by Tobin (1969) and studied by Brunner and Meltzer (1973) and Friedman and Schwartz (1982). Contemporary studies of the portfolio rebalancing channel in connection to quantitative easing of monetary policy are to be found for instance in D'Amico and King (2010), Hamilton and Wu (2011) and Gagnon et al. (2011) and is also frequently advocated by central bankers, see e.g. Draghi (2015). The portfolio rebalancing channel works through relative changes of nominal asset prices with respect to nominal prices

of other assets that are being considered as an investment alternative. Investors initiate the portfolio-rebalancing process when they see opportunity to better optimize their own portfolio in respect to bear maximal yield on an unit of risk, when the current portfolio yields are affected by external factors. The portfolio rebalancing channel works through lowering term and risk premium of purchased assets and assets that are close investment alternatives to them. Under the condition of imperfect substitutability of short-term and long-term sovereign bonds, its yield curve can be affected by APP targeted for instance on the long end of the yield curve. Several term structure theories, one of them is Preferred Habitat Theory developed by Vayanos and Vila (2009), suggest that different types of investors prefer to hold bonds of the specific maturity rather than bonds with maturity significantly different from the preferred maturity range. The theory also suggests that when all characteristics except the maturity are the same, investors prefer to hold short-term bonds instead of long-term bonds and that the yields of longer term bonds should be therefore higher than shorter term bonds for risk premium. The central bank by purchasing long-term sovereign bonds lowers their yields and via arbitrage processes also the yields of similar assets that are being perceived as investment alternatives. Some investors on bond markets may be opened to an idea of reinvestment of their own portfolios towards more risky assets with higher yields, such as corporate bonds or asset-backed securities (ABS), putting pressure on their yields as well. A lowering of the yields of private debt obligations ultimately means a reduction in funding costs for private companies or even lowering the costs of loans for individuals while commercial banks may be more motivated to chase loan-providing-related profits rather than face diminishing bond yields.

The more direct alternative is when the central bank directly purchases private sector assets (e.g. ABS, MBS, equities or equity ETFs, corporate bonds etc.) and directly reduce market risk premiums. This practice of buying directly on the primary market is however not an option for sovereign bonds, while this would directly mean monetization of government debt and the central bank would definitely face overwhelming critics and after all is usually forbidden to do so by law.[6] The central bank is then, in the case of the sovereign bonds, limited either to the secondary markets or usually tries to bypass this limit by involving primary dealers as an intermediary between the government authority (usually the finance ministry) issuing the government bonds and the central bank immediately buying the same bonds. By purchasing the above mentioned assets, that are obviously imperfect substitutes for sovereign bonds and are connected with a higher risk of issuer default, the central bank is directly affecting given markets without relying on spillover effects from sovereign bond markets. On the other side it means to bear all risks of given assets instead of private

[6]In 2017 the European Central Bank faced a legal challenge over its QE programme when Germany's highest court said that the QE monetary policy may violate EU law. Germany's Constitutional court and the European Court of Justice however did not find the Bundesbank QE policy unconstitutional and against the law, yet this decision was not straightforward and easily anticipated without uncertainty. See e.g. Bodoni (2018).

investors and to face increasing criticism of opponents of this practice. For instance, the purchases of the ECB under the CSPP were designed to lower yields primarily on CSPP-eligible corporate non-financial bonds in the Eurozone. Decrease in yields of CSPP-eligible bonds should cause investors to demand lower credit premia in the segment of originally less attractive alternative investment assets, first in other corporate bonds (in CSPP-ineligible universe) and later in other similar assets. Friedman and Schwartz (1963) led this idea of portfolio rebalancing way down the road even to the markets for goods and services and ultimately to price level in the economy.[7] The ECB is however in the case of the CSPP less demanding as for explicit goals and follows mainly the goal of lowering of funding costs for Eurozone companies and to foster economic growth.

There could theoretically exert many other possible transmission channels of QE, some that belong to potentially the strongest ones are described in Krishnamurthy and Vissing–Jorgensen (2011). One of them is the liquidity channel that works through an increase of liquidity reserves of the commercial banks that are held on their accounts at the central bank for interbank clearing purposes and regulatory purposes. When the central bank purchases assets from MFIs and credits their accounts, MFIs are consequently more willing to hold less liquid assets than cash and highly liquid prime sovereign bonds and could move to ABS for instance. As a liquidity channel is also perceived the central bank presence on markets with low liquidity, like markets for ABS or assets with long maturity. The presence of the central bank supply liquidity on the bid side (during the active phase of QE) and represent a possible counterparty for other investors and allows them to trade without additional costs caused by low market liquidity. Liquidity premia is reduced and investors more willingly hold these usually less liquid assets. The effects of QE in the U.S. on liquidity and market functioning are analyzed and discussed e.g. in Kandrac (2018) or Christensen and Gillan (2018).

The other channel works through a specific demand of some investors for near zero-default-risk bonds – spread between bonds with the lowest riskiness (Aaa) and bonds with higher riskiness (Baa) could get wider as a consequence of supply shock induced by limited relative supply of bonds with a better rating. The specific group of investors is basically willing to pay extra for holding the bonds with minimal default risk. This channel is very similar to the portfolio rebalancing channel while it depends not on asset duration (term premium) but rather on its riskiness (risk premium).

Another channel important especially for MBS purchases performed by the FED is connected with the possibility of prepayments of underlying mortgages of MBS. Commercial banks face significantly reduced overall risk of mortgages prepayments while they sell part

[7] *"This, in turn, tends to make existing nonfinancial assets expensive relative to newly constructed nonfinancial assets. At the same time, the general rise in the price level of nonfinancial assets tends to raise wealth relative to income, and to make the direct acquisition of current services cheaper relative to the purchase of sources of services. The monetary stimulus is, in this way, spread from the financial markets to the markets for goods and services".*

of their holdings of MBS to the central bank. Fuster and Willen (2010) argue that the FED purchases of MBS in 2008 caused mortgage providers to significantly lower mortgage loan rates to households.

Another important transmission channel is the inflation expectations channel, which is fairly similar to the signalling channel while this time depending entirely on the ability of the central bank to convince market participants that its QE monetary policy will be successful in bringing inflation to levels consistent with its long-term goals. Changes of interest rates of inflation swaps and Treasury Inflation-Protected Securities (TIPS) in the U.S. as a reaction to important monetary policy decisions show the positive impact of asset purchases announcements on expected inflation. Elevated demand for TIPS during the time of QE announcements and implementation reflects the rise of inflation expectations of investors given the introduced monetary policy measures. Krishnamurthy and Vissing–Jorgensen (2011) argue that inflation expectations rose thanks to QE in the U.S. by 35 to 96 basis points depending on the maturity.

There are many other possible transmission channels of the QE described theoretically in QE-related academic research papers, nonetheless their importance is in general lower than that of the channels mentioned above. Other channels like the bank lending channel, examined for impacts of QE in the United Kingdom by Butt et al. (2015), and other are not of primary interest to this thesis and play only the complementary role. This thesis focuses mainly on the signalling channel and the portfolio rebalancing channel and the effects of stock and the flow of central bank purchases on purchased assets and relevant markets. Other possible effects of the QE monetary policy as are exchange rate effects, wealth effects and many other effects are nonetheless mentioned in this thesis with relevant references but their detailed analysis rather remains beyond the scope of this thesis.

1.4 Existing academic research

Quantitative easing became the crucial monetary policy tool for the major central banks in the last decade (almost two decades as for the Japan QE experience). Its important role and its different implementation across the world are being studied by the extensive number of central bank and academic researchers and the extensive number of analyses, working papers and discussions on this theme corresponds to this reality. In this section, only a fraction of them, the most important or interesting ones from these studies, being mentioned, ordered by countries, that more or less corresponds to chronological order.

Japan

Studies that focus on the very first modern QE monetary policy implementation in Japan are represented primarily by Bernanke, Reinhart and Sack (2004), Oda and Ueda (2005) and Kimura and Small (2004). Oda and Ueda (2005) found that BOJ's monetary policy causing decline in medium and long-term interest rates since 1999 has functioned mainly through the zero interest rate commitment rather than through supplying ample liquidity or purchases of long-term government bonds via the portfolio rebalancing effect. Increase of bank excess reserves of ¥10 bln. decreased the yield of 3-year government bonds by 19 bp and 5-year government bonds by 17 bp. Kimura and Small (2004) on the contrary found significant effect of the portfolio rebalancing caused by BOJ's long-term government bond purchases. They argue that the portfolio-rebalancing effects were beneficial in reducing the risk premiums on assets with counter-cyclical returns (government and high-grade corporate bonds) but it also brought adverse effects of increasing risk premiums on assets with pro-cyclical returns (equities and low-grade corporate bonds). Bernanke, Reinhart and Sack (2004) found by the event study method no strong evidence that BOJ has been successful in using nonstandard policies but found some evidence that the relative supply of government bonds matters for yields in the United States. This is the necessary condition for achieving the desired effects of QE and Bernanke et al. promoted this idea long before the FED's 2008 first QE wave implementation.

The United States of America QE1 and QE2

The majority of studies from 2009-2012 focus on QE monetary policy undertaken by the FED in the U.S. Some of the most important studies concerning the initial implementation of QE in the U.S. are D'Amico and King (2010), Gagnon et al. (2011) or Wright (2011). D'Amico and King (2010) analyzed price elasticities and substitutability of the U.S. Treasuries, preferred-habitat theories of the term structure and the ability of large-scale asset purchases (LSAPs) to reduce overall yields. They claim that overall purchases undertaken by the FED in its first

QE wave[8] caused average yields decrease of targeted assets of around 50 bp (the stock effect) and each purchase operation caused a decrease around 3.5 bp (the flow effect). Gagnon et al. (2011) also used event study methodology and conclude that the FED's Large-Scale Asset Purchase programmes did lower long-term private borrowing rates through lowering important interest rates in the economy with widespread effects especially noticeable in the mortgage market, Treasury securities, corporate sector bonds and interest rate swaps. Notable decline was quantified in 10-year Treasury yield (91 bp), 10-year agency debt yield (156 bp) and current-coupon agency MBS (113 bp). Wright (2012) employed the Structural Vector Autoregression model (SVAR) and high-frequency event study to identify the effects of 2008-2010 monetary policy shocks on selected long-term interest rates and found that LSAP-related events (The Federal Open Market Committee [FOMC] meetings, chairman speeches etc.) induced stronger economic outlook thanks to a decrease in term premia of corporate and mortgage rates and Treasury yields with the effects fading fairly fast over the following months. He also argues that corporate and mortgage rates fell more than Treasury yields and explicitly react to Chung et al. (2011) that did not identify differences between decrease in Treasury yields and corporate rates induced by QE2 and their simulation assumed the same 25 bp decrease of term premia for long-term corporate and mortgage rates as well as Treasury yields with no direct effect on spreads between them.

The United Kingdom

Studies that analyze the impact of QE in the United Kingdom include Joyce et al. (2011), Bridges and Thomas (2012), Harrison (2012) or Daines, Joyce and Tong (2012). Joyce et al. (2011) found significant impact of the Bank of England's quantitative easing monetary policy on UK asset prices. Their results based on event study and econometric methods (VAR-IRFs and GARCH-M models) showed that the BOE's asset purchases financed by the issuance of central bank reserves (circa £200 billion in February 2010) may have depressed medium- to long-term government bond yields about 100 bp. Their analysis showed that the largest part of the APP impact on government bonds yields came through the portfolio balance channel and that most other asset prices showed a recovery through 2009, suggesting that QE in the UK had wider effects. Bridges and Thomas (2012) used simple money demand and supply framework to estimate the impact of the BOE's QE on asset prices and nominal spending. Their central case estimate is that QE boosted the broad money supply by £122 billion (8%) and the application of their QE impact estimates on the money supply to a set of monetarist econometric models showed that an 8% increase in money holdings may have lowered the yields on average around 150 bp in 2010 and increased asset values by approximately 20%. They claim that these effects in turn would have had a peak impact on output (GDP) of 2% by the start of 2011 and impact on inflation of 1% approximately a year later. Harrison (2012)

[8] $300 billion of U.S. Treasury coupon securities announced and implemented during 2009.

studied optimal monetary policy in a stylized New-Keynesian model extended for assumed imperfect substitutability between short-term and long-term bonds in the framework of the households preferred portfolio allocation. The households' relative holdings mixture of short-term and long-term bonds can be in this model influenced by the policymakers purchasing and selling these assets to households. The welfare function that the policymakers should work with includes the output gap and inflation and also the deviations of households' relative holdings of short-term and long-term bonds from the preferred portfolio mix. Harrison argues that central bank asset purchases could reduce long-term interest rates over and above the effect of expected future short rates and aggregate demand can be consequently stimulated and higher inflation achieved through a standard New Keynesian Phillips Curve. Daines, Joyce and Tong (2012) examined the impact of the BOE's QE programme for the period from March 2009 to January 2010 on the UK gilts using high-frequency ISIN-disaggregated data. They argue that market expectations of £200 billion of the BOE's purchases reduced yields on average over the period by around 35 bp and the temporary effect during the purchase period was about 50 bp. QE appears to have had significant persistent effects on the shape of the Gilt term structure and their results provide some evidence of local supply and duration risk effects consistent with imperfect asset substitutability theories.

The United States of America MEP and QE3

More recent studies regarding QE implementation in the U.S. incorporate not even the first and the second wave of QE realized by the FED (QE1 and QE2) but also the consequent so-called Maturity Extension Program (MEP) which was under way since September 2011 to December 2012 and the last, third QE wave (QE3). The cornerstone analysis concerning the Federal Reserve's MEP is Swanson (2011) that contains analysis of the so-called Operation Twist from 1961 and its goal was to re-examine its impact and to estimate possible effects of using this framework by the FED in 2011.[9] The original Twist from 1961 was considered a failure since Modigliani and Sutch (1966) and (1967) analysis, but Swanson (2011) suggests that Operation Twist was more effective than originally thought and may be used by the FED within monetary policy framework. Swanson's event study analysis showed that Operation Twist and QE2 are similar in magnitude and that the cumulative effect of six important announcements regarding Operation Twist in 1961 had significant effect on longer-term Treasury yields about 15 bp. Another study concerning the MEP is Li and Min (2013) where the authors constructed the arbitrage-free term structure model and evaluated term

[9]Back in 1961 the U.S. was facing a current account deficit and gold outflows balancing its external account deficit. Interest rates in the U.S. were already low and the FED was unable to cut rates further under the Bretton Woods exchange rate system due to the fact that dollar was pegged to gold. Rate cut would destabilize the dollar value under the Bretton Woods due to the gold outflow. The Federal Reserve and the U.S. administration cooperated and initiated Operation Twist – bought long-term securities and the U.S. Treasury issued more short-term bonds to push long term interest rates lower.

premium effects of the Federal Reserve's Large Scale Asset Purchase Programmes (LSAPs). The Federal Reserve's Maturity Extension Program was designed to change the maturity composition of the Federal Reserve's balance sheet holdings worth $400 billion but not the size of total asset holdings held for monetary policy purposes. Li and Min found that the MEP together with preceding QE1 and QE2 may have altogether helped to lower long-term Treasury yields about 100 bp in the 10-year maturity segment. Their estimated results also suggest that a 1% decline in Treasury 10-year equivalent to GDP ratio or the MBS par-to-GDP ratio would reduce the 10-year Treasury yield by about 10 bp, while a 1-year shortening of the average effective duration of private MBS holdings would lower the 10-year Treasury yield by about 7 bp.

Other papers like Kandrac and Schlusche (2017) tried to verify or reject monetary theories in which reserve creation plays a crucial role in the transmission of the FED's QE. They empirically tested causal effects of bank-level reserves accumulation on bank lending and risk taking activity and found that reserve creation leads to higher total loan growth and increased risk taking. Christensen and Krogstrup (2016a) also reached very similar conclusions in their analysis incorporating a portfolio model of asset price effects arising from the FED's large-scale asset purchases. Their results imply that central bank reserve expansions can affect long-term bond prices even in the absence of long-term bond purchases. They argue that when the central bank asset purchases are executed with nonbanks, they can give rise to two separate portfolio effects on bond prices – supply-induced portfolio balance effect (via reduction in the available bonds supply) and reserve-induced portfolio balance effect (via expansion of bank reserves). In contrast, when the central bank asset purchases are executed with banks, only supply-induced portfolio balance effects occur whereas there is no expansion of banks' balance sheets.

The Swiss Confederation

The Swiss National Bank (SNB) and its QE implementation is a subject of various research papers – Christensen and Krogstrup (2016b) for example examined issuance of central bank reserves and its combined effect with large-scale asset purchases on long-term interest rates. They argue that when the Swiss National Bank expanded reserves by purchasing short-term debt securities rather than long-term debt securities, long-term debt securities yields declined due to decrease of term premiums via reserve-induced portfolio balance effects following the SNB QE announcements. Their results suggest that this effect on long-term securities is independent of the assets purchases and rather depends on anticipated creation of reserves, while the SNB bought only short-lived securities and the supply of long-term government bonds remained unchanged. They also ruled out the possible role of the signaling channel that otherwise may be considered as a cause working through lowering the expected path of future short-term interest rates.

The Eurozone

QE implementation of the ECB is together with the FED's implementation the source of abundant academic research focusing on its many different aspects and manifestations. Altavila, Carboni and Motto (2015) evaluated the effects of the ECB's asset purchase programme (namely the PSPP) on asset prices and its main transmission channels. By extending a term structure model for bond supply effects and consequent predictions for cross-asset price movements, they identified the sizeable impact of the APP on asset prices. They argue that impact, verified by event study, was sizeable despite the fact that the PSPP was announced in a time of low financial distress and worked through the duration and the credit channels and spill-overs to non-targeted assets universe were more pronounced precisely because of the environment of low financial distress. Koijen et al. (2018) used security-level data on portfolio holdings by investor type and across countries in the euro area to quantify changes in risk concentration induced by the ECB's PSPP. Their estimates of the evolution of the distribution of duration, sovereign, and corporate credit risk exposures across investor sectors and geographies showed that home bias (regarding asset portfolio holdings) in the euro area mostly varies geographically instead of by institutional type and that investors did not rebalance their portfolios to large extent towards other assets such as corporate bonds or equities in the euro area during the first quarters of the PSPP (from 2015Q2 to 2016Q4). Albertazzi, Becker and Boucinha (2018) on the contrary found an active portfolio rebalancing channel using a similar approach based on the valuation of the financial portfolio held by different sectors in the Eurozone. In more vulnerable Eurozone countries (with relatively high risk premia, e.g. in Italy or Ireland) the APP was mostly reflected in a rebalancing towards riskier securities, in less vulnerable countries (with relatively less-binding constraints on loan demand and supply, e.g. in Germany or France) the rebalancing was observed mostly in terms of bank loans. Arrata and Nguyen (2017) from Banque de France examined three possible types of supply shocks possibly caused by the PSPP on security-level data. One related to the cumulative past purchases ("stock"), one related to the daily purchases ("flow") and one related to the variation in the expected total size of the programme ("expected stock"). Their results showed that purchases corresponding in size to 10% of the outstanding total bond available amount correlates with a decrease in yield of about 13 bp to 26 bp on average in the first year of implementation of the PSPP, with bigger effects in the most illiquid segments (up to 53 bp decrease for longer maturities). They also conclude that no significant supplemental effect from flows was found and that the reduction of the total size of the PSPP expected by market participants seem to have played a role but cannot explain the magnitude of the sell-off by itself.

A number of analyses concerning the ECB's PSPP and its transmission channels, mainly the portfolio rebalancing channel, include Andrade et al. (2016), Gambetti and Musso (2017) or Bua and Dunne (2017) and each of them came with specific conclusions. Andrade

et al. (2016) argue that the announcement of the PSPP has significantly and persistently reduced sovereign yields on long-term bonds and raised the share prices of banks that held more sovereign bonds in their portfolios, which is consistent with the portfolio rebalancing channel hypothesis acting through the reduction of duration risk and the easing of leverage constraints. Gambetti and Musso (2017) acknowledged appearance of several transmission channels – the portfolio rebalancing channel, the exchange rate channel, the inflation re-anchoring channel and the credit channel. Their time-varying parameter VAR model with stochastic volatility suggest that the PSPP had a significant upward effect on real GDP and Harmonised Index of Consumer Prices (HICP) in the euro area, while the effect on real GDP appears to be stronger in the short-term vicinity and the effect on HICP inflation in the medium-term. Bua and Dunne (2017) found that funds holding PSPP-related assets reduced their holdings of government bonds and rebalanced towards bonds issued by deposit taking corporations, but rather as a reaction to expansion of the PSPP purchases in March 2016 and towards assets predominantly issued outside the Eurozone. Funds holding non-PSPP-related assets also tend to rebalance their portfolios towards non-Eurozone issued government bonds and bonds issued by non-financial corporations. Their analysis results suggest no evidence of rebalancing towards equities or derivatives.

Later on, after the ECB introduced the Corporate sector purchase programme (CSPP) in March 2016, there emerged a variety of academic researches focused on some specific issue. The CSPP as a new form of QE monetary policy targeting this time corporate bonds motivated in the first place formulation of several expertises – see e.g. Fiedler, Jannsen and Raddant (2017) or Macchiarelli, Monti and Vedolin (2017) and academic papers e.g. Abidi and Flores (2017). Abidi and Flores (2017) used a regression discontinuity design framework exploiting the risk management divergence between the ECB and market participants and came with the following results: yield spreads between corporate and sovereign bonds declined by around 15 bp due to the CSPP announcement; the impact was mostly noticeable in the high yield CSPP-eligible bonds; liquidity conditions worsened for the CSPP-eligible bonds and the CSPP seems to have generally stimulated new issuance of corporate bonds. Their overall results are consistent with the explanation considering the portfolio rebalancing mechanism and the liquidity channel. Other especially interesting analysis are those focused on Germany, given its leading role as a sovereign bond benchmark country and country with high ratio of prime corporate bonds in the Eurozone. Development of bank lending in Germany is studied by Tischer (2018) using micro data on German banks. Tischer argues that QE encouraged banks to rebalance from securities to loans, especially more exposed banks and banks with equity constraints increased their loan growth during QE relative to other banks and that QE can affect bank lending even if banks do not hold PSPP-targeted assets. The scarcity effect of QE on Bund market is examined by Schlepper et al. (2017) using intraday transaction-level data for German government bonds (purchased under the PSPP) and matching high-frequency QE purchases data with high-frequency inter-dealer

data. Their results indicate that significant price impacts of the Eurosystem (Deutsche Bundesbank for Germany) PSPP purchases at high (minutes) and low (daily) frequencies are the cause of scarcity effects in German bond markets. The PSPP-induced scarcity had in Germany an adverse impact on liquidity conditions as measured by bid-ask spreads and inter-dealer order book depth.

Criticism of QE

While a majority of available analyses regarding QE speaks in favor of this unconventional monetary policy, it is equally important to mention its most profound criticisms. The main problem of the majority of researches of QE policy stems from the fact that their authors are usually active members of research departments of the major central banks that did realize QE policy (FED, ECB, BOE etc.) and may be biased. Initial newspaper-based counter opinions against QE and its possible effects back in 2008 were strongly overreacted and its warnings against hyperinflation and other catastrophic scenarios did not come to pass. There is however strong intellectual opposition against QE policy outside the central banks that has well theory-based grounds and even some modest critiques coming from central banks-funded researches exist.

Taylor (2013) as an advocate of predictable strategy for the instruments of monetary policy rejects QE monetary policy as unjustifiable. He argues that the FED's monetary policy (as measured by the federal fund rate reaction) appropriate for given inflation rate and business cycle conditions deviated significantly since 2003, while it was working well in the 1980s and 1990s. Since then the deviation continues in different ways. Reserve balances act as a good measure of how much liquidity the monetary authorities are providing to the financial markets and were not removed in 2009 after the normalization of the panic of 2008 and continue to rise via QE policy until today. Costs of this departure from a rule-based policy for the monetary instruments may outweigh any benefits in the future. The so-called Taylor Rule (Taylor, 1993) for the setting of the federal fund rate (FFR) would not go under -1% in 2009 and only the rule incorporating the output gap and sometimes used by the FED (see Yellen, 2012) would go deeper into negative numbers (to its minimums around -7% in 2009). The Taylor Rule did not imply large negative values for the FFR and thus would not alone justify the QE policy. International spillovers could also be the source of the negative impact of QE, while deviations from sound monetary rule-based policies in the developed countries can end up causing a negative feedback, via the emerging market economics, on the developed countries themselves according to Taylor (2013).

Meltzer (2011) and (2013) criticized the FED for concentrating too much on short-term events, with little influence over them, rather than on the long-term consequences of its operations and for misinterpreting its dual mandate to allocate all its powers just to reduce unemployment when the unemployment rate rises. Subjects of his critique are also the

overreliance of the FED on the Phillips curve to forecast inflation, the failure to follow a rule-based systematic policy for money and interest rates and for the FED's role as a lender of last resort. The FED has during the QE implementation vastly expanded its balance sheet, engaged in credit allocation and held down market rates on all Treasury securities. Meltzer sees it as a sacrifice of independence by responding to pressures from Congress and the federal administration – loss of independence that permits others to pressure the FED to achieve other usually short-term objectives. He perceives as a rather disturbing fact that the FED has never announced a lender-of-last-resort policy, and it continues to support too-big-to-fail policies that shift costs to taxpayers. Meltzer (2013, p. 406) explicitly mentioned QE2 as the one of the FED's failures, when the FED announced QE2 in November 2010 under the pressure of the opinion that the economy was headed toward even slower growth, recession, and deflation. While, *"... within a few months, it was clear that the summer slowdown was a transitory change that reversed before the purchases started."* He argues that the evidence suggesting a monetary nature of the current problems is nonexistent and that these problems are rather real and that the U.S. economy is not in a liquidity trap.

Not all Keynesian thinking-related economists have generally accepted QE positively as a measure that increases aggregate demand and promoted the mantra that anything that increases demand at the times of demand shortage is welcome. Palley (2011) for instance argue that QE in the U.S., especially its second wave initiated in 2010 (QE2), that was not a direct reaction to financial distress and elevated risk premiums, was not justifiable and may have caused problems under normal financial market conditions in that time. Palley pointed out the Keynesian unemployment structural mismatch argument arguing that there are structural problems on the demand side of the economy concerning the income distribution and demand generating process that cannot be changed by monetary policy. Palley based his critiques on the logic of the so-called Second-best theory (see Lipsey and Lancaster, 1956) in which fixing one market imperfection in the presence of many can actually worsen outcomes. Rogoff (2019a) and (2019b) sees quantitative easing and forward guidance as ineffective policies with very limited impact and would rather see central banks to push interest rates well into negative territory in a state of deep emergency, not in normal times, as a way to try to stimulate the economy. Rogoff criticizes the way of thinking that stimulus should be used in response to a financial crisis and that there isn't wider perception of a need to address the problems within the financial sector. He argues that this way of thinking took shape in the U.S. as a write-down of subprime debts using the government's balance sheet and in the Eurozone as a write-down of debts of the highly indebted periphery countries. He points out that the regulators are quick to prescribe to banks to maintain bigger buffers of "liquid" assets to fight runs on deposit and debt-rollover problems, but these "liquid" assets in normal times often turn out to be highly illiquid in a crisis. Rogoff suggests to involve into crisis management the entire government, not just the monetary authority and to require banks to raise a larger share of their funding through equity issuance or by reinvesting dividends.

Koo (2014), the promoter of the theory of balance sheet recessions, argues that while QE might have the effect of mitigating of economic recession, its withdrawal in the recovering economy could lead to slower growth than otherwise. Its overall effect might be negligible or even negative in the long-term. Central banks that undertook some kind of QE policy via the purchases of long-term assets (mainly government bonds) experienced a larger drop in long-term rates, and to that extent economic recovery arrived sooner than in countries with no QE policy. The problem may occur when the economy starts to recover from the recession and the central bank tapering will become an issue of the day. The bond market may fear the sell-off of central bank asset holdings, draining the excess reserves by either selling long-term bonds or to stop re-investing the maturing bonds, and may push long-term rates sharply higher, and consequently slow down the economic recovery. As a result, the central bank will become more reluctant to proceed tapering in order not to negatively affect economic recovery, the economy eventually picks up again, but this QE-induced recovery – tapering – slowdown cycle may last for some time. Koo called this cycle "The QE trap".

Haas and Young-Taft (2017) addressed in their study the fear that QE might invariably lead to overvaluation of assets, instigating economic instability and a formation of price bubbles. They examined the causal links between QE, asset overvaluation, and macroeconomic performance and came to the conclusion that rather than being pro- or counter-cyclical, QE acts as a sort of phase shift with respect to time. They argue, in contrast to monetary theorists, that the utility of QE is heavily parameter dependent and that quantitative easing has little effect at the level of macroeconomic indicators. It was neither expansionary nor deeply harmful, but merely ineffectual.

There are many other researches that uncovered weak points of QE policy: Boermans and Keshkov (2018) in its analysis of the PSPP impact on the micro market structure of sovereign bonds came to the conclusion that QE had market distortionary effects (bond scarcity, market liquidity dry-ups and price spikes) in the European sovereign bond market. Lehment (2018) argues that the ECB's PSPP had major side-effects on fiscal policy. He found that the PSPP not only led to partly negative seigniorage gains, but more importantly produced super-seigniorage gains resulting from negative interest rates on the excess reserves which have been created by the PSPP implementation. Another negative effect of the PSPP is its interference with fiscal debt management making fiscal budgets more vulnerable to changes in short-term interest rates. Ferdinandusse, Freier and Ristiniemi (2018) examined the effects of QE on liquidity and prices of bonds on a search theoretic model of over-the-counter debt. They argue that APPs initially improve liquidity, but bonds subsequently become scarcer and liquidity will strongly diminish. The APPs can crowd out other buyers, eventually leading to lower liquidity of the bonds with magnitude depending on market structure. The higher the share of preferred habitat investors holding the bonds, the more intense decrease in liquidity and vice versa. Lower share of preferred habitat investors is associated with more elastic demand so that liquidity improves more initially, but then falls

more than with the high share of preferred habitat investors. Price impact is larger in case of the high share of preferred habitat bond investors. Koetter, Podlich and Wedow (2017) tackled the redistributive effects of the Securities Markets Programme (SME) of the ECB from a commercial bank perspective. Using detailed security holdings data at the bank level they found that banks exposed to the SME programme mildly gained local loan and deposit market shares. Shifts in market shares were driven by banks that increased SMP-eligible security holdings during the SMP lifetime and banks that held the largest relative SMP portfolio shares.

General criticism of quantitative easing emphasizes its redistributing nature and its controversial targeting of purchased assets. Frank (2012) in his column and many others expressed their concerns about the QE policy as an instrument that helps the rich. Frank argued that the reason is that QE drives up the prices of assets, especially financial assets and most of the financial assets in the U.S. are owned by the wealthiest 5%. Even the Bank of England (2012) admitted in its report regarding distributional effects of its asset purchases that by pushing up a range of asset prices, asset purchases have boosted the value of households' financial wealth held outside pension funds in the UK, but holdings are heavily skewed with the top 5% of households holding 40% of these assets. Montecino and Epstein (2015) used the data from the Federal Reserve's Tri-Annual Survey of Consumer Finances (SCF) and analyzed the evolution of income by quantile between the pre-QE period and the QE period. They conclude that while employment changes and mortgage refinancing were equalizing under the QE policy, these impacts were largely accompanied by the large dis-equalizing effects of asset appreciations caused by the QE policy. Purchases of government bonds via the QE programmes is being criticized for similar reasons – while it is a rather political question how to redistribute wealth among public and private sector, it is likely that QE per se is highly demotivating as for implementing fiscal austerity measures. Maintaining a fiscally prudent government budget is not a standard nowadays, especially in the case of the southern states of the Eurozone. Not all are as fiscally prudent as Germany that is constantly reducing its total federal debt since 2012 given the favorable conditions on sovereign debt markets. E.g., Italy is currently facing worsening of economic forecasts, and the OECD-expected budget deficit will rise to 3.0 percent of GDP in 2020. Very problematic, especially if a more severe economic downturn should emerge, is the transfer of risks associated with the nature of assets purchased under APPs. For example, the ECB bought non-financial corporate sector bonds that would otherwise remain within the private sector and all risk associated with the issuer were transferred to the ECB as well. The CSPP implementation was not as smooth as the Governing Council would like it to be, while the ECB bought into the €800m bond issue by Steinhoff's European subsidiary in July 2017. South African retail conglomerate Steinhoff International faced several financial problems and debt restructuring. Estimated ECB losses over the Steinhoff International incident may be about €50m on the debt sale, as argued by Smith (2018).

1.5 Contemporary discussion about monetary policy and its future prospects

While the active period of quantitative easing, when central banks on a regular basis bought targeted assets and boosted its balance sheets, has come to an end, the period of cooling and searching for the new way of monetary policy, whatever shape it may have, is underway. The reality is uneasy, the FED and the ECB find themselves in the phase of policy normalization and uncertain global economic outlook (especially in the Eurozone) threatened currently by the U.S. – China trade wars gives them no easy choices. Slower than previously anticipated monetary policy tightening and enormously swelled balance sheets of central banks that have undergone QE policy represent the current uneasy situation. Monetary policy rates still too close to zero with exceptionally high excess reserves would probably bind hands in some ways to central banks in case of another severe economic downturn. Some believe (e.g. Koo, 2014) that faster economic recovery thanks to QE in the past will now bring the prolonged period of sluggish growth during the monetary policy normalization. Some believe that the return to monetary policy from before QE implementation would not be possible for a long time given the size of the central banks' balance sheets and the slow dissolving process of assets held for monetary policy purposes. The ECB's Governing Council for example currently *"... intends to continue reinvesting, in full, the principal payments from maturing securities purchased under the APP for an extended period of time past the date when it starts raising the key ECB interest rates, and in any case for as long as necessary."*[10] Some Eurozone countries will however be more exposed than others to the decrease in net QE flows in following years – according to Goldman Sachs estimates (see Crimella, 2018), the private sector will be required to absorb around 80% of gross Italian and French long-term sovereign bond issuance in 2018, compared with just 50% in Germany and 65% in the Netherlands. The FED's FOMC committee is since 2015 maintaining *"... its existing policy of reinvesting principal payments from its holdings of agency debt and agency mortgage-backed securities in agency mortgage-backed securities and of rolling over maturing Treasury securities at auction."*[11] The FED has the long-standing plan to shrink its balance sheet to a point before the first signs of reserve scarcity emerge. These signs have not appeared yet, and economic analysis suggest this point will be reached with approximately \$1 trillion in reserves and a roughly \$3.$^1/_2$ trillion total balance sheet in early 2020 (see Hatzius et al., 2019).

Possible exit strategies for QE monetary policy are being discussed for some time and extensive literature is available, e.g. Kohn (2014) summarizing the opinions on this issue of

[10] See the ECB Monetary policy decision from 26th April 2018.

[11] See the FOMC Monetary policy decision from 18th March 2015. Reinvestments are currently being done for Treasury securities maturing during each calendar month that exceeds \$15 billion and for the amount of principal payments from the Federal Reserve's holdings of agency debt and agency mortgage-backed securities received during each calendar month that exceeds \$20 billion.

known economists – Blinder, Jordan, Kohn and Mishkin. Series of papers regarding policy normalization contains e.g. Chen et al. (2016), their model incorporating multiple Federal Reserve liabilities and a superabundant supply of reserves showed that policy tools including interest on excess reserves (IOER), overnight and term reverse repurchase agreements, and term deposits should allow the FED to raise the level of short-term interest rates at the appropriate time. As for the Eurozone, the possibility of tiered excess reserves is being discussed as well. Commercial banks currently have to pay for excess reserves, while their deposits are subject to the ECB's deposit facility rate (-0.4%). A tiered deposit rate would exempt part of the banks from costly paying for its excess reserves held at the ECB and possibly boosting their profits as they may struggle in current conditions of low rates and sluggish economic growth. The boost to bank profits from tiering would likely lead to little easing of financial conditions, less than 5 bp according to Goldman Sachs financial conditions index (see Stehn et al., 2019).

Contemporary discussion also contains a fair share of ongoing critique of the QE policy. General critique of QE for its possible long-lasting negative effects on the economic growth that it may bring and critique that rejects QE policy per se were mentioned in preceding section. What is being more intensively discussed in newspapers is rather QE redistributive nature. Dobbs (2018) and many others are mentioning QE as a source of price bubbles of the "sorts of things investment bankers buy". The reasoning starts from QE increasing liquidity among financial institutions and to suppressing interest rates, just the FED estimated infusions sums up to 2011 total of $29 trillion (Carney, 2011). Reasoning continues through asset prices: *"Stock prices, for example, have more than tripled despite effectively no growth in productivity. That is to say that we have experienced one of the most dramatic and longest lasting bull markets in history but are not actually producing much more on an hourly basis than we were during the last recession. Overall gross industrial output only increased 14% on inflation adjusted terms over the same period. This is unprecedented, and stocks have gone gangbusters because of unprecedented QE."* And this whole price bubble contains not only equities but also property prices that may have been directly affected by the FED's MBS purchases and indirectly via portfolio balance channel. It is the reasonable assumption that under the conditions of low Treasury yields and low productivity growth[12] investors will eventually turn either to reinvesting abroad (e.g. in emerging markets) or to investments into real estate. This finally concerns everyone since everyone needs a home and this issue of rising property prices and rising rents is more frequently being discussed not even in countries that have undergone QE but also in countries that strongly economically depends on economic development in these countries and this issue became global.

[12]Productivity change in the manufacturing sector 2007-2018 was annually only 0.7%. See the U.S. Bureau of Labor Statistics (2019).

1.6 Context of this thesis and its place within academic research

The first research paper constituent to this thesis in chapter 2, named "The Impact of Quantitative Easing on Purchased Asset Yields, its Persistency and Overlap", as for the subject of research, its timeframe and used methodology belongs among working papers analyzing QE policy of the FED in the U.S., that were mentioned above in section 1.4. This paper nonetheless analyzes the whole QE with all its phases and enriches research papers that are focused only on a particular phase (wave) of QE policy in the U.S. In this paper I employed detailed event study and VAR-IRFs analysis containing all important events capturing the whole active phase of QE in the U.S. The event study was used in an uncommon way that allows control for other than monetary policy APPs impacts by using the OIS-Treasury spread analysis approach. Resulting impulse-response functions from VAR-IRF analysis capture the immediate effect and persistency of QE-related events. While this paper incorporates the whole U.S. QE period, it presents the intercomparable results of each wave of QE in the U.S. (QE1 to QE3 and MEP) and allows us to discuss the impact of all QE-related events together and describe the major differences among each QE phase.

The second research paper constituting this thesis chapter 3, named "The True Nature of the Portfolio Balance Channel of Quantitative Easing Policy", as for the subject of research and its timeframe belongs among working papers regarding the ECB's PSPP mentioned in section 1.4. In this paper I employed sectoral data regression analysis of asset holdings of different investors in the Eurozone and the counterfactual analysis approach to uncover a possible role of the portfolio balance channel during the PSPP implementation. This study addresses questions regarding size and direction of investors' reallocations – what types of investors were acting as the main counterparts to the ECB on the market for government bonds and what asset classes were preferred and chosen as an alternative by investors in the Eurozone to reallocate their funds. The ex-ante and ex-post counterfactual analysis enriches in the original way the research analyzing the ECB's QE policy and shows how the portfolios of various types of the Eurozone investors may have looked in the no-PSPP scenario.

The third research paper constituent to this thesis chapter 4, named "The Outreach and Effects of the ECB's Corporate Sector Purchase Programme", as for the subject of research and its timeframe belongs among working papers regarding the ECB's CSPP mentioned above in section 1.4. In this paper I employed detailed disaggregated ISIN-based event study adjusted for impacts of events nonrelated to the CSPP implementation and VAR-IRFs analysis. ISIN-based analysis is Eurozone-wide and extends by its original methods existing academic research, that either focuses only on the narrow part of the CSPP effect using different micro-level data or does not incorporate ISIN-based data at all. Model outputs give us disaggregated results capturing the CSPP impact on corporate bonds and its persistence in time. Results are country-specific, sector-specific, maturity-specific and the study also

contains company-specific results of selected companies and consecutive analysis of corporate CSPP-induced funding developments in the Eurozone.

The fourth and final research paper constituent to this thesis in chapter 5, named "The SER Spread under the ECB's Quantitative Easing", as for the subject of research belongs among working papers studying the ECB's PSPP and its impact on German sovereign bond markets and the Eurozone financial and economic indicators. In this paper I employed high-frequency cluster analysis together with complementary descriptive analysis to uncover possible distortionary effects of the PSPP on German sovereign bond markets and its impact on the SER spread with possible implications for its indicative powers. This kind of analysis, as far as I am aware of, is original and the SER spread cluster analysis of the effects of the PSPP on this indicator represents the only existing academic research of its kind.

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Chapter 2

The Impact of Quantitative Easing on Purchased Asset Yields, its Persistency and Overlap[1]

Abstract: *The main focus of this paper rests on the event study and SVAR analysis of quantitative easing that was initiated as a reaction to the financial crisis at the turn of 2008/2009 that finally ended in 2014. The FED was virtually unable to continue with its conventional monetary policy regime in the environment of zero-bound threshold, where there is no easy way to decrease the main monetary policy rate any further. As a reaction to this limitation, the FED started to practice quantitative easing and other unconventional measures. This event study examines changes in yields of purchased assets, namely U.S. Treasuries, MBS and agency debt, and on a two-day event window of the OIS and yield spreads quantifies imminent impact of QE announcements and relevant chairman speeches. In the following VAR model and impulse-response functions, the impact of QE and its persistency on purchased assets and on alternative asset classes was examined in the framework of various transmission channels such as signaling, portfolio-balancing and liquidity channels. In this study a non-negligible impact of QE was found on purchased assets in both models through all waves of QE and time persistency patterns in IRFs part. Furthermore, some evidence for portfolio-balancing channel and other related channels was found.*

Keywords: Monetary Policy, Quantitative Easing, Credit Easing

JEL classification: E520, E580, E440

[1]JAKL, J. (2017). The Impact of Quantitative Easing on Purchased Asset Yields, its Persistency and Overlap, Journal of Central Banking Theory and Practice, 6(2), 77-99. This article is a part of the research funded by the University of Economics, Prague, under the project IGS F1/5/2014 Finanční a hospodářský cyklus.

2.1 Introduction

As a reaction to the Great Recession, the FED started to take unconventional monetary policy countermeasures and, after several decreases of the federal fund rate (FFR) during 2008, reached the effective bottom of this rate. In this band 0-0.25% the FED reached zero-bound which represents the frontier of conventional monetary policy of setting FFR (see Bernanke, 2008). The circumstance forced the FED to implement unconventional measures in the form of quantitative easing (QE) and forward guidance (FG)[2]. The FED followed the Bank of Japan, which started a certain form of QE already in 2001, and was followed by the Bank of England, the ECB and others as well – for details of measures taken across the central banks see Klyuev, Imuset and Srinivasan (2009).

During the three waves of QE, the FED purchased mortgage-backed securities (MBS), treasury securities (TS) and agency bonds of Government-Sponsored Enterprises (GSEs)[3] in its effort to ease deterioration in the MBS market and lower yields of purchased assets in order to transfer yield decline to other markets and indirectly lower the costs of long-term investments of firms and individuals.

There are several effects that form a theoretical ground of QE and are related to specific channels – signaling channel, portfolio-rebalancing channel, liquidity channel and other more or less important channels that altogether can make QE policy valid in unconventional times of zero bound. The frequently mentioned portfolio-rebalancing channel, for instance, can be working when a decrease in yield of one asset in a pool of available investment assets lowers the rate of required yields in other assets considered by investors during their investment decision making. The signaling channel can influence the expected path of future FFR etc. Moreover, an increase is important in non-borrowed reserves (NBR) of commercial banks in the FED caused by the QE purchase program itself. This increase eases conditions on the interbank money market and can foster issuance of cheaper loans and mediate economic growth and bring the FED nearer to its goals in the form of maximum employment, stable prices and moderate long-term interest rates – see Bernanke, Reinhart and Sack (2004).

This study uses event study method to examine the immediate impact of the FED's QE announcements on USD denominated Treasury bonds, MBS and agency bonds yields and its effect on commercial investment substitutes – corporate bonds and equity indices. The event study analysis is based on the spread between overnight indexed swap (OIS) and Treasury security yield change. The structural vector autoregression (SVAR) model analysis follows and together with impulse–response functions (IRFs) quantifies the impact and persistence of QE announcements on yields. The main focus of this study is to identifypossible channels

[2] *"Forward guidance is communication about the likely future course of monetary policy and in addition, the FOMC used forward guidance language about the flow-based asset purchase program."* See the Board of Governors of the FED.

[3] Fannie Mae, Freddie Mac, and Ginnie Mae.

of QE transmission and to quantify the impact and persistence of QE on yields of the purchased assets with overlap to commercial assets by event study and IRFs and to provide the connection with existing theoretical concepts of considered transmission mechanisms and existing studies. Brief QE related events descriptions and both methods follow in the next sections.

2.2 Transmission mechanism of QE

The conventional monetary policy has become ineffective in the zero-bound environment and the FED was forced to choose an alternative way that would be effective even under this condition. The FED decided to implement QE and forward guidance (sometimes called "open-mouth operations").[4] During the exercising of conventional monetary policy with providing liquidity via repo operations and influencing the level of NBR by outright Open Market Operations (OMO), the goal of the FED is usually only to temporarily influence the level of NBR and not to affect prices or yields of purchased assets. This is the main difference compared to QE, when the FED contrariwise wants to affect prices and yields of purchased assets and consequently prices and yields of other assets in the economy – therefore the purchases have to be great in numbers. These operations are not sterilized in the SOMA (System Open Market Account) portfolio and there is eventually no decrease in NBR as there is in the case of conventional operations redeemed by counter operation when the objective of such an operation is not the adjustment of the level of liquidity provided in order to satisfy commercial bank needs or currency in circulation demands. The proclaimed nature of QE by Bernanke et al. (2004) is a reduction of risk and term premia of long-term IRs. The working mechanism described by theoretical studies is not unified and a variety of possible transmission channels of QE is presented.

In the framework of New Keynesian economics (NKE) and Ricardian equivalence, the effectiveness of QE is inseparably connected with its ability to affect expectations of economic agents regarding the expected future path of FFR or inflation. It is, in fact, the signal channel where the FED signals its devotion to hold the FFR low even for the time period that is longer than adequate according to the Taylors rule. This channel is examined for instance in Eggertsson and Woodford (2003) or Clouse, Dale, Athanasios, Small and Tinsley (2003). The FED did both, simultaneously implemented FG, which is an explicit form of communication about future FFR, and initiated QE purchases that are credible evidence of its intention to adhere proclaimed lower FFR for long period. This, together with increasing inflation expectations that are raised by QE itself, lead to a decrease of future expected real market IR and works as a strong QE channel especially in a deeply indebted economy such as the U.S. economy.

NKE extended for financial frictions or incomplete markets and imperfect substitutability of purchased assets can also cover the asset prices channel when QE monetary policy causes the price changes by influencing the relative supply of purchases assets and consequent yield changes as well. Vayanos and Vila (2009) came with the Preferred-habitat model of the term structure of interest rates where interaction amongst preferred-habitat investors and risk-averse arbitrageurs determines bond prices within the NKE framework and found

[4]For other possible unconventional measures effective in zero-bound environment, there is number of theoretic studies, see e.g. Yates (2003).

theoretical support for QE in a fact that a shock to bond supply affects bond prices especially in long duration segment. Andrés, López-Salido and Nelson (2004) presented a similar model of imperfect asset substitution between money and long-term bond holdings of some households. Therefore, a necessary condition is a preferred habitat or market segmentation when the perfect arbitrage between short-term and long-term Treasury securities is ruled out. Under these conditions, the FED can impact the prices on the affected markets as describes Mishkin (2010).

The majority of studies, e.g. D'Amico and King (2010), Hamilton and Wu (2011) and Gagnon, Raskin, Remache and Sack (2011), mention the portfolio balance channel formally described by Tobin (1969) and studied by Brunner and Meltzer (1973) and Friedman and Schwartz (1963), as a subset of asset price channel, when relative changes of nominal asset prices with respect to prices of other assets that are being considered as an investment alternative are the cause of the portfolio rebalancing process. QE simply increases the prices of purchased assets and lowers their yields and drains purchased investment securities from the market as well. These purchased securities are no longer available for private investors and their relative scarcity compared to securities that are not the subject of QE purchases is boosted. Investors consequently optimize their portfolios with respect to their relative prices, yields, riskiness and scarcity of preferred securities held. If, for instance, the yields of low-risk Treasuries would fall, investors would demand lower risk premium in the segment of alternative investment assets, first in corporate bonds and later in nonfinancial assets. *"This, in turn..."*, as quoted in Friedman (1969, p. 231), *"...tends to make existing nonfinancial assets expensive relative to newly constructed nonfinancial assets. At the same time, the general rise in the price level of nonfinancial assets tends to raise wealth relative to income, and to make the direct acquisition of current services cheaper relative to the purchase of sources of services. The monetary stimulus is, in this way, spread from the financial markets to the markets for goods and services"*, and ultimately affects the price level in the economy.

Simultaneously, the non-interest bearing credit balances of the FED's counterparties are on the rise and could be used for purchases of available investment assets, such as corporate bonds and equities, with higher relative yield / total returns. This spillover effect supports the prices of these assets and through higher demand boosts their prices and lowers their yields. That could lead to the easing of long-term credit conditions in the corporate bond segment and positive effect on equities with spillover effect onto the real economy. Wealth effect associated with the increase in asset prices may also positively influence consumer consumption decisions – a growth of consumer spending and an increase in investment activity of firms due to lowering the cost of financing by corporate bonds issuance could arise.

As for MBS purchases and Treasury securities with long duration, it is important to mention the market liquidity channel, when an entrance of the FED in a distorted or low liquidity market allows investors to trade assets without additional costs caused by low

liquidity. Liquidity premium is reduced and investors more willingly hold these assets. The MBS market after the burst of property price bubble was one particular example of such a market. This and other possible channels of QE transmission are further introduced e.g. in Krishnamurthy and Vissing-Jorgensen (2011).

2.3 QE-related events

Already in 2002 Bernanke in his speech[5] referred to the future possibility of QE in case of deflationary pressures and FFR close to zero and warned of negative effects of deflation on the economy with reference to "The Lost Decade" in Japan. His remarks and speeches as the FED chairman in 2006 – 2014 were always in the way of advocating QE and his voice was perceived by markets as an important guideline of future unconventional measures, therefore, all important speeches regarding QE were included in the set of events.

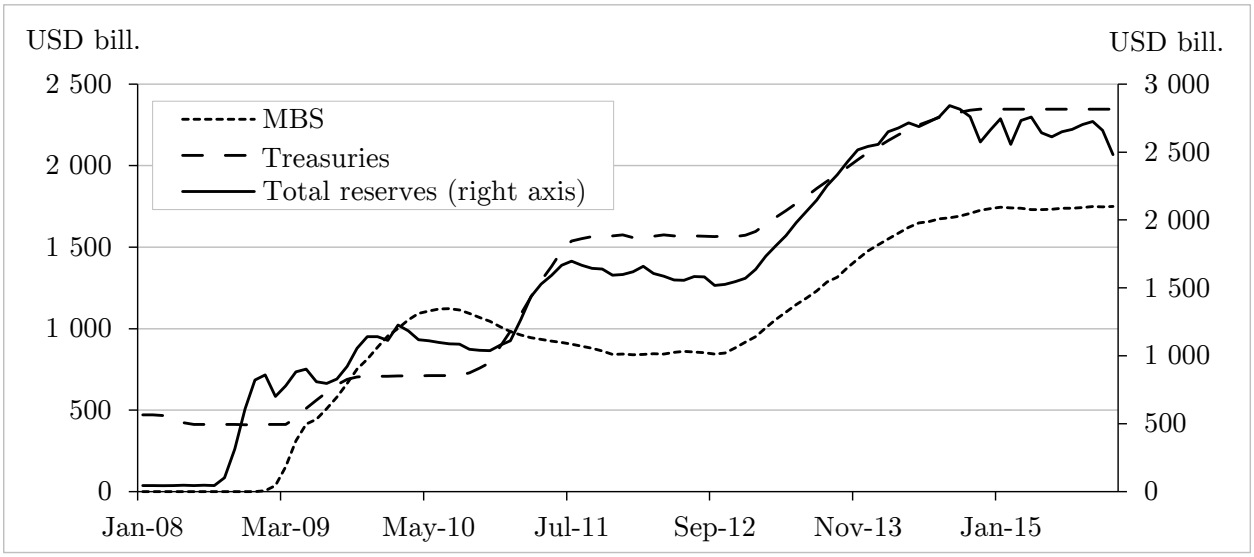
The FED initially announced purchases of $500 billion of MBS and $100 billion of agency bonds (AB) in November 2008. These purchases were at the beginning sterilized in SOMA holdings in this phase, so no contemporary increase in the FED's balance sheet appeared until the approval of the Federal Open Market Committee (FOMC) in December. In his speech[6], Bernanke outlined QE and later on the QE program was formally approved at the FOMC meeting on 16th of December. The program was extended in March 2009 for other purchases of $750 billion in MBS and $100 billion in agency bonds and $300 billion of Treasury securities in a time scope of following six months. In August 2010, the FED announced its intention to reinvest maturing MBS to Treasury securities and roll over maturing Treasury securities.

In his speech in August 2010, Bernanke mentioned the possibility of the second round of QE (QE2) as a valid option for monetary policy and stated that *"the evidence suggests that the FED's earlier program of purchases was effective in bringing down term premiums and lowering the costs of borrowing in a number of private credit markets"*.[7] At the following meetings, the FOMC confirmed its intention to keep SOMA holdings on the level of $2 trillion and approved the second round of QE in November 2010 with approved purchases of $600 billion of long-term Treasury securities (LTTS) at a pace of $75 billion per month. During the consideration process of QE2, Bernanke argued with a series of academic studies that verified and quantified impact of QE1 e.g. D'Amico and King (2010), Gagnon et al. (2010) or Hamilton and Wu (2010) and their findings are presented further in the next sections.

In September 2011, the FOMC decided to implement the Maturity Extension Program (MEP), also referred to as the Operation Twist (OT)[8], which represented duration changes in holdings of Treasury securities – $400 billion of Treasury securities with a duration of three years or less were meant to reinvest into Treasury securities with duration with a range of six to thirty years till the end of 2012. The MEP, as it was claimed by the FOMC in its statement from 21st of September 2011, *"should put downward pressure on longer-term interest rates and help make broader financial conditions more accommodative"*, without further increase

[5] Bernanke's speech from November 21st, 2002 – Bernanke (2002).
[6] Bernanke's speech from December 1st, 2008 – Bernanke (2008).
[7] Bernanke's speech from August 27th, 2010 – Bernanke (2010).
[8] According to the original Operation Twist (1961) when the FED intended to flatten treasury yields and strengthen dollar. More details are in Swanson (2011).

Figure 2.1: The FED's Balance Sheet



Source: FED; Units: currency; Currency: USD.

of purchases held on the FED's balance sheet. Reason was partially rooted in the fact that the FED was criticized for monetization of federal debt and inducing the risk of future higher inflation above target, see for example open letter to Bernanke from a group of academics and financial market professionals from November 2010 where QE2 is opposed: *"The planned asset purchases risk currency debasement and inflation..."*[9]. Asset purchases in fact caused growth of NBR from $12 billion at 2007 to ca. $2.4 trillion at the end of 2013 (see Figure 2.1).

The third wave of QE – QE3 was introduced in September 2012, when the FED announced its open-ended commitment to purchase MBS at a pace of $40 billion per month and in December followed by purchases of LTTS at a pace of $45 billion per month. Tapering was announced in December 2013 with further reductions of $10 billion of cumulative monthly pace on each FOMC meeting. In October 2014 with the tapering finally ended, the QE was technically concluded. All QE-related events that possibly had impact on yields of purchased assets are in the following Table 2.1 capturing QE1 events, in Table 2.2 capturing QE2 events, in Table 2.3 capturing MEP events and finally in Table 2.4 capturing QE3 and tapering events.

[9]Available at The Wall Street Journal.

Table 2.1: QE1-related events

Date	Event	Description	Scale
25-Nov-08	MPR	Purchases of the GSEs direct obligations and MBS.	+ up to $100 bln. ABS and $500 bln. MBS
1-Dec-08	BS	FED could purchase L-T Treasury or agency securities.	
16-Dec-08	St.	Ready to expand its purchases and considers purchasing TS.	
28-Jan-09	St.	Ready to expand purchases and the duration of the purchase program and is prepared to purchase longer-term TS.	
18-Mar-09	St.	FOMC announced a longer-dated Treasury purchase program.	+ $750 bill. MBS, + $100 bill. AB, + up to $300 bill. LTTS
12-Aug-09	St.	Total of announced amounts of TS will be purchased and decided to gradually slow the pace of these purchases.	
23-Sep-09	St.	Total of announced amounts of MBS and agency debt will be purchased. Slows the pace of these purchases.	
4-Nov-09	St.	FED will purchase a total of $1.25 trillion of MBS and $175 bill. of AB from announced maximum of $200 billion.	- $25 bill. AB
10-Aug-10	St.	Keep constant holdings of purchased securities by reinvesting principal payments in LTTS and roll over maturing TS.	

Note: MPR stands for Monetary Policy Release, St. stands for FOMC statement, BS stands for Bernanke speech, AB stands for agency bonds, TS stands for Treasury securities; Source: FED, author's.

Table 2.2: QE2-related events

Date	Event	Description	Scale
27-Aug-10	BS	„Additional purchases of longer-term securities would be effective in further easing financial conditions.“	
21-Sep-10	St.	FOMC maintain its existing policy of reinvesting principal payments from its securities holdings.	
12-Oct-10	Min.	FOMC members' sense that such accommodation (additional) may be appropriate before long.	
15-Oct-10	BS	Program of securities purchases was successful, FOMC is prepared to provide additional accommodation if needed.	
3-Nov-10	St.	Further purchases of LTTS ($75 billion per month)	+ $600 bill. LTTS
22-Jun-11	St.	The Committee will complete its purchases of $600 billion of longer-term Treasury securities → end of QE2	

Note: St. stands for FOMC statement, BS stands for Bernanke speech, Min. stands for FOMC minutes, TS (LTTS) stands for Treasury securities (long-term); Source: FED, author's.

Table 2.3: MEP-related events

Date	Event	Description	Scale
21-Sep-11	St.	Purchase of $400 billion of TS with remaining maturities of 6-30Y, sell of TS with remaining maturities of 3Y or less.	+ $400 bill. 6Y-30Y TS / - $400 bill. 1Y-3Y TS
20-Jun-12	St.	FED continues to reinvest TS in MEP.	

Note: St. stands for FOMC statement, TS stands for Treasury securities; Source: FED, author's.

Table 2.4: QE3-related and tapering events

Date	Event	Description	Scale
22-Aug-12	Min.	Many (FOMC) members judged that additional monetary accommodation would likely be warranted fairly soon.	
13-Sep-12	St.	Further purchases of MBS at a pace of $40 bill. per month. MEP and reinvesting principal payments still under way.	+ $40 bill. in MBS per month
12-Dec-12	St.	FED will purchase LTTS after MEP, initially at a pace of $45 bill. per month.	+ $45 bill. of LTTS per month
18-Sep-13	St.	Committee decided to await more evidence that progress will be sustained before adjusting the pace of its purchases.	
18-Dec-13	St.	FOMC decided to reduce the pace of its asset purchases by $10 billion per month.	- $5(5) bill. in MBS (TS) per month
29-Jan-14	St.	same as for 18th Dec-13	same as before
19-Mar-14	St.	same as for 18th Dec-13	same as before
30-Apr-14	St.	same as for 18th Dec-13	same as before
18-Jun-14	St.	same as for 18th Dec-13	same as before
30-Jul-14	St.	same as for 18th Dec-13	same as before
17-Sep-14	St.	same as for 18th Dec-13	same as before
29-Oct-14	St.	End of QE, holdings of L-T securities at sizable levels.	

Note: St. stands for FOMC statement, Min. stands for FOMC minutes, TS (LTTS) stands for Treasury securities (long-term); Source: FED, author's.

2.4 Event study approach

One of the few plausible methods to analyze the impact of QE on market expectations is the event study approach widely used in the analysis of the initial impact of monetary policy announcements. Bernanke et al. (2004) used this approach to analyze the impact of the FED's announcements on asset prices. Gagnon et al. (2010) used the same method to examine yield changes of U.S. Treasury securities until March 2010. Joyce et al. (2011) and Christensen and Rudebusch (2012) used event study method to study the response of interest rates to QE in the UK and the U.S. Hausken and Ncube (2013) widely used the same method to study QE undertaken by the FED, the ECB, the BOE and the BOJ. This study uses event study method on all crucial official announcements and chairman's speeches regarding the QE in the U.S. and extends the preceding studies that covered only initial parts of QE in the U.S. Event study is used to capture the immediate impact of events on yields of purchased assets when the announcement itself can be fully reflected in the short period around the time of announcements without the need to wait for the real exercise of purchases. This could be achieved by transmission channels arising from the nature of communication itself such as a signal channel and partially other effects, e.g. the portfolio rebalancing channel or the liquidity channel of forward looking market participants that immediately reflects announcements in its expectations regarding future asset prices and the market liquidity and will in advance affect the markets without the FED to even interfere. The announcement should be, of course, backed by a credible commitment and a timeline of purchases, otherwise no such effect would appear.

The modified event study method based on OIS-TS spread presented in Joyce et al. (2011) was used in this analysis – when the change in yields induced by QE announcement can be split in two components and distinguished, the first one captures the change in future FFR expectations and the second one captures changes in term premium. OIS rate is a good proxy for the first component because of its ability to bear minimal counterparty credit and liquidity risks and fully reflects expectations about the future FFR path. At maturity, both counterparties determine the net payment by the difference between the accrued interest of the fixed rate and the geometric averaging of the floating index rate on the notional swap principal. OIS swaps have little credit risk exposure because there is no exchange of principal and at the maturity only the net difference in interest rates is being paid. Hull and White (2013) suggest that the OIS rate is the best proxy for risk-free rate currently available rather than LIBOR, in both situations, when portfolios are not collateralized and for collateralized portfolios as well. This assumption about OIS rates gives us a chance to use OIS-TS spread to quantify only the second component that reflects only changes caused by QE itself rather than future FFR expectations solely based on non-QE monetary policy. Joyce et al. (2011) consider also a liquidity channel at the time of announcement which is a rather fearless assumption given the fact that at the time of announcement the FED is not actually present

in the market, therefore, this effect is considered to be weaker at the time of announcements and rather stronger during the actual exercise of purchases.

Formally, this relation of OIS-TS yield spread is characterized in the following way – equation (2.1) decomposes the yield of Treasury securities into expected future short-term interest rates and term premium components:

$$y(TS)_t^n = \left(\frac{1}{n}\right) \sum_{i=0}^{n-1} E_t r_{t+i} + TP(TS)_t^n, \tag{2.1}$$

where $y(TS)_t^n$ is the yield on Treasury security maturing after n-periods at time t, r_{t+i} denotes a one-period risk free interest rate while $TP(TS)_t^n$ denotes a n-period term premium associated with Treasury security at time t. $TP(TS)_t^n$ can be further decomposed, see Hausken and Ncube (2013), into the $TP1(TS)_t^n$ component, which captures instrument-specific effects that involve credit risk and imbalances caused by demand and supply interactions (e.g. Preferred Habitat-induced effects) and the $TP2(TS)_t^n$ component, which captures premiums determined by uncertainty regarding future interest rates within the maturity of Treasury security:

$$TP(TS)_t^n = TP1(TS)_t^n + TP2(TS)_t^n. \tag{2.2}$$

Under consideration of negligibility of credit risk premium of the U.S. Treasury securities and an omission of the part of the liquidity premium change in the immediate vicinity of the announcements, which is connected with exercise of purchases rather than announcements, the component $TP1(TS)_t^n$ can be considered to reflect various effects of these announcements well. Change caused by the first or the second component would be marked $\Delta TP1(TS)_t^n$ and $\Delta TP2(TS)_t^n$ respectively.

Equation (2.3), which basically represents expectations about overnight interest rates, and equation (2.4) together capture the OIS market in the same way as equations (2.1) and (2.2) capture the U.S. Treasury market:

$$y(OIS)_t^n = \left(\frac{1}{n}\right) \sum_{i=0}^{n-1} E_t r_{t+i} + TP(OIS)_t^n. \tag{2.3}$$

Equation (2.4) shows that the term premium of OIS – $TP(OIS)_t^n$ can be decomposed in the same manner into the $TP1(OIS)_t^n$ component that captures instrument-specific premium and the $TP2(OIS)_t^n$ component that captures premium determined by uncertainty regarding future interest rates within the maturity of OIS:

$$TP(OIS)_t^n = TP1(OIS)_t^n + TP2(OIS)_t^n. \tag{2.4}$$

Change caused by the first or the second component would be marked $\Delta TP1(OIS)_t^n$ and $\Delta TP2(OIS)_t^n$ respectively. If the reasonable assumption that negligibility of the component $TP1(OIS)_t^n$ that captures liquidity and credit risk premiums and effects of demand and supply interactions in OIS is correct due to the very liquid OIS market and virtually non-existing credit risk threat (see Hull and White, 2013), we can consider the remaining component $TP2(OIS)_t^n$ to be affected equally by the expected future short-term interest rate as component $TP2(TS)_t^n$ as it is captured in equation (2.5).[10] Therefore, a change caused by QE announcements would cause the same change in $TP1(TS)_t^n$ as in $TP1(OIS)_t^n$ – changes are expressed by $\Delta TP1(TS)_t^n$ and $\Delta TP1(OIS)_t^n$:

$$\Delta TP(OIS)_t^n = \Delta TP2(OIS)_t^n \sim \Delta TP2(TS)_t^n. \tag{2.5}$$

Thus, the spread in yield changes between OIS and TS stated in equation (2.6) gives us the size of the instrument-specific effect, which includes credit risk and imbalances caused by demand and supply interactions in Treasury security market caused by QE announcements:

$$\Delta y(TS)_t^n - \Delta y(OIS)_t^n \sim \Delta TP1(TS)_t^n. \tag{2.6}$$

Existing event studies emphasized the correct "fairly narrow interval" of the event window to capture most of the reaction and not to include other unrelated effects. Krishnamurthy and Vissing-Jorgensen (2011) used two-day window claiming that a one-day window would be enough only for Treasury securities with shorter maturities due to higher market liquidity. Joyce et al. (2011) in their study of QE in the UK and Hausken and Ncube (2013) chose a two-day window as well and rejected a one-day and three-day window. Gagnon et al. (2011) and Christensen and Rudebusch (2012) on the other hand chose a one-day window. This study follows the majority and uses a two-day window on its event study analysis and originally applies this method using OIS-TS yield spread changes on QE in the U.S. and unlike the majority of existing studies examines the whole QE in years 2008 – 2014 including the events of 2013 and 2014 tapering and not only part of it.

Assumptions regarding this event study can be summarized as follows:

- Official events that are included had exclusive impact on the creation of expectations regarding QE of economic agents in the concerned markets.
- Event window is chosen correctly in the way that results are influenced by other external factors in the lowest possible way and instrument-specific shocks in the event windows are negligible.

[10] The meaningfulness of this reasoning is inseparably connected with consideration regarding OIS – they are ordinarily used as a hedging against unexpected future changes in overnight LIBOR rates and its maturity is fixed for that purposes to n periods to satisfy hedger funding needs.

- Markets are effective in a way that they are capable of absorbing the most information about future asset purchases already at the time of announcements rather than during the implementation.[11]

All QE directly affected assets classes are present – Treasury securities are represented by constant maturity U.S. TS with maturities 2, 3, 5, 10 and 30 years[12], MBS represented by Ginnie Mae and Fannie Mae MBS indices and agency debt represented by Fannie Mae and Freddie Mac indices.[13] For comparative purposes Moody's seasoned corporate bonds Aaa and Baa indices are included.[14] Yields changes of all these assets are adjusted for OIS rate changes with corresponding duration. Two-day window instrument-specific yield changes in basis points of analyzed assets are captured in following Table 2.5:

[11]The realistic assumption is to consider adaptive market hypothesis proposed by Lo (2004). Lo (2004, p 18) suggests that *"If multiple species (or the members of a single highly populous species) are competing for rather scarce resources within a single market, that market is likely to be highly efficient, e.g., the market for 10-Year U.S. Treasury Notes, which reflects most relevant information very quickly indeed."* Since this paper deals mainly with U.S. Treasury market, it seems appropriate to assume validity of adaptive market hypothesis.

[12]Treasury Inflation Protected Securities (TIPS) are not involved due to their low importance (ca. 7% of total Treasury issued debt securities – Monthly Statement of the Public Debt).

[13]All indices used are constructed and provided by Merrill Lynch.

[14]Used as index of the performance of all bonds with Aaa/Baa rating by Moody's Investors Service.

Table 2.5: Assets yields changes

Date	Event	Treasury						MBS		GSEs		Corp.	
		1Y	2Y	3Y	5Y	10Y	30Y	GM	FaM	FaM	FrM	Aaa	Baa
25-Nov-08	MPR	3	-10	4	2	-14	-2	-44	-46	-32	-28	2	6
1-Dec-08	BS	-4	8	8	3	-35	-37	18	4	-6	-7	-38	-34
16-Dec-08	St.	4	5	7	6	-15	-14	-60	-57	-24	-23	-17	-23
28-Jan-09	St.	0	-5	-2	1	43	46	49	31	1	-1	42	37
18-Mar-09	St.	-7	-11	-12	-17	-26	-6	-84	-83	-19	-21	-5	-2
12-Aug-09	St.	1	-1	-1	4	-6	6	6	6	0	-3	4	5
23-Sep-09	St.	0	0	2	3	9	12	2	3	5	3	12	11
4-Nov-09	St.	2	4	3	1	-4	-4	-3	-3	9	8	-2	-5
10-Aug-10	St.	-1	3	2	0	-15	-9	-14	-15	1	2	-10	-7
27-Aug-10	BS	1	-2	-4	-4	2	5	0	4	-4	-4	8	6
21-Sep-10	St.	0	0	1	-1	-27	-24	-8	-29	-1	-1	-21	-24
12-Oct-10	Min.	1	3	4	3	13	17	2	5	3	3	16	14
15-Oct-10	BS	1	0	-2	1	-2	0	9	9	-3	-2	0	1
3-Nov-10	St.	-1	1	0	-2	2	23	-8	-5	0	1	21	18
22-Jun-11	St.	-1	0	0	-2	-10	-8	-4	-4	1	1	-10	-9
21-Sep-11	St.	-2	-1	4	4	-11	-30	-38	-69	-1	1	-9	-14
20-Jun-12	St.	0	0	-1	-1	-1	-2	1	0	-2	-2	-6	-7
22-Aug-12	Min.	0	-2	-2	-1	-1	-1	-26	-29	-2	-2	-3	-4
13-Sep-12	St.	-1	2	2	1	5	3	-32	-41	2	1	5	2
12-Dec-12	St.	-2	2	-1	0	1	2	2	14	1	0	0	-2
18-Sep-13	St.	-1	-2	-2	-2	-1	0	-11	-7	-2	0	4	4
18-Dec-13	St.	-3	-2	-2	1	-2	-6	-4	-1	-1	-2	-17	-10
29-Jan-14	St.	0	0	0	0	0	1	-2	-1	0	0	1	1
19-Mar-14	St.	-1	1	1	1	0	-1	-7	-5	-2	-4	-8	-8
30-Apr-14	St.	-1	-1	-2	-2	-2	0	-7	-5	4	1	-2	-3
18-Jun-14	St.	-1	1	-1	-1	1	1	-4	-3	-1	2	4	3
30-Jul-14	St.	0	-2	-1	0	1	0	7	8	5	6	-1	0
17-Sep-14	St.	-2	0	0	1	2	1	-4	-4	-4	-2	-1	0
29-Oct-14	St.	-2	1	1	0	0	-2	-4	-3	0	0	-10	-4
Total		**-15**	**-9**	**7**	**-1**	**-94**	**-30**	**-269**	**-326**	**-72**	**-73**	**-42**	**-49**
QE1		-2	-8	11	3	-64	-8	-131	-160	-65	-70	-12	-13
QE2		1	3	-2	-4	-22	13	-10	-20	-3	-2	14	6
MEP		-2	-1	4	4	-11	-30	-38	-69	-1	1	-9	-14
QE3		-12	-3	-5	-2	4	-2	-91	-77	0	0	-28	-21
SD events		2	5	7	10	11	9	21	22	9	9	9	9
SD all		1	3	4	6	6	6	10	10	5	5	6	6

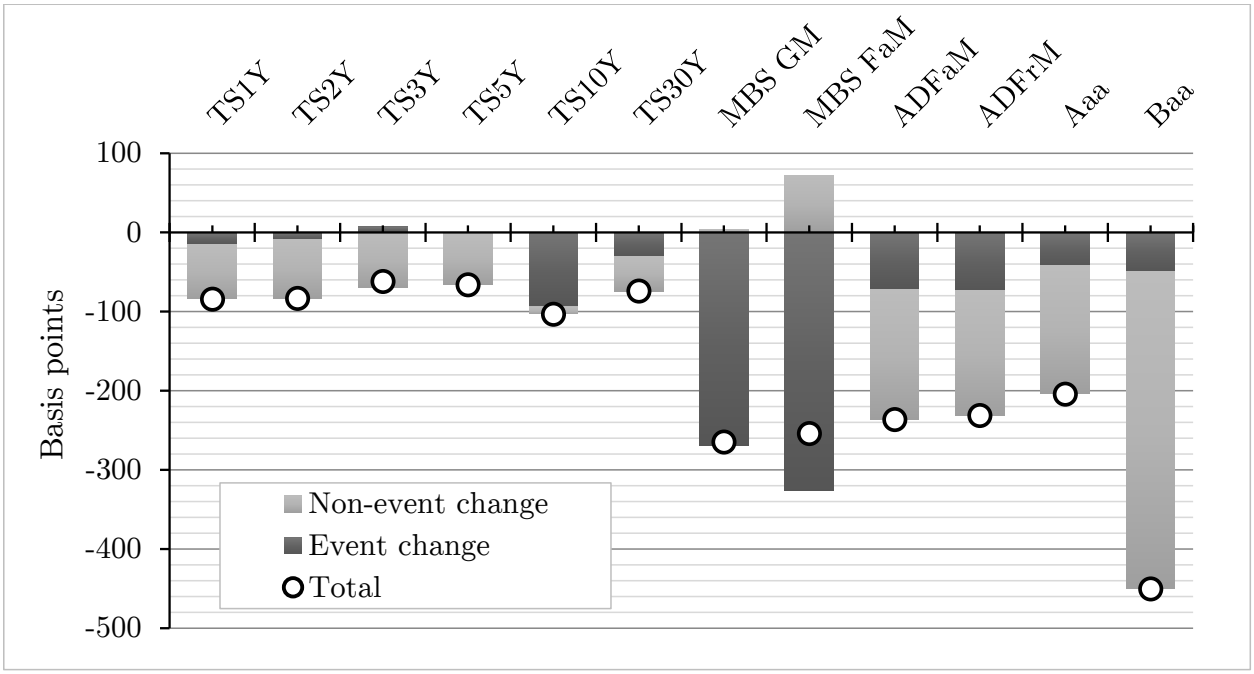
Note: GM stands for Ginnie Mae (The Government National Mortgage Association), FaM stands for Fannie Mae (The Federal National Mortgage Association) , FrM stands for Freddie Mac (The Federal Home Loan Mortgage Corporation); Source: author's.

Cumulative changes in yields represent the overall effect of QE news explicitly published in announcements and speeches. The biggest impact is noticeable in MBS where announcements severely affected this market. The drop of yields in MBS around 300 bp, around 150 bp in QE1, can be accounted not only to signaling and portfolio-balancing effects but, in contrast to TS, also to improvements of market functionality caused the by FED participation. Hancock and Passmore (2011), for instance, mention a clearer government backing of the MBS market. The MBS market was paralyzed for a long time after a burst of the property price bubble and this did not improve until the FED embarked on this market. Cumulative yield change in Treasury securities segment is the most noticeable at 10Y, and not surprisingly, exactly in this segment the FED realized most of its purchases. a noticeable decrease in yield of 30 bp is present in 30Y, especially at a time of the MEP when the FED announced its intention to buy rather Treasury securities with longer maturities. The important assumption-confirming finding is a presence of the biggest effect in initial phases of QE when market subjects had no exact idea of the consequences of QE, a fairly unconventional measure at that time. A key finding is the fact that a large difference in changes of the yields of 10Y and short Treasury securities (2Y and 3Y) in turn means that the change was caused mainly due to a reduction of term premium rather than by explicit commitment to hold FFR low for the "extended period" of time as mentioned in FOMC statements concerning the policy rate guidance. Changes in yield of Moody's seasoned corporate bonds Aaa and Baa indices suggest that the FED actions had overflowing effect on other financial markets in a way which is in line with the portfolio balance hypothesis.

Studies that examine this theme using various methods found out that purchases undertaken by the FED had some effect on yields of Treasury securities – as for 10Y TS during QE1 the drop of yield is in the range from 13 bp according to Hamilton and Wu (2010), through 39 bp according to Doh (2010), 45 bp according to D'Amico and King (2010), 60 bp according to Mayer (2010), 91 bp according to Gagnon et al. (2010) and to 107 bp according to Neely (2010). This study, with the method used, falls by its results of 64 bp in the yield drop of U.S. Treasury 10Y in QE1 somewhere in the middle as for the strength of quantified effect. In comparison with the conventional monetary policy, the reduction of Treasury securities yields with a remaining maturity 10-15Y about 50 bp would be equivalent to 200 bp reduction in FFR, as Meaning and Zhu (2011) claim.

For QE2 events the impact was 22 bp, in D'Amico and King (2010) and in Krishnamurthy and Vissing-Jorgensen (2011) it was 55 bp and 33 bp respectively. The MEP caused change of 11 bp, Swanson (2011) came with 15 bp. QE3 brought no clear effect in segment of Treasury securities, only in MBS and corporate bonds. That is probably the consequence of the fact that QE3 involves the tapering process and the fact that market participants were broadly familiar with QE in that time.

Figure 2.2: Cumulative changes in yields



Source: author's; Note: AD stands for agency debt of stated agency; Units: basis points.

Figure 2.2 depicts cumulative changes in yields across markets from the initial announcement in November 2008 to the end of asset purchases in October 2014. It is obvious that yields fell greatly during that period and changes induced by the FED purchases can be accounted only for a part of it, especially in Treasury securities markets with longer maturities and the MBS market. a significant impact is also visible in the agency debt and corporate Aaa and Baa debt markets, but only as a contributor to the overall impact, which was visibly influenced by other factors. That was the FED's intention, after all, to affect the long end of yield curve and to support investments of individuals and companies. The rest of yields decline in these markets can be accounted to lower expectations of future FFR and improved conditions on financial markets with regaining trust and lowering risk premium. What is also important to mention is a possible effect of the European debt crisis approximately in years 2010 to 2012 when sovereign bonds in the EMU were under the pressure and U.S. and UK bond markets acted as a safe haven as mentioned in Stracca (2013). Therefore, there was possibly upward pressure on both sovereign and corporate bond prices that could further enhance full potency of asset purchases in the U.S., which would be consistent with the findings of this paper. It is visible especially in the market for corporate bonds where QE-related effects are accountable only for a part of yield decrease overall. Equity markets were also possibly affected in the opposite direction by the European debt crisis, especially with downward pressures on excess returns in the financial sector.

The weak point of the event study approach is the fact that there can still be other effects captured in two-day event window and that movements in the prices of analyzed instruments during the event window could be partially caused by instrument-specific events and shocks. Therefore, VAR-IRFs modeling was applied in the following section to find out the impact and the persistence of large scale asset purchases of the FED in a different manner.

2.5 Impulse-response analysis

To determine a possible relations and impacts across the time of the time-series of yields of purchased assets classes and QE time-series that capture the strength of QE announcements, two structural vector autoregressive models (SVARs) were used in this section. Due to the fact that it is difficult to describe relations amongst all variables in an easy not-restrictive way without imposing heavily binding assumptions of the model and that the a priori determination of exogeneity, or rather endogeneity is also questionable. Hence VARs in this section were used to allow approach all variables as endogenous and the extension for impulse response functions (IRFs) since they can give us the information about the size and persistency of the impact of the shock in one variable on the other. IRFs measure the effects of a one SD shock induced by one endogenous variable to another endogenous variable.

All components of both SVARs are stationary – first differences of data time-series were used for all non-stationary data time-series. As for the appropriate lag lengths, the Hannan–Quinn information criterion (HQIC) and the Akaike information criterion (AIC) were applied and VARs were subsequently constructed as VAR(5) and VAR(6). In VAR(5) there are eight and in VAR(6) there are six variables marked from y_{1t} to y_{8t} and y_{1t} to y_{6t}, respectively, where current values of variables depend on a specific combination of the previous k values of all variables and error terms. Constructed VAR(5) in general form can be written as:

$$\begin{pmatrix} y_{1t} \\ \vdots \\ y_{8t} \end{pmatrix} = \begin{pmatrix} \alpha_{10} \\ \vdots \\ \alpha_{80} \end{pmatrix} + \begin{pmatrix} \beta_{11} & \cdots & \beta_{18} \\ \vdots & \ddots & \vdots \\ \beta_{81} & \cdots & \beta_{88} \end{pmatrix} \begin{pmatrix} y_{1t-1} \\ \vdots \\ y_{8t-1} \end{pmatrix} + \ldots + \begin{pmatrix} \phi_{11} & \cdots & \phi_{18} \\ \vdots & \ddots & \vdots \\ \phi_{81} & \cdots & \phi_{88} \end{pmatrix} \begin{pmatrix} y_{1t-5} \\ \vdots \\ y_{8t-5} \end{pmatrix} + \begin{pmatrix} u_{1t} \\ \vdots \\ u_{8t} \end{pmatrix}$$

(2.7)

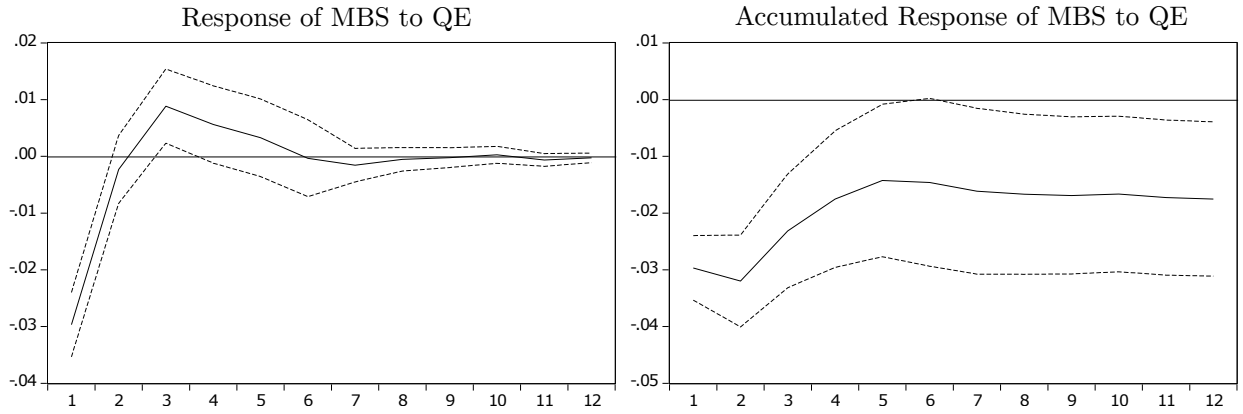
where u_{it} is a white noise disturbance with $E(u_{it}) = 0$, $(i = 1, .., 8)$ and $E(u_{1t} \ldots u_{8t}) = 0$ and $k = 5$ in the case of VAR(5). The second estimated VAR – VAR(6) is estimated accordingly in the same manner with $k = 6$. Stability of VARs was tested for a unit root where the unit root was ruled out with the Augmented Dickey-Fuller test (ADF). For calculating the IRFs, the correct ordering of the variables is important because IRFs refer to a unit shock to the errors of only one equation, other equations error terms in the VAR are being held constant. Orthogonalised impulse responses are generated for variables according to the explicit ordering to avoid issues stemming from the fact that error terms are likely to be correlated in the VAR. Therefore, Cholesky adjusted ordering was used in both VARs to avoid this possibility.

VAR(5) captures relations between QE announcements expressed by the total amount of announced purchases – SOMA holdings of Treasury securities, MBS and agency debt, yield

changes of the very same assets purchased by the FED and the OIS rate of corresponding maturity. VAR(6) captures relations between yield changes of purchased assets, the OIS of relevant maturity, and other assets that are being considered to be an investment alternative for portfolio-balancing decision taking investors such as corporate bond yields and total return of the equity index Russell 3000. Both VARs were estimated several times with a different structure of maturities of involved variables according to the structure of purchased assets and only the most representative ones were chosen in the following IRF discussion. The Granger Causality test indicates strong evidence of lead-lag interactions between the series of VAR(5) where the yields of TS ($TR10Y$), MBS (MBS) and agency debt (AB) show causality at 5% significance to the series that captures QE announcement (QE). For VAR(6) the test indicates evidence of causality from the yield of Treasury securities with the remaining maturity of 10+ years ($TR10Y$) to commercial bonds yields with the remaining maturity of 10+ years ($C10Y$) and the total return series of the Russell 3000 index ($R3000$) that represents the U.S. equity market at the 10% significance level. On the contrary, the Granger Causality test did not show causality from $R3000$ and $C10Y$ to MBS yields.

Obtained IRFs for constructed VAR(5) are as follows:[15]

Figure 2.3: Response of MBS yield



Source: author's model output results (EViews).

The responses of Treasury securities, MBS and agency debt yields to the shocks in QE announcements derived from VAR(5) are short-lived and disappear within a few days, which is caused by the high efficiency of the TS market.[16] The IRF and accumulated IRF of MBS yield is presented above in Figure 2.3 as a representative for all assets purchased because IRFs are more or less the same in shape for all involved asset classes. It is clear from these

[15] Responses / accumulated responses to Cholesky one SD Innovations ± 2 SE

[16] U.S. Treasury backed debt securities market is the most liquid sovereign bond market especially in the segment of 10 year maturity. E.g. daily average volume traded on CME 10Y on the run futures is ca. 800 thousand lots.

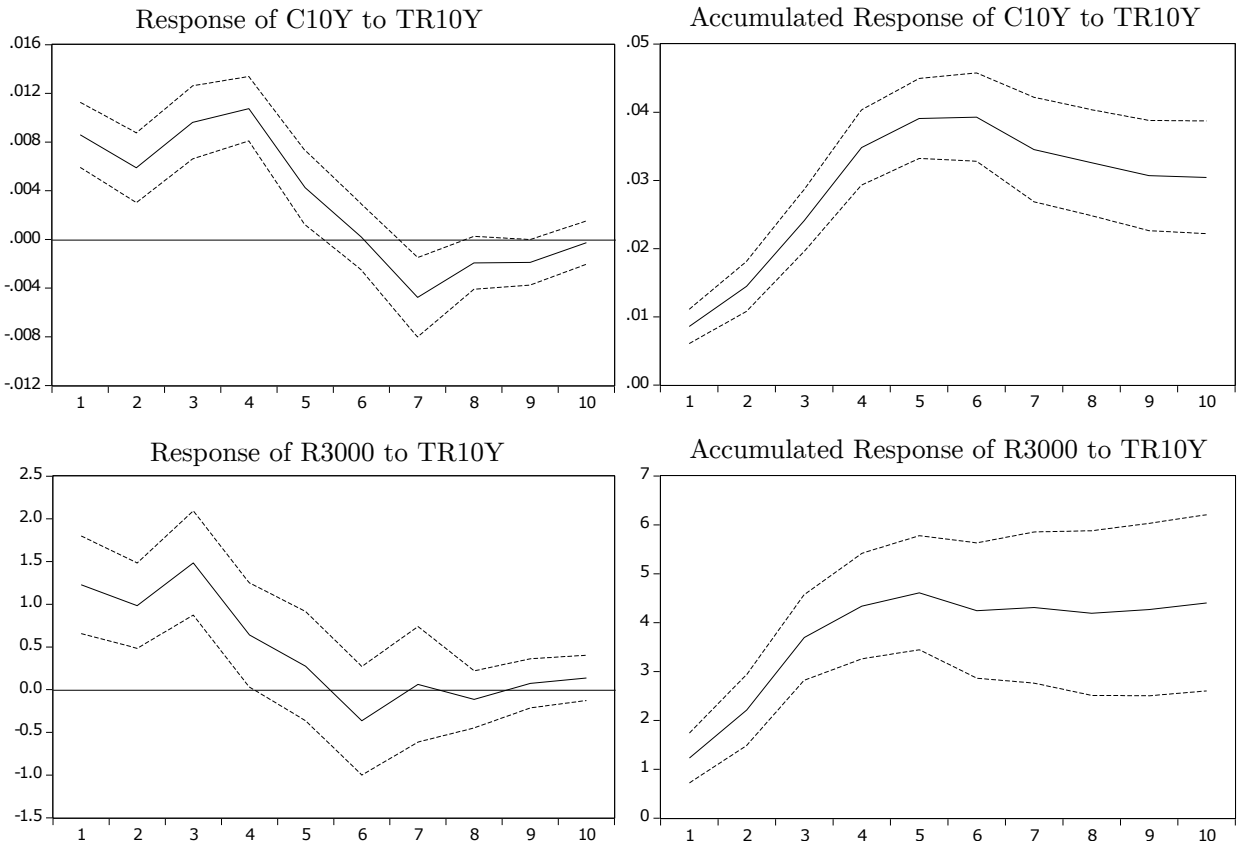
responses that announcements had some measurable effect on MBS yields – one SD shock in time-series of QE (39.4) has the initial impact of around 3 bp which means that in the case of the 25th of November 2008 it could induce yield shift of 45 bp for MBS. For Treasury securities and agency debt it is 1.3 bp and 1 bp, respectively, which would mean ca. 20 bp and 15 bp, respectively, as of the 25th of November 2008 QE announcement.

As for SOMA holdings, the IRFs did not show any clear effect which is probably caused by weekly frequency of FED-provided data that is not high enough to supply all other variables with daily frequency and by the fact that the amount of U.S. Treasury backed federal debt securities grew faster than before and therefore the FED purchases of Treasury securities could be partially offset. An important finding, which is in line with assumptions stated in the previous section, is the fact that OIS IRFs provide no unambiguous evidence of QE announcement impact on these rates that represent the benchmark for credit risk-free IRs in the economy. The possible explanation is that the signaling channel of future accommodative monetary policy that arises from QE announcements did not play the strong role in days of announcement. Future accommodative monetary policy was apparently communicated well enough before the beginning of QE and was already well reflected in OIS. This strengthens the assumption about a greater importance of the effects such as the portfolio-balance effect in yield changes during the event study two-day window, mentioned in the previous section, and reduces the possible impact of the component, which captures premium determined by uncertainty regarding future interest rates within the maturity of OIS and consequently Treasury securities.

Obtained IRFs for constructed VAR(6) follow in Figure 2.4.[17] IRFs and accumulated IRFs of 10Y corporate bond yield (*C10Y*) and the Russell 3000 total return index (*R3000*) are presented Figure 2.4. There is virtually no response for both to the one SD shock in QE announcements derived from VAR(6). That would suggest that announcements of QE had no direct effect on alternative assets in portfolio-balance framework and that the imminent signalling effect is absent and the whole pressure on yields of these assets was induced entirely through TS yields, as it is observable in IRFs of *C10Y* and the *R3000* to one SD shock in *TR10Y* in Figure 2.4. One SD shock in series *TR10Y* (0.063) has initial impact around 1 bp which means that in the case of the Bernanke speech of the 1st of December 2008 it could induce the yield shift of 5.6 bp for *C10Y*. For the *R3000* it is 1.3 index points which would mean ca. 7.2 ip (index points) as of the 1st of December 2008. The effect of one SD shock in the QE announcement time-series disappeared within six days in both cases.

[17] Responses / accumulated responses to Cholesky one SD Innovations ± 2 SE

Figure 2.4: Responses of alternative assets yields



Source: author's model output results (EViews).

All IRFs show some evidence of the impact of examined QE events that are in line with model assumptions. Treasury yields were affected by these events and this effect quickly fades off, as one would expect in the highly efficient Treasury securities market. Alternative assets' yields are affected through change in TS yield, which speaks in favor of the portfolio-balance channel. Signalling and other channels of transmission could also be present, but their identification and the separation of one from another is rather complicated and can be only assumed within the limited boundaries of the model used.

2.6 Conclusions

The event study and SVAR analysis undertaken in this study revealed significant impact of the FED's announcements concerning the QE on U.S. Treasury yields and an intermediary impact of these changes on other assets in the economy, namely corporate bonds and equity indices represented by the Russell 3000 total return index. The FED virtually overcame the limitations of its conventional monetary policy and used this unconventional measure to further ease credit conditions in the economy beyond the standard framework. The event study showed the different impact of particular announcements on Treasury securities, MBS and agency bonds yields in different phases of the QE program – the calming effect of the FED's interventions on the MBS market in the early stages of the program and the shifting of the effect on Treasury securities with longer maturities during the MEP is clearly observable. Tapering announcements of the QE meant no surprise for market participants and these announcements were apparently highly expected. The following VAR model and IRFs showed intermediated QE impact on other yields in the economy and its persistency – this shows some indirect evidence of portfolio-balance effect, but the possible role and strength of various transmission channels is unclear due to the nature of the model and its limited ability to uncover these relations.

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Chapter 3

The True Nature of the Portfolio Balance Channel of Quantitative Easing Policy[1]

Abstract: *This paper analyses the effects of the ECB's Public sector purchase programme (PSPP) on portfolios of the Eurozone investors. The ECB claims that the PSPP works mainly through the portfolio balance channel when the conditions on the asset markets are changed by the presence of a bidding central bank and investors are under those conditions forced to reallocate their portfolio to the state that better corresponds to ECB-changed market conditions and their preferences. This paper incorporates counterfactual analysis approach rather than analysis of direct change of prices and yields of given assets and uses sectoral data regression analysis of asset holdings of different investors in the Eurozone. This study addresses questions regarding size and direction of investors' reallocations – what types of investors were acting as the main counterparts to the ECB on the market for government bonds and what asset classes were preferred and chosen as an alternative by investors in the Eurozone to reallocate their funds. The series of obtained regression estimates and counterfactual analysis graphic representation answer to questions mentioned above and identify a nonnegligible effect of the PSPP on the rebalancing of government bond portfolios towards riskier corporate bonds and equities across investor types in major Eurozone countries.*

Keywords: ECB, Portfolio Balance Channel, PSPP, Quantitative Easing

JEL classification: E52, E61, G11, E65

[1]JAKL, J. (2019). The True Nature of the Portfolio Balance Channel of Quantitative Easing Policy, Review of Economic Perspectives. Vol. 19, Issue 2, pp 95-117. This work was supported by the project IGA F1/18/2017 Makrofinanční stabilita a finanční cyklus v zemích s negativní čistou investiční pozicí.

3.1 Introduction

Monetary policy of the main central banks around the world changed significantly after the late 2000s and early 2010s so-called Great Recession. The Federal Reserve System (FED), the European Central Bank (ECB), the Bank of England (BoE) and others followed the path of unconventional monetary policy in the form of asset purchases trying to affect prices and yields of purchased assets and reestablish proper functioning of dysfunctional markets in the short run and reach its main objectives of price stability in the long run. In the European Union (EU) followed the episode of European debt crisis since the end of 2009, when several Eurozone member states (Spain, Portugal, Ireland, Greece, and Cyprus) were unable to manage repayments of their government debt and to bail-out the domestic deeply indebted commercial banks. In the wake of these and following events, the ECB established several unconventional programmes dealing with emerged problems. Among other measures, that are mentioned in the next section of this paper, the ECB introduced its Public sector purchase programme (PSPP). The PSPP was officially introduced to help the ECB to achieve its primary objective of maintaining price stability.[2] It was designed to ease monetary and financial conditions in the Eurozone and to improve the borrowing conditions for non-financial corporations and households, supporting aggregate consumption and investment spending and ultimately contributing to return of inflation rates to desired levels close to the ECB's 2% goal.

While the officially presented goals of the PSPP and its implementation are clear, the academic debate still goes on about how the policy of quantitative easing (QE) works and what transmission mechanism stands behind it. ECB policymakers repeatedly emphasized the role of the so-called portfolio balance channel as the main transmission channel that leads from asset purchases to the ECB monetary policy final goal embodied in price stability, see e.g. Cœuré (2017). Many academic papers examine the portfolio balance channel indirectly by analyzing the effects of asset purchases on prices and yield changes of purchased assets rather than by analyzing direct portfolio reallocations of investors and other market participants. The goal of this paper is to disclose portfolio balance channel nature by focusing on the regression sectoral analysis of the various types of investors and to identify and estimate the strength of the possible effects of the ECB's asset purchases undergone via the PSPP on the real portfolio reallocations between different asset classes.

To what extent did different types of investors reallocate their portfolios as a reaction to ECB's bond purchases? What type of investor was the main counterpart to the ECB on the market for government bonds? Into what asset class did different types of investors in the Eurozone reallocated their funds while facing changes in bond markets caused by the ECB's purchases? Were portfolio changes induced by the PSPP towards more risky assets?

[2] In that time the inflation was well below the target, under 1% whole 2014, reaching its low 0,3% in November.

These questions constitute the core questions tackled in this paper. This study follows the counterfactual analysis approach presented by Pesaran and Smith (2012) and uses the regression analysis of sectoral data of asset holdings provided by the ECB and the Eurostat. The study also incorporates the ex-ante and the ex-post impact measurement presented e.g. by Joyce, Liu and Tonks (2014) to investigate portfolio rebalances from the different perspective and in more detail and to tackle this issue using the counterfactual analysis that provides a more suitable way to access the PSPP. Counterfactual type of analysis is suitable in cases when one would need to know and evaluate what would otherwise have happened, for example in the no-QE scenario. Analysis carried out in this paper enriches the existing academic research by originally using tailored counterfactual sectoral analysis approach on portfolio changes in the Eurozone rather than using asset prices/yields changes and by including of the ex-ante and the ex-post analysis on the ECB's asset purchases answers the above-mentioned QE-related research questions.

The rest of this paper has the following structure: the second section introduces the asset purchase programmes (APP) of the ECB and the theoretical framework of the portfolio balance channel and explains why it could work as policymakers present it. The third section describes empirical methodology and data used in this analysis and its limitations followed by the fourth section presenting the results of the sectoral analysis of portfolio reallocations and their discussion.

3.2 Asset purchases and the Portfolio balance channel

The ECB's asset purchase programme

In the first wave of exceptional steps taken by the ECB in order to face economic and financial disturbances in 2009, there were undertaken liquidity-providing long-term refinancing operations (LTRO)[3] and introduced the first Covered bond purchase programme (CBPP).[4] The CBPP was the first programme classified by the ECB in the so-called Asset purchase programmes (APPs), which is basically quantitative easing (QE) directed by the ECB representing only insignificant part of the ECB's balance sheet till the introduction of the following APP in 2015. These measures already followed some preceding monetary policy tentative response measures taken already in 2008. In 2010 followed the Securities Markets Programme (SMP)[5] and the second CBPP in 2011 (CBPP2).[6] The second wave of measures taken in and after 2014 began with Targeted longer-term refinancing operations (TLTROs)[7] in the segment of open market operations and the third CBPP (CBPP3)[8] in the segment of Asset purchase programmes (APPs).

The Governing Council of the ECB decided on 22nd of January 2015 that undergoing asset purchases should be expanded by including a secondary market public sector bonds and introduced its expanded asset purchase programme. As a core programme was introduced the Public sector purchase programme (PSPP) aiming at sovereign Eurozone bonds, introduced on 4th March 2015, see ECB (2015). The PSPP is furthermore a central subject regarding this paper. Factors leading to the introduction of the PSPP, mentioned by the ECB, include lower than expected monetary stimulus from adopted monetary policy measures and a downward drift in actual and expected euro area inflation. In March 2015, the Eurosystem member banks initiated purchases of eligible assets on secondary markets, and by the end of 2018, the total Eurosystem holdings were over two trillions EUR.[9] The pace of the monthly PSPP

[3]For details of the LTRO ECB's decisions see decisions of the Governing Council of the European Central Bank from 7th May 2009 and 8th December 2011.

[4]The CBPP was aimed at euro-denominated covered bonds issued in the euro area. For details of the CBPP ECB's decisions see Decision (EU) 2009/522 of the European Central Bank of 4th March 2015 on the implementation of the covered bond purchase programme.

[5]The SMP was aimed at euro-area public and private debt securities markets to ensure its depth and liquidity. For details of the SMP see Decision (EU) 2010/5 of the European Central Bank of 14th May 2010 on the establishing of a securities markets programme.

[6]For details of the CBPP2 see Decision (EU) 2011/744 of the European Central Bank of 3rd November 2011 on the implementation of the second covered bond purchase programme.

[7]For details of the TLTRO ECB's decision see Decision (EU) 2014/34 of the European Central Bank of 29th July 2014 on measures relating to targeted longer-term refinancing operations and Decision (EU) 2016/10 of the European Central Bank of 28th April 2016 on a second series of targeted longer-term refinancing operations.

[8]For details of the CBPP2 see Decision (EU) 2014/40 of the European Central Bank of 15th October 2014 on the implementation of the third covered bond purchase programme.

[9]Intended allocations were roughly 90% of the total purchases to the government bonds and recognized agencies, and 10% to securities issued by international organizations and multilateral development banks.

purchases and the length[10] of the programme were changed several times when the original monthly pace was €60 billion from March 2015 until March 2016, €80 billion from April 2016 until March 2017, once again €60 billion from April 2017 to December 2017 and €30 billion since January 2018 till the December 2018.[11] In 2016 the ECB also introduced the Corporate sector purchase programme (CSPP) aimed this time at a corporate bond issued by the Eurozone non-financial corporations, see ECB (2016) for details.

While all figures mentioned above sum the PSPP together with other programmes under APP, mainly with the CBPP3 and the CSPP, the PSPP accounts by far for the greatest share of monthly purchases always exceeding 80% of all purchases. The ECB uses the capital key for purchases among the member states of the EMU, which implies that large, economically significant countries with lower debt to GDP ratio and high population (Germany for instance) have the relatively highest ratio of the ECB-bought assets to the total government debt. Eligibility criteria requirements were set to a rating of BBB or better with remaining maturity from 2 to 30 years. Another condition imposed in December 2016 was that yield to maturity of purchased bonds must exceed deposit lending rate of the ECB. There was also the limit of 33% on the outstanding issued debt of a sovereign and 25% on a particular issuance.

Transmission of monetary policy asset purchases

In recent academic papers, there are mentioned many possible channels through which the unconventional policy of QE could work however with connection to asset purchase programmes of the FED, the BOE or the ECB the channel of portfolio balance reallocation is always emphasized by policymakers and is being given leading role over the others.[12] The portfolio balance channel is formally described in many papers e.g. in D'Amico and King (2010), Hamilton and Wu (2011) or Gagnon et al. (2011) and abundantly mentioned by central banks representatives e.g. Bernanke (2010).[13] Transmission of the portfolio balance channel is going through relative changes in asset prices with respect to the prices of its investments alternatives. When the ECB buys government bonds from investors in the

[10] Originally planned for 18 months, extended in December 2015 to March 2017, in August 2016 extended to December 2017 and finally extended in October 2017 until the end of 2018. For details see amending decisions of the ECB 2015/33, 2015/48, 2016/8 and 2017/1.

[11] With further intentions *"...to continue reinvesting, in full, the principal payments from maturing securities purchased under the APP for an extended period of time past the date when it starts raising the key ECB interest rates, and in any case for as long as necessary to maintain favourable liquidity conditions and an ample degree of monetary accommodation."* See ECB (2018).

[12] Among other transmission channels are mainly important signalling channel and liquidity channel – both described e.g. in Krishnamurthy and Vissing-Jorgensen (2011).

[13] *"I see the evidence as most favorable to the view that such purchases work, primarily through the so-called portfolio balance channel, which relies on the presumption that different financial assets are not perfect substitutes in investors' portfolios. For example, some investors who sold MBS to the Fed may have replaced them in their portfolios with longer-term, high quality corporate bonds, depressing the yields on those assets as well."* – Ben S. Bernanke, Jackson Hole, August 27th, 2010, p 4.

Eurozone, preferably from non-bank private investors, it comes with an increase of broad money holdings in the economy and upward pressure on prices of purchased assets.

At the beginning of this process investors have portfolios that correspond to their own holding preferences in the given time – the composition of assets, the portfolio duration, its liquidity, the riskiness of assets held, its yield, regulatory framework, tax regime and other characteristics and this state is eventually affected by the ECB's asset purchases and must inevitably lead to transformation of these portfolios given the changed conditions. The state of the world for investors is different than it was before the beginning of the ECB's purchases. The ECB's counterparts sell long-term, profit-yielding assets with limited liquidity for the short-term, high-liquid asset that yields no profit. Investors are not forced to sell any assets to the ECB, but they are highly motivated to do so by the prospect of short-term profit gains stemming from the fact that prices of the assets bought under the APP are on the rise. This in turn naturally leads to a rebalancing process when the investors who initially sold part of their holdings of government bonds to the ECB stand before the question of where to put their money.[14] The money they received from the bond sale in the environment of different types of available investment opportunities characterized in the first place by different level or riskiness, duration, and yield they bear. The programmes of the ECB as the PSPP and later the ECB's Corporate sector purchase programme (CSPP) are designed to lower yields on government and prime corporate bonds and consequently lower credit premia required by investors in the segments of less attractive alternative investment assets. This mechanism could consequently lower the funding costs for small and medium-sized enterprises (SMEs) and households (which is directly intended by ECB) and for less sound governments (not officially admitted by the ECB)[15] and other subjects in the Eurozone. Together with the rise of asset prices, the net wealth of asset holders rises as well. Thus, both mentioned effects then stimulate the real economic activity and consequently lead to upward pressure on inflation.

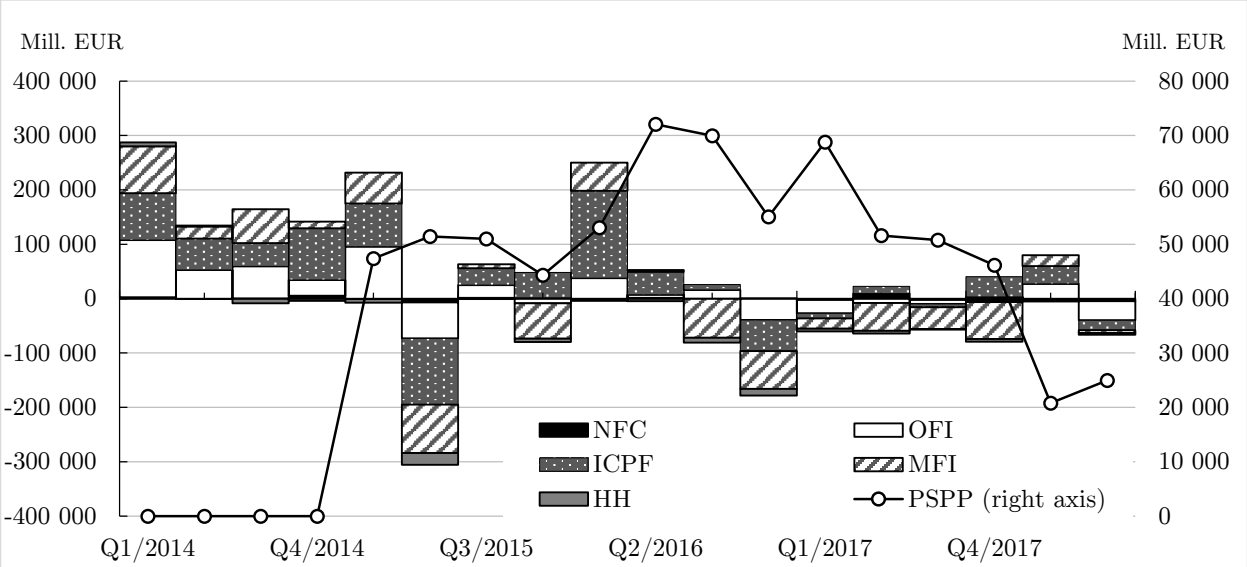
The portfolio balance channel can in theory, under certain circumstances, work in several different ways – for instance in the environment of efficient markets the announcement of APP itself would induce an instantaneous reaction in the bond markets when the price would rise up to the level that corresponds to expectations of future availability, respectively prices of ECB-targeted assets. The price through the time afterward would be linearly moving upwards, which would be caused by the prospect of the future ECB purchases and the necessity for the asset holders to be rewarded for their willingness to hold the asset just for a time till it is bought by the ECB, see D'Amico and King (2010) for detailed view. Through

[14]Under the condition that money is not being seen as the perfect substitute to investment assets that could be bought during the portfolio rebalancing.

[15]In fact, that was probably the main reason, why the capital outflow from Italy and Spain reached its maximum, it was most likely caused by the purchases carried out by Banco de España and Banca d'Italia. These purchases would be a part of capital outflows accounted for in the balance of payments and would also be transferred through the local central banks' purchases to the ECB as their uncovered liability in TARGET 2.

price increase in the benchmark portfolio bonds bought by the ECB and the reduction of availability of these bonds on secondary markets, this would lead to higher investors' willingness to buy other riskier bonds on the secondary markets or a higher demand for newly issued government and corporate debt securities and consequently lowering the funding costs of their issuers. Substitution for other assets caused by asset purchases done by the central bank and other real effects are covered in Krishnamurthy and Vissing-Jorgensen (2011). In reality, however, the notoriously slow adjusting of portfolios of institutional investors, the novelty of APPs at the beginning and the lack of details about eligible bonds and possible tapering options or future parameter changes of purchase programmes moved the theory incorporating market efficiency miles away from praxis. A revaluation of bond prices was undoubtedly present in the time of the PSPP announcements, but this mixture of signals about QE, the future path of conventional rate-setting monetary policy and liquidity-providing programmes to commercial banks didn't really cause that much movement which would imply the theory mentioned above. Reality working differently and with more complexity allows us to use an analysis based on regressions over sectoral asset holdings data. Quarterly net changes in portfolio holdings for the main types of investors and the ECB's net purchases since 2014/Q1 are depicted in Figure 3.1. below for illustration:

Figure 3.1: Quarterly PSPP and investors' net Government bond purchases



Source: ECB, author's; NFC stands for Non-Financial Corporations, ICPF stands for Insurance Corporations and Pension Funds, HH stands for Households, OFI stands for Other Financial Institutions, MFI stands for Monetary Financial Institutions and PSPP stands for the Public sector purchase programme; Units: currency; Currency: EUR.

The reasons that repricing of purchased assets is not instantaneous and rather slow, dependent on persistent ECB's purchases, is that markets are far from being perfectly efficient, asset holders are slowly changing its portfolio of assets, and economic subjects other than the central bank (CB) must be necessarily convinced about the CB's intentions. The lack of information about the ECB's purchases and the presence of information asymmetry among the Eurosystem member banks undertaking the APPs and investors regarding frequency of purchases, timing, and structure of purchases leads to slower repricing as well. The central bank is in fact by its decisions to undertake its QE policy signalling its future intended rate path and under the Ricardo-de Viti-Barro equivalence, the QE could be effective only by convincing the public.

Academic research and publications on asset purchases

Theory incorporating relevance of the asset supply side is developed in the preferred habitat investors model presented in Modigliani and Sutch (1966), Vayanos and Vila (2009), Greenwood and Vayanos (2014) or Christensen and Krogstrup (2015). The instantaneous part of the asset QE-induced price changes of targeted assets can be assigned to the signalling channel, described e.g. in Krishnamurthy and Vissing-Jorgensen (2011), D'Amico and King (2013), Gagnon et al. (2011), Glick and Leduc (2011) or Bauer and Rudebusch (2014), rather than to the portfolio-balance channel.

A working mechanism and empirical evidence of the portfolio balance channel is mentioned by policymakers' speeches, e.g. in Bernanke (2012) or in working papers e.g. in Haldane et al. (2016) or Gambeti and Musso (2017) and in variety of academic papers with a focus on different aspects of this channel. Christensen and Rudebusch (2012) for instance analyzed the direct instantaneous impact of the QE announcements of the FED and the BOE on government bond yields. Joyce et al. (2011) analyzed the UK asset price changes induced by the BOE asset purchases and found significant evidence for the portfolio balance channel.[16] Altavila et al. (2015) found that the impact of the ECB's asset purchases had a sizeable impact on asset prices. Using extended term structure model with bond supply effects and model-based predictions for cross-asset price movements associated with the transmission channels their estimated results indicate sizeable impact on long-term sovereign bonds, with yields declining by about 30-50 bp at the 10-year maturity for the implied euro area term structure, and by roughly twice as much in higher yield member countries such as Italy and Spain. Moreover, considering the non-targeted corporate bonds, they found a sizeable spill-over effect when corporate-sovereign spreads have declined by about 20 bp for both euro area financial and non-financial corporations.

[16]The APP of the BOE have depressed medium to long-term government bond yields by about 100 bp by the 02/2010, with the largest part of the impact coming through a portfolio balance effect.

The majority of other studies and those mentioned above examine the impact of asset purchases on prices or yields of asset classes rather than the direct impact on investment portfolios of important investors which are the key movers in the whole transmission mechanism of this monetary policy. Some of the latest are Arrata and Nguyen (2017) or Schlepper et al. (2017). Arrata and Nguyen (2017) tested on daily security-level data the impact of the PSPP on bond returns of French sovereign bonds. Their results showed that having purchased 10% of a bond outstanding correlates with a decrease in the yield of about 13 bp to 26 bp on average in the first year of the PSPP implementation. They however did not find any significant supplemental effect from flows of purchases. Schlepper et al. (2017) matched the high-frequency ECB's QE purchase data with high-frequency inter-dealer data on German government bonds and found economically significant price impacts at high (minute-by-minute) and low (daily) frequencies, highlighting the relevance of scarcity effects in bond markets. They argue that induced scarcity harms market liquidity conditions as measured by bid-ask spreads and inter-dealer order book depth.

Many existing studies dealing with portfolio allocations analyze different economies than the Eurozone, e.g., Joyce, Liu and Tonks (2014) for the UK, Carpenter et al. (2013) and (2015) for the U.S. or Hogen and Saito (2015) for Japan. Joyce, Liu, and Tonks (2014) examined how the BOE asset purchase programme affected via the portfolio balance channel the investment behavior of insurance companies and pension funds. Their counterfactual analysis is based on explanation of portfolio allocations by variables invariant to the QE monetary policy and their results suggest that QE of the BOE led institutional investors to shift their portfolios away from government bonds towards corporate bonds. Carpenter et al. (2013) and (2015) examined the Federal Reserve's asset purchase programme and on the flow of funds data assessed the types of investors that were selling assets to the FED and their portfolio adjustments after these sales. Their goal was to uncover possible effects described by the preferred habitat theory and the transmission of unconventional monetary policy across asset markets. Their findings were that the FED was buying from only a handful of investor types, primarily households, with a different reaction to changes in the FED holdings of long-term versus short-term assets and that the key participants were rebalancing their portfolios toward more risky assets.

Other studies analyze the ECB's asset purchases impact on specific market segment, e.g. Albertazzi, Becker and Boucinha (2018) analyzed 25 largest euro area commercial banks, providing evidence of an active portfolio rebalancing channel. They argue that "search for yield" mechanism is an important part of the transmission of purchase programmes, as it implies that the monetary stimulus is passed-through onto sectors which do not hold nor issue eligible securities and therefore do not directly benefit from the programme itself. The results of their study indicate that *"... in more vulnerable countries, where macroeconomic unbalances and relatively high risk premia remain, APP was mostly reflected into a rebalancing towards riskier securities. In less vulnerable countries, where constraints*

on loan demand and supply are less significant, the rebalancing was observed mostly in terms of bank loans."[17] A different perspective than this study followed Koijen et al. (2018) or Bua and Dunne (2017) focusing on quantifying changes in risk concentration by investor type across countries in the Eurozone using data on security-level portfolio holdings by investor type across the Eurozone countries. Their instrumental variables estimator showed that the average impact on bonds decreased yields about 13 bp. Moreover, they did not find large portfolio shifts towards other assets such as corporate bonds or equities in the euro area.

An alternative view on asset purchases of central banks raise moral hazard concerns about a possible reduction of incentives to restructure the banking sector and to make reforms of fiscal policy to hold it self-sustainable in the long term. Cúrdia and Woodford (2011) expressed the concerns about the incentives to investors to take higher risks by switching to riskier assets and to take high leverage. Brunnermeier and Sannikov (2014) or Coimbra and Ray (2019) described the possible mechanisms of these negative phenomena that could accompany the QE policy. Coimbra and Ray for instance claim that when monetary policy rates are low, a further stimulus can increase aggregate risk while inducing a fall in the risk premium – there could be a trade-off between stimulating the economy and financial stability.

[17] Albertazzi, Becker and Boucinha (2018, p. 1)

3.3 Empirical methodology and data

Regression model

The core of the portfolio balance process of an individual investor, his portfolio changes and asset flows among different asset classes for the whole sector is a simple utility optimization of economic agents. Mathematic interpretation is basically the maximization of the value of the expected utility function tomorrow with respect to portfolio asset allocations that are being made today. Formally written as:

$$\max \mathrm{E}[U(x_{1,T+1}, \ldots, x_{n,T+1}, L_{T+1})|T], \tag{3.1}$$

where $(x_{1,T}, \ldots, x_{n,T})$ represent the market value of agent's available assets with different characteristics, that can be chosen in the portfolio decision making in given time and space. Every asset type $x_{i,t}(c_1, c_2, \ldots, c_n)$ has its own unique characteristics $c_1, \ldots, c_n$ that represent e.g. duration, liquidity, riskiness, yield, regulatory framework, tax regime etc. L_T represents the sum of liabilities of the same agent (market value of investor's debt owed to other subjects). L_T can be also decomposed to different types of liabilities with its own unique characteristics as it is for different assets.

Constraints of this optimization problem are as given:

$$\mathrm{E}\left(\sum_{i=1}^{n} x_{i,T+1}|T\right) = \sum_{i=1}^{n} x_{i,T} R_{i,T}. \tag{3.2}$$

Representing the expected market value of the sum of the whole portfolio holdings, where $x_{i,T}$ is the value of i-th asset held in time T and $R_{i,T}$ is the forthcoming return of i-th asset over one period.

Expected market value of the debt for given portfolio holdings is then:

$$\mathrm{E}(L_{T+1}|T) = L_T \mathrm{E}_T(R^L_{T+1}), \tag{3.3}$$

where $\mathrm{E}_T(R^L_{T+1})$ is the expected liability growth ration over one period incorporating expected return – expected liability in time $T+1$ will then be equal to liabilities in time T multiplied by this ratio and finally:

$$\mathrm{E}\left(\sum_{i=1}^{n} x_{i,T+1}|T\right) - \mathrm{E}(L_{T+1}|T) \geq C_{T+1}|T, \tag{3.4}$$

where $C_{T+1}|T$ represents required capital in time $T+1$ derived from the value of capital C_T known in time T and required yield from own capital for period t. Together, it gives

us reasonable initial assumptions about funding sources at the beginning of this decision-making process. The simplified solution of this optimization problem, when we assume not risk-loving agent and optimized relation of assets and liabilities among periods (balanced funding / same market value of assets and liabilities), gives us optimal demand function:

$$f_T^* = f^*(R_T, \nu_T, \Sigma_T^x, \kappa_T), \tag{3.5}$$

where ν_T is the vector of values of the whole portfolio, Σ_T^x is the variance covariance matrix of the asset returns for each investment asset and κ_T is the vector of higher-order moments.

This solution of utility optimizing problem would allow us to construct a structural model upon consumer theory to derive the portfolio reallocation model incorporating the demand function for investment assets. Non-linearity and dynamics in such a model would be difficult to construct correctly and to interpret accurately – this paper, therefore, follows a different approach of the counterfactual analysis advocated in Pesaran and Smith (2012).

The counterfactual analysis is based on the conditional model incorporating parameters which are invariant to the change in the monetary policy decision being studied, e.g., the ECB's decisions about asset purchases in this case. The baseline model for explaining investors' behavior as a reaction to the PSPP purchases on the sectoral level is defined as:

$$y_t^i = \alpha^i + \beta_p^i p_t + \beta_{w_1}^i w_{1,t} + \cdots + \beta_{w_n}^i w_{n,t} + \epsilon_t^i, \tag{3.6}$$

where the dependent variable y_t^i stands for the net acquisition of asset i held by the given investor in time t and regressors include p_t that represents the central bank policy (in this case the net acquisition of government bonds) over time period t and the invariant variables $w_1, \ldots, w_n$ that in the first place affect the dependent variable and on the other hand are to some extent invariant to the policy change captured in the first regressor. A problem-specific form of the equation (3.6) for the given problem of this paper is therefore given as:

$$y_{I,t}^i = \alpha_I^i + \beta_{I,p}^i p_t + \beta_{I,iss.}^i issuance_t + \beta_{I,i.r.}^i inv.regressors_t + \epsilon_t^i, \tag{3.7}$$

which is the regression equation for the portfolio of investor I, asset i, over time t with the specific invariant regressors that include government bonds issuance and other invariant regressors. The list of invariant regressors includes issuance of the given type of purchased asset (in this case the PSPP-eligible government bonds denominated in EUR), the U.S. Treasury 10Y benchmark yield, the U.S. government-corporate high yield spread[18], the S&P 500 total return index and the U.S. Economic policy uncertainty index (EPU).[19] All these variables on the list are fairly invariable to the monetary policy changes in the Eurozone, on

[18]Stands for spread between the U.S. Treasury 10Y benchmark yield and the U.S. government-corporate high yield represented by the Bloomberg Barclays U.S. Corporate High Yield Total Return Index.

[19]The Economic Policy Uncertainty Index represents the measurement of policy-related economic uncertainty constructed from three types of underlying components: newspaper coverage of policy-related

the other hand the expected invariance would not be absolute due to advanced globalization and worldwide character of portfolio investment opportunities.

The second set of data used in this study is compiled from several Eurozone holdings statistics provided in monthly and quarterly frequency by the ECB and the Eurostat, namely the MFI holdings of securities statistics[20], the Securities holding statistics (SHS)[21] and the Integrated euro area economic and financial accounts[22]. The Securities holding statistics is a valuable source of information about the structure of debt security holdings across the Eurozone countries and different types of investors, collected on a security-by-security basis and broken down by instrument type, issuer country, and further classifications. Asset segments analyzed within the framework of this paper are governmental bonds issued in the Eurozone – both in EUR and non-EUR currencies, government bonds issued outside the Eurozone held by investors with the Eurozone domicile, corporate bonds issued in the Eurozone, corporate bonds issued outside the Eurozone held by investors with the Eurozone domicile and listed equity shares and investment fund shares held by investors with the Eurozone domicile.[23] All the above mentioned statistics provide a firm set of data about asset allocations of various types of investors in the Eurozone and allow us to cover estimated sectoral regressions with the sufficient set of data.

Invariant variables allow us to control for variety of possible factors that may have some impact on portfolio reallocations – sovereign PSPP-eligible bond issuance covers supply side on primary market; U.S. Treasury 10Y benchmark yield covers possible effects of unsynchronized monetary policy of the ECB and the FED and investment tendencies between the U.S. federal and the sovereign Eurozone bonds; S&P 500 total return index covers development on equity markets and its inverse relationship to bond markets; and the Economic policy uncertainty index covers policy-related economic uncertainty on markets. All time series used in this paper are in the form of net change between periods in given units – millions of EUR as for series representing the PSPP purchases and asset holdings, in basis points change for time series representing yield changes and in index point changes in case of the S&P and the EPU. By focusing solely on net asset holdings changes it is more straightforward and problems with the passive recomposition of holdings due to valuation

economic uncertainty, number of federal tax code provisions set to expire in future years and disagreement among economic forecasters as a proxy for uncertainty. Sectoral classification is based on the ESA 2010.

[20]The MFI holdings of securities statistics contains monthly data about the holdings of debt securities, equity and non-MMF investment fund shares of MFIs in the Eurozone excluding the Eurosystem. Classification of this statistics is based on the ESA 2010. Data cover of this statistics is in range 09/1997 - 08/2018.

[21]The Securities holding statistics contains detailed quarterly data about the holdings of debt securities of different holders in the Eurozone. Data cover of this statistics is in range 12/2013 - 06/2018.

[22]The integrated euro area economic and financial accounts contain monthly sectoral data of the opening and closing balance sheets of financial assets and liabilities of the individual sectors of the Eurozone economy. Data cover of this statistics is in range 06/1999 - 06/2018.

[23]Issuance variables of government bonds include all types of bonds – nominal and inflation-linked issuances.

changes can be omitted. Time series data are not additionally adjusted for the possible impact of valuation effects, while it is being considered to be implicitly contained in investors' decisions that are well aware of all elements that have some impact on the yield of their portfolio and take this impact into account in the decision process. Unfortunately, it is not possible to separate in an easy way (other than by comprehensive questionnaire) the elements of their decision-making and to access them per se.

The expected results of the equation (3.7) according to the economic theory would suggest following beta values for government bond holdings of private investors: $\beta^i_{I,p} < 0$, which would mean that asset purchases of the central bank of given asset p_t caused rebalancing of investors' portfolios towards other types of assets; $\beta^i_{I,iss.} > 0$, which would mean that positive net issuance of government bonds ($issuance_t$) causes increase of investors' government bond holdings, however, this effect should be smaller compared to pre-QE times due to smaller share of government bonds on the secondary markets available to private investors; and individual elements (betas) of matrix $\beta^i_{I,i.r.}$ should be either > 0 or < 0 depending on the nature of the particular invariant regressor ($inv.regressor_t$) – e.g. for the net change of value of the S&P500 Index the expected estimation of beta should be < 0, because equity indexes are negatively correlated with the price of the government bonds since the late 1990s, see e.g. Baz et al. (2019). It is also reasonable to assume that the sum of estimated beta parameters of all investor types for government bonds would be close to -1 ($\sigma^n_{i=1}\beta^{gov.bond}_{i,p} \approx -1$). It can be claimed intuitively that for each unit of government bonds purchased by the ECB, there should be one unit sold by other market participants to the ECB.[24] Beta values should be different for the investors' corporate bond holdings and equity holdings: $\beta^{corp.bonds}_{I,p} > 0$ and $\beta^{equity}_{I,p} > 0$, which would mean that government bond purchases of the central bank p_t caused rebalancing of investors' portfolios towards other types of assets (corporate bonds, equities and possibly other asset types that are not involved in this study).

[24]This assumption fully holds under the condition of zero net issuance of government bonds and in case of net issuance $0 < / > 0$ deviates accordingly.

Counterfactual analysis

Counterfactual graphic analysis of ex-ante and ex-post impacts[25] of the PSPP that follows the regression results in section 3.4 is formally defined in the following equations (3.8) and equations (3.9). For ex-ante approach as:

$$\begin{aligned} PSPP_{ex.a._{T+l}} = & E(y_{T+l}|y_T, p_{T+l}, issuance_{T+l}, inv.regressors_{T+l}, \Omega_{full.sample}) \\ & - E(y_{T+l}|y_T, 0, issuance_{T+l}, inv.regressors_{T+l}, \Omega_{full.sample}), \end{aligned} \tag{3.8}$$

where the ex-ante impact of the PSPP is derived from the difference between the expected outcome of variable y_{T+l} estimated according to equations (3.7) and the same variable in the no-PSPP scenario with $p_{T+l} = 0$, both estimated over the full sample starting in the time T (Q1/2015). Graphic representation of ex-ante impact therefore starts on following Figures 3.2, 3.3 and 3.4 in time of the beginning of the PSPP. The ex-post approach is formally defined as:

$$PSPP_{ex.p._{T+l}} = y_{T+l} - E(y_{T+l}|y_T, 0, issuance_{T+l}, inv.reg._{T+l}, \Omega_{subl.sample}), \tag{3.9}$$

which is the difference between the reality and the no-PSPP scenario estimated from the same equation (3.7) over the sub-sample data ending by the time of the PSPP beginning in Q1/2015.

Methods used in this paper, theoretically described above, by its nature does not allow to control for all other possible factors that may have had been nonnegligible and may have some impact on the portfolio rebalancing phenomenon. It would be overcomplicated and uneasy to develop and to interpret a system of linear regression equations incorporating for example slow-changing preferences of investors together with the wide investor-based perception of the relative safety of sovereign bonds of different European countries and external factors. One of the known external factor is e.g. sale of China's public sector debt holdings in the same period corresponding to this analysis. It would probably not yield better results and control for explicitly mentioned factors in this analysis seems to be convenient for its goals.

[25] For similar use of this analysis of asset purchases in the United Kingdom see Joyce et al. (2014).

3.4 Sectoral analysis of portfolio reallocations

Detailed regression results estimated upon equations (3.7) for Monetary Financial Institutions (MFIs), the crucial counterpart of the ECB and representative of investors, are reported below in Table 3.1. This model is based on the monthly Integrated euro area economic and financial accounts data and the MFI holdings of securities statistics described in the preceding section. Each column in Table 3.1 and Table 3.2 represents one regression outputs estimated on variables stated in the first column and corresponding asset type stated in the first row. Each regression estimate in Table 3.1 and Table 3.2 includes variables described in preceding section – the PSPP variable representing the ECB's purchases, issuance variable representing net issuance of given underlying bonds (relevant to a given type of dependent variable → changing in some regressions), invariant variables described in the previous section and the lagged dependent variable (LDV) to capture possible dynamic effects.[26] All models presented below in this study were estimated by OLS, while t-statistics and standard errors (SE) of all coefficients are based on Newey-West robust estimation of the covariance matrix[27] to overcome possible autocorrelation and heteroskedasticity in the error terms in the presented models. N-W kernel function heteroskedasticity- and autocorrelation-consistent (HAC) estimators of the variance-covariance matrix can bypass the issue of serially correlated error term ϵ_t^i. Kernel choice is based on Andrews (1991), where he has found a HAC that minimizes the average root mean square error (AMSE) of the "long-run variances" (LRV). Regressions presented in Table 3.1 and Table 3.2 were also estimated with respect to findings of Keele and Kelly (2006) – they argue that under certain conditions it is viable to use OLS (or GLS) with corrected standard errors with autocorrelated data and that the LDV can provide estimates that are superior to the other models or estimators. Inclusion of LDV is appropriate so long as the stationarity condition holds for the dependent variable, which holds for our model (dependent variables are stationary). The nature of the models in this study however does not imply direction between variables and presented regression estimates are merely directionless and based upon the spread of data points from the regression line (curve). Therefore, only possible relations supported by the relevant economic theory are mentioned in the following discussion of model results.

Statistically significant results from estimated regressions are presented in Table 3.1 and Table 3.2, showing that reactions of MFIs to the ECB's PSPP purchases are negative – one unit bought by the ECB was accompanied by the decrease in MFIs holdings of government bonds (denominated in EUR) by 0.25-unit. The different pattern applies for corporate bonds (denominated in EUR), where one unit bought by the ECB was accompanied by an increase in MFIs holdings of about 0.26-unit / 0.19-unit and in equity holdings, where 0.12-unit increase could have been caused.

[26] LDV was not included in regressions presented in Table 3.3 and Table 3.4.

[27] Appropriate truncation lags for Newey-West are based on the AIC automated selection rule.

Table 3.1: MFIs' net acquisitions of assets regression results (1)

	Gov.bonds EUR	Gov.bonds non-EUR	Gov.bonds non-EUR	Corp.bonds EUR	Corp.bonds EUR
Constant	2994	195	134	6375**	1157
	(-1.3)	(-1.32)	(-1.02)	(-2.35)	(-0.63)
ECB PSPP	**-0.25*** **	-0.001	-0.003	**-0.26** **	**-0.19***
	(-4.05)	(-1.14)	(-0.73)	(-2.25)	(-1.74)
Issuance Gov. EUR	0.06	-0.004		-0.04	
	(-0.88)	(-1.13)		(-0.41)	
Issuance Gov. non-EUR			-0.14*		
			(-1.76)		
Issuance Corp. EUR					**0.32*** **
					(-6.32)
Issuance Corp. non-EUR					
US Gov. 10Y Yield	**-135.13** **	-2.56	-3.87	**-135.6** **	-114.56*
	(-1.93)	(-0.54)	(-0.79)	(-2.12)	(-1.88)
US Gov. - Corp. Spread	**-68.59*** **	**-3.06** **	**-3.21** **	-16.9	-5.53
	(-3.22)	(-2.05)	(-2.22)	(-0.46)	(-0.31)
S&P500	-28.39*	**-5.14*** **	**-4.57** **	-32.42	-17.73
	(-1.66)	(-2.61)	(-2.3)	(-1.3)	(-0.84)
US EPU Index	-46.77	**11.49** **	**13.1** **	-208.25*	-180.89*
	(-0.55)	(-2.05)	(-2.3)	(-1.72)	(-1.6)
LDV	-0.02	-0.12	-0.12	**0.27*** **	0.12*
	(-0.35)	(-1.14)	(-1.04)	(-2.97)	(-1.69)

Note: sample period 10/1997 - 08/2018; T-statistics reported in parentheses are based on Newey-West heteroskedasticity consistent standard errors. *, **, *** indicates significance at the 90%, 95%, and 99% level, respectively. Number of observations: 249; Source: author's.

Table 3.2: MFIs' net acquisitions of assets regression results (2)

	Corp.bonds non-EUR	Corp.bonds non-EUR	Equity
Constant	625** (-2.1)	747*** (-2.41)	2801 (-1.56)
ECB PSPP	-0.005 (-0.35)	-0.004 (-0.32)	**-0.12*** (-2.9)**
Issuance Gov. EUR	0.01 (-1.1)		0.08* (-1.69)
Issuance Corp. non-EUR		0.025 (-1.13)	
US Gov. 10Y Yield	36.7* (-1.73)	34.55* (-1.68)	29.18 (-0.3)
US Gov. - Corp. Spread	6.66 (-1.53)	6.57 (-1.5)	-23.75 (-1.26)
S&P500	-6.34 (-1.48)	-7.05* (-1.64)	**69.22*** (-3.43)**
US EPU Index	**-37.08** (-2.17)**	-38.77¨(-2.38)	-16.37 (-0.29)
LDV	**-0.16*** (-2.85)**	**-0.17*** (-2.85)**	0.04 (-0.86)

Note: sample period 10/1997 - 08/2018; T-statistics reported in parentheses are based on Newey-West heteroskedasticity consistent standard errors. *, **, *** indicates significance at the 90%, 95%, and 99% level, respectively. Number of observations: 249; Source: author's.

The overall picture shows that the ECB's purchases could have caused MFIs to reduce government bond holdings and reallocate their own portfolios towards corporate bond and equity holdings. The relative increase was smaller for corporate bonds and equities compared to the decrease in government bond holdings. The results are not statistically significant for bond holdings denominated in non-EUR currencies.

In the second set of estimated regressions presented in Table 3.3, there are presented all major private investor types. Investor types included in Table 3.3 are as follows: Monetary Financial Institutions (MFI), Insurance Corporations and Pension Funds (ICPF), Other Financial Institutions (OFI), Non-Financial Corporations (NFC), Households (HH) and Non-Residents. Local and central governments from the Eurozone were excluded from all analysis in this paper to focus solely on the private sector. Model results presented in Table 3.3 are based on the quarterly Securities holding statistics data. Each row in Table 3.3 represents estimated regression results for one type of investor with changing the dependent variable (portfolio asset class) stated in the first row of each column. Each regression estimate was constructed on the same set of explanatory variables as it was in Table 3.1 and Table 3.2 (except the LDV), but in this case, only constant C and the estimates for variable representing the issuance of government bonds and the PSPP-variable coefficients are presented for better results' clarity.

Table 3.3: Investment portfolio reallocations regression results

		Gov.Bonds [EMU]	Corp.Bonds [EMU]	Gov.Bonds [Worldwide]	Corp.Bonds [Worldwide]	Equity [Worldwide]
MFI	C	28346	-55803***	6057**	14.359***	-1005
		(1.9)	(-6.6)	(2.4)	(4.9)	(-1.1)
	Issuance	0.2 (1.4)	0.01 (0.1)	0.06*** (5.2)	-0.05** (-2.9)	0.01 (0.3)
	PSPP	**-0.36*** **	0.21***	-0.04**	**0.06** **	**0.03** **
		(-6.8)	(4.4)	(-2.2)	**(-2.9)**	**(2.6)**
ICPF	C	39125**	4963	-2436	6494	17063
		(2.5)	(0.9)	(-0.7)	(9.7)	(0.9)
	Issuance	-0.01 (-0.4)	-0.03 (-0.6)	0.04 (1.5)	0.02** (2.7)	0.4* (1.7)
	PSPP	**-0.17** **	-0.00	0.02***	0.01	0.06
		(-1.9)	(-0.1)	(2.8)	(1.3)	(1.5)
OFI	C	49671***	14861	2453	25293	27684
		(4.8)	(1.6)	(0.5)	(4.6)	(1.4)
	Issuance	0.03 (0.4)	0.12 (2.1)	0.002 (0.1)	0.006 (0.1)	0.13 (1.0)
	PSPP	**-0.32*** **	-0.05	**0.08***	-0.03	-0.14
		(-13.1)	(-1.5)	**(1.6)**	(-0.4)	(-1.2)
NFC	C	671 (1.4)	-2087 (-0.8)	-169 (-1.2)	27 (0.2)	3071 (1.15)
	Issuance	-0.02 (-0.2)	-0.003 (-0.2)	-0.001 (-0.8)	0.004 (1.4)	0.02 (0.3)
	PSPP	**-0.01**	0.01***	0.002	0.01***	-0.02
		(-0.2)	(3.2)	(1.5)	(3.7)	(-1.3)
HH	C	-3832***	-31822	25	-1388**	34806
		(-5.9)	(-0.01)	(0.5)	(-2.4)	(1.4)
	Issuance	0.01 (0.3)	0.002 (0.0)	0.0 (0.4)	-0.007 (-0.7)	0.17 (1.4)
	PSPP	**-0.02*** **	0.05	-0.001	**0.02*** **	**-0.25***
		(-4.8)	(0.01)	(-0.4)	**(21.3)**	**(-1.8)**
Non - Residents	C	43783***	69946*			
		(3.2)	(2.1)			
	Issuance	0.26 (1.2)	-0.46 (-1.4)			
	PSPP	**-0.66*** **	**0.21***			
		(-4.9)	**(2.2)**			

Note: sample period 03/1999 - 06/2018; T-statistics reported in parentheses are based on the Newey-West heteroskedasticity consistent standard errors. *, **, *** indicates significance at the 90%, 95% and 99% level, respectively; Source: own model estimations; Source: author's.

Statistically significant results in Table 3.3 show that reactions across all types of investors to the ECB's PSPP purchases are the same – accompanied by reduction of their own holdings of government bonds and increase of holdings of different types of assets. The strongest possible reactions to the ECB's bond purchases are present in the estimated parameters for foreign holders (-0.66), MFIs (-0.36), OFI (-0.32) and through a weaker reaction of ICPF (-0.17) to almost invariant HH (-0.02) and statistically insignificant NFC. One unit bought via the PSPP could have caused the majority of investors to shift its holdings of government bonds to corporate bonds, equities and possibly other kinds of assets that are difficult to trace and are not analyzed within this study (e.g. precious metals, real estates or intangibles).

Significant are especially portfolio reallocations of MFIs in corporate bonds segment (domestic and worldwide) and equities (investment fund shares, and listed shares), where one unit of the PSPP purchases was accompanied by net increase of 0.21 unit in corporate bonds and 0.03 in equities. These results are in line with preceding results presented in Table 3.1 and Table 3.2, estimated on a different set of data. The same pattern of reallocations from government bonds applies for corporate bond holdings of non-residents, also the very important counterpart of the ECB. For other types of investors, the portfolio reallocations towards corporate bonds and equity are not so unambiguous – they mostly exhibit similar, though not that significant, pattern with the exception of household's equity holdings that exhibit the decrease rather than the increase. Decrease of household's equity holdings could be the result of locking in the equity profit arising from the increase in equity prices. This could be the consequence of the ECB's asset purchases as well and it's not necessarily against the model expectations. The segment of foreign investors cannot be analyzed in equity holding segment due to lack of data on their asset holdings and unknown structure of assets abroad. Worldwide holdings of Eurozone-located investors show no strong pattern in relation to the ECB's purchases with some possible tendencies to shift portfolios more towards non-EU government and corporate bonds.

Coefficients estimated in Table 3.3 for the possible PSPP-induced changes in government bonds segment sum up together a number slightly higher than 1, which would be against intuition using the perfect model (someone would have to always buy what others sell) but is slightly overestimated given the model and data imperfections.

Table 3.4 shows estimated regression results for local investors' bond reallocations in four selected Eurozone countries that represent the most important countries in the Eurozone as for nominal GDP and population – Germany (the sovereign debt benchmark country), France and countries that face publicly-known fiscal challenges, Spain and Italy. Selection of countries mentioned above is traditionally used in academic research, see e.g. Altavila et al. (2015), and on the professional level, while their credit rating[28] differs from benchmarked Germany (AAA), through France (AA/Aa2), Spain (A-/Baa1) to relatively lowest-rated Italy (BBB/Baa3).

[28]Credit rating provided by Moody's, Fitch and S&P.

Table 3.4: Investors' bond portfolio reallocations by country

		Germany	France	Italy	Spain
MFI	Gov. Bonds	**-0.28*** **	**-0.21*** **	**-0.52** **	**-0.32*** **
		(-6.98)	**(-10.48)**	**(-2.12)**	**(-2.77)**
	Corp. Bonds	**-0.27*** **	0.15	**0.36*** **	-0.03
		(-7.38)	(1.23)	**(3.2)**	(-0.24)
ICPF	Gov. Bonds	**-0.11*** **	**-0.21** **	-0.25	**-0.22*** **
		(-3.02)	**(-2.09)**	(-0.98)	**(-2.97)**
	Corp. Bonds	**0.03*** **	-0.03	0.03	**-0.11** **
		(3.77)	(-0.46)	(0.48)	**(-2.16)**
OFI	Gov. Bonds	**-0.14*** **	-0.11	**-0.65*** **	**-0.39*** **
		(-5.61)	(-1.43)	**(-4.01)**	**(-2.84)**
	Corp. Bonds	0.02	**-0.2** **	**-0.26***	-0.17
		(0.39)	**(-2.29)**	**(-1.64)**	(-1.61)
NFC	Gov. Bonds	-0.002	0.03	0.01	**-0.05*** **
		(-0.36)	(0.59)	(0.22)	**(-2.75)**
	Corp. Bonds	-0.002	0.01	0.02	-0.05
		(-0.5)	(0.7)	(1.27)	(-1.29)
HH	Gov. Bonds	-0.001	-0.002	**-0.15*** **	0.03
		(-0.76)	(-0.8)	**(-11.91)**	(0.8)
	Corp. Bonds	**0.04*** **	0.02	0.04	0.06
		(3.34)	(1.13)	(0.27)	(1.39)

Note: sample period 01/2014 - 09/2018; T-statistics reported in parentheses are based on Newey-West heteroskedasticity consistent standard errors. *, **, *** indicates significance at the 90%, 95%, and 99% level, respectively; Source: author's.

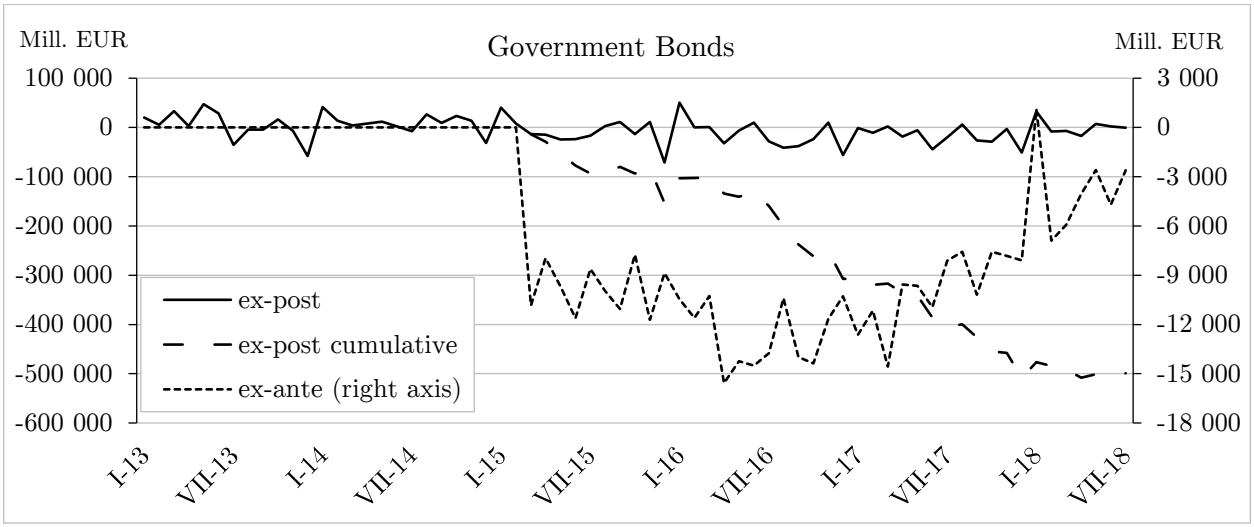
Model results presented in Table 3.4 are based on the quarterly Securities holding statistics (SHS) data described in the preceding section. For all countries, the PSPP purchases were undoubtedly accompanied by the decrease of local investors' sovereign bond holdings[29] – they were shifting portfolios from government bonds to other assets in this time period in relative terms. In Italy MFIs bought mainly corporate bonds and on the contrary in Germany the reaction was the opposite. German corporate debt segment is also being considered prime compared to other corporate debt in other EU countries and bears little yield. It was also targeted for the ECB's CSPP purchases and investors (mainly MFIs) were

[29]For all statistically significant results.

probably not willing to face these conditions and reallocated towards other assets that were not directly targeted by any APP. Eurozone investors are certainly not limited to invest only in assets within the Eurozone, there are plenty of investment opportunities abroad, e.g. in emerging markets. There are no results for equity investments because the SHS does not provide country-specific holdings data for equities, therefore only the results for government and corporate bonds are presented below.

Following figures (Figure 3.2 – Figure 3.4) contain the graphic representation of ex-ante and ex-post impact formally described in equations (3.8) and (3.9). Figures (Figure 3.2 – Figure 3.4) depict the PSPP ex-ante and ex-post impacts in three main asset classes held by MFIs as a representative type of investor. For other important investor types, such as ICPF or OFI, the graphic representations of ex-ante and ex-post impact are similar to MFIs, therefore only MFIs figures are presented below. The ex-ante impact is being measured as a difference between the QE and the no-QE monetary policy scenario, in this particular case as the PSPP and the no-PSPP scenario described in equation (3.8). The calculation incorporates net investment differences into specific asset class over the full sample period in scenario with (see equation (3.7)) and without the PSPP.[30]

Figure 3.2: Ex-ante and ex-post effects of the PSPP on MFIs' gov. bond holdings



Source: author's; Units: currency; Currency: EUR.

The ex-post impact is measured as a difference between the realized net investment flows and estimated no-PSPP counterfactual scenario formally defined in equation (3.9). Counterfactual scenario is estimated as a forecast from the out-of-sample data subset available before the implementation of the PSPP in 2015 (on data since Q4/1997). The same approach of counterfactual analysis was originally used and formally described by Pesaran

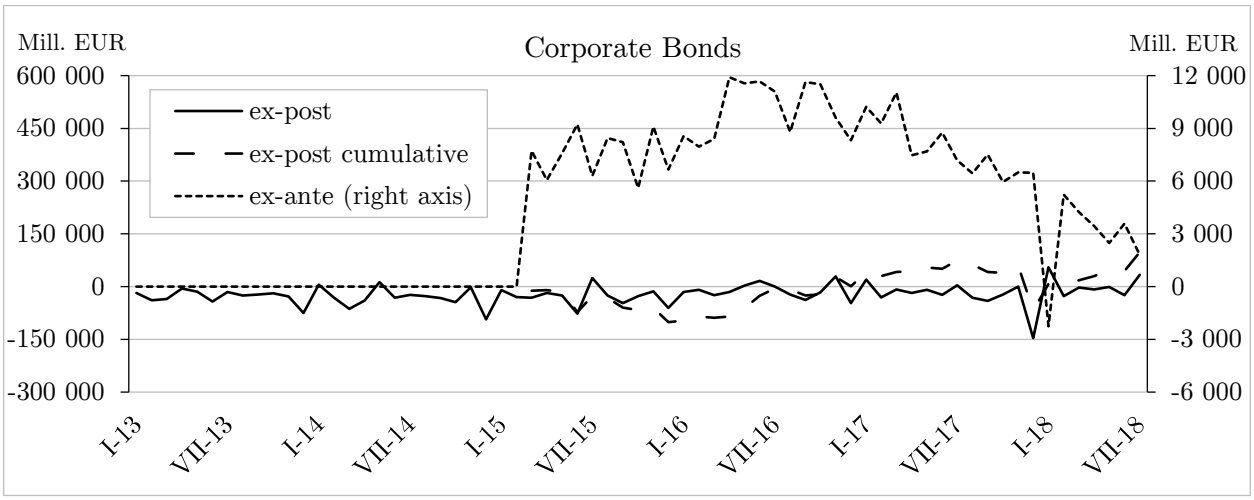
[30]There is no ex-ante impact till the beginning of the PSPP because there is no counterfactual.

and Smith (2012) on analysis of the QE adopted by the Bank of England. For convenience and easier interpretation of ex-post impact, the cumulative curve of ex-post impact, since the beginning of the PSPP, was also added in figures below.

It is clear from Figure 3.2 that for government bond holdings of MFIs the impact of the PSPP on their holdings was negative in both impact comparisons, ex-ante and ex-post. This fact suggests that the expected net investment flow of MFIs into government bonds was affected by the PSPP and would have been greater in the no-PSPP scenario. Figure 3.3 and Figure 3.4 both exhibit strong and positive ex-ante impact on corporate bonds and equity segments. At the same time, the cumulative ex-post impact in equities is a positive but rather small and ex-post impact in corporate bonds segment is ambiguous. This suggests that net investment flows of MFIs into corporate bonds and equities would have been weaker in the case of no-PSPP scenario.

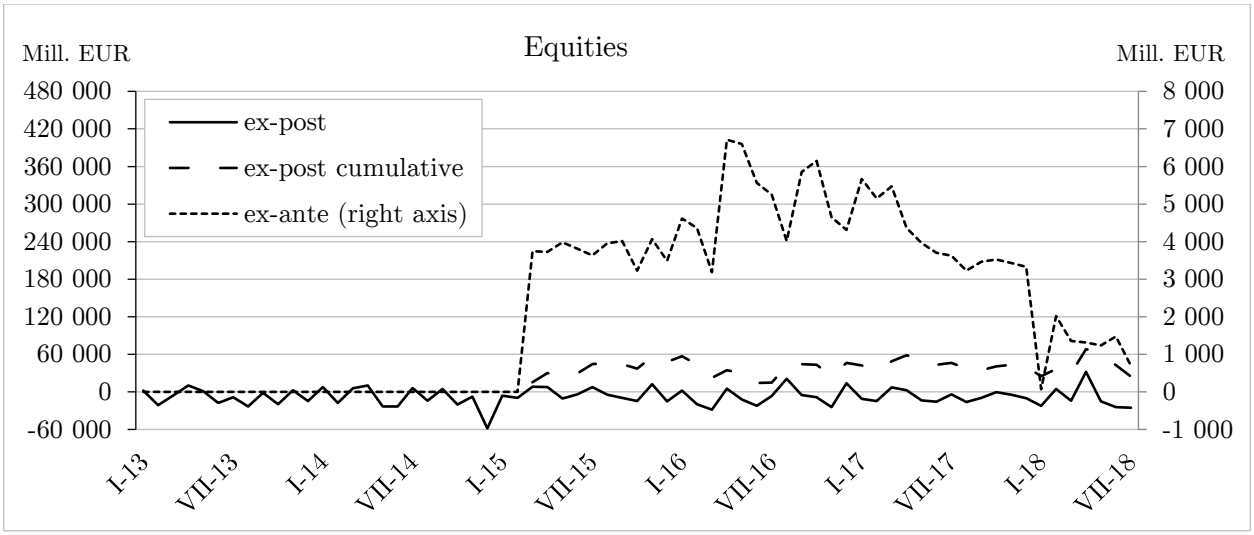
Estimated counterfactual ex-ante and ex-post impacts in all three asset segments are in line with the regression results in Table 3.3 and possibly imply that the PSPP had non-negligible portfolio-reallocation effect that was intended in the first place by the ECB when the PSPP was put in place. Results anticipated according to the economic theory explained in Section 3.3 are also in line with estimated results. Overall evidence of the counterfactual analysis shows that rebalancing of portfolios was significant towards corporate bonds and was accompanied by a reduction of allocation to conventional government bond portfolios.

Figure 3.3: Ex-ante and ex-post effects of the PSPP on MFIs' corp. bond holdings



Source: author's; Units: currency; Currency: EUR.

Figure 3.4: Ex-ante and ex-post effects of the PSPP on MFIs' equity holdings



Source: author's; Units: currency; Currency: EUR.

3.5 Conclusions

In this paper, the regression models and the counterfactual analysis provide evidence about the nature of the so-called portfolio balance channel that is being so frequently mentioned by the ECB in connection to its unconventional monetary policy programmes. The evidence is mainly consistent with the picture that is being presented by the ECB – all types of investors reshuffled its portfolios, selling government bonds to the ECB and buying different types of assets, mostly corporate bonds and equities (listed shares) and equity funds shares. The ECB by its PSPP simply changed conditions on the markets enough to motivate even portfolio notoriously slow-adjusting investors to undertake some steps in order to change their own portfolios to make it correspond their own preferences and current market prices and yields of available investment assets. The analysis showed that investors are quite willing to sell government bonds, particularly foreign investors and MFIs. The closest alternative investment asset classes are corporate bonds and equities and were verifiably bought more than would be in the case of no-PSPP scenario. There is an exception for buying corporate bonds in Germany, which is most likely given by its exceptional position as a government and corporate bond benchmark country with the most high-rated issues in both government and private sectors. The PSPP led to portfolio reallocations towards riskier assets and it is an open question whether the benefits of lower funding costs across the Eurozone, caused by the ECB's asset purchases, is justifiable facing the higher risk exposure of investors in the Eurozone. There is also always the question of why the ECB did not use some alternatives to quantitative easing – e.g. more conventional policy affecting the euro exchange rate by direct or indirect interventions or rather more technical solution by considering some kind of lowering its monetary policy rates even further and the costs and the benefits of each variant.

There are several possible ways of how to enhance this paper by additional research – adding control for other possible acting factors, that are beyond the scope of this analysis, e.g. for regulatory environment factor or widening the portfolio of analyzed assets that are difficult to trace and are not analyzed within this study (e.g. precious metals, real estate or intangibles). The Security holdings statistics used in this study also do not provide country-specific holdings data for equity issuers, it would be enriching to fill in this data gap in the future. Better data frequency and more detailed security holdings statistics and the ECB's statistics with longer history would provide better grounds for further research on the theme of portfolio purchase channel and other monetary policy channels that accompany unconventional monetary policy of quantitative easing. Nevertheless, the availability of data and the future APP tapering praxis of the ECB, characterized by a reduction of the ECB's balance sheet, is needed to approach the ECB's asset purchases as a closed issue in any following research.

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Chapter 4

The Outreach and Effects of the ECB Corporate Sector Purchase Programme[1]

Abstract: *This paper analyses the effects of the ECB's Corporate sector purchase programme (CSPP) on yields of the corporate sector bonds and its impact on the corporate sector's debt markets. The CSPP started as a part of the existing asset purchase programme and significantly affected corporate bond markets. Any research undertaken in this area of the ECB's respective actions is fairly limited by restrained access to data and its OTC nature. This paper analyses the CSPP effects by using two distinct methods – a detailed regression-controlled event study and an impulse-response analysis of constructed VAR models. This study addresses questions regarding time, size and place of effects caused by the CSPP on corporate bond markets and deals in detail with related issues and related economic theory backgrounds. Series of obtained sector, country and company-specific results gives us a picture of the non-negligible impact of the CSPP on purchased bonds and of the size and persistency of stock and flow effects of the ECB's actions.*

Keywords: Quantitative Easing, Corporate Bonds, Corporate Sector Purchase Programme

JEL classification: E52, E44, G12

[1]JAKL, J. (2019). The Outreach and Effects of the ECB's Corporate Sector Purchase Programme, Prague Economic Papers, Status: accepted for publication / not yet published. This work was supported by the project IGA F1/18/2017 Makrofinanční stabilita a finanční cyklus v zemích s negativní čistou investiční pozicí.

4.1 Introduction

The ECB's Governing Council in March 2016 decided to introduce the new part of the asset purchase programme (APP) alongside other well-established ones as e.g. the Public sector purchase programme (PSPP), the one targeting this time on corporate sector bonds – the Corporate sector purchase programme (CSPP). As an additional measure taken in order to ease funding conditions in non-bank corporate sector by lowering the yields of corporate bonds and thereby reducing the costs of funding. In June 2016 the CSPP came into power and by the end of 2017 total ECB's holdings were more than €130 bln. of securities.[2] Eligible universe consisted of over 1,400 issues with over €800 bln. face value of investment grade (IG) euro-denominated bonds issued by non-bank corporations. Purchases were planned to continue at least to September 2018 at a current monthly pace of €30 bln. As for impact on other than targeted markets we can mainly think of ineligible corporate bonds consisting of another €600+ bln.

Questions answered in this paper are: How much were bond markets affected, both eligible and ineligible? In what industry and country was the effect on yields the most significant? In what phase of the CSPP introduction was the effect on corporate bond yields measurable and what were the causes and consequences? Were companies from the Eurozone (EZ) motivated to raise bond issuance and restructure company debt exposure towards bond issuance rather than bank financing? What transmission mechanism probably stands behind it?

Due to limited accessibility of relevant data and analysis challenges, there is virtually no existing research on the CSPP going beyond very basic analysis of this programme. In this study, several methods are used to investigate the CSPP in more detail and to overcome problems arising from the fact that decisions on the CSPP are being made together with conventional rate decision, other APP programmes and they are wrapped in the forward guidance. Firstly, the controlled event study (ES) was used to examine immediate impact of the CSPP announcements, its implementation and effects of preceding discussion and expectations about this program on corporate bond yields. Secondly, the vector autoregression (VAR) model and its subsequent impulse-response functions (IRFs) were used to assess impact of ECB's activities on bond markets. And finally, analysis of estimated ECB's holdings shows yield changes in constructed synthetic corporate bond portfolios and gives us the picture about the funding costs of selected companies. All these approaches together also form a wider picture of possible stock and flow effects of the CSPP and provide us with more details on present transmission of monetary policy programmes aiming on asset prices.

[2]Secondary market purchases 85%, primary market purchases 15%.

4.2 The CSPP and its framework

Eligible conditions on bonds purchases in the CSPP are: non-financial companies with 6 months to 31 years to mature, denominated in euro, with investment-grade credit rating and with yield to maturity (YTM) not lower than the ECB deposit rate. Issue share limit is 70% per ISIN and issuer limit follows a predefined benchmark. Purchases were initiated by a monthly pace of €80 bln., changed to €60 bln. since April 2017 and the current pace of €30 bln. will continue until September 2018. All figures are for APP as a whole – mainly the PSPP and the CSPP. The ECB (2017) informed about CSPP purchases, that the monthly net purchases from June 2016 to May 2017 ranged between €4 bln. to below €10 bln.

Monetary policy today is characterized by affecting assets prices – targeted asset price changes transfer to other assets and ultimately affect, in the end, unemployment, inflation, GDP and other macroeconomic variables via complex system of relations. In the case of the APP it is targeting the sovereign and corporate sector bonds to change their price and yield. The effect of lowering the yields is being done by several different transmission channels – first of all, by signalling channel by announcement of the unexpected move of the central bank, where reaction of asset prices is more or less instant and depends on the credibility of a given central bank. When the ECB in March 2016 announced its intention to purchase corporate bonds beginning in June, the reaction on markets for these bonds was already present in the following days and weeks yet with no real actions of the ECB on markets. Signalling channel in the world of New Keynesian economics and Ricardian equivalence works only to extent how much the ECB is able to influence the expectations of an average economic agent regarding expected future path of its rates or expected effects of asset purchases. This channel is examined e.g. in Eggertsson and Woodford (2003) or Clouse et al. (2003).

The frequently mentioned transmission channel, with connection to asset prices, is the portfolio rebalancing channel, described e.g. in D'Amico and King (2010), Hamilton and Wu (2011) or Gagnon et al. (2011). It works through relative changes of nominal asset prices with respect to nominal prices of other assets that are being considered as an investment alternative. Investors initiate the portfolio-rebalancing process when they see opportunity to optimize better their own portfolio to bear maximal yield given the existing risks when the current portfolio yields are affected by external factors. Purchases of the ECB are designed to lower yields on prime corporate bonds and when they do, investors would demand lower credit premia in the segment of less attractive alternative investment assets, mainly in other corporate bonds. Money spent by the ECB to buy bonds goes through bond sellers to other segments of the market and possibly finds its way to issuers of other, less favored corporate bonds – the ECB is also aiming to lower funding costs for SMEs in the Eurozone.

Another possible channel of transmission, especially important in less liquid markets, is the liquidity channel, mentioned in Krishnamurthy and Vissing-Jorgensen (2011). The ECB by its presence on markets with lower liquidity, like markets for corporate bonds, supply

liquidity and represent possible counterparty for other investors and allows them to trade without additional costs caused by low liquidity. Liquidity premia is reduced, and investors more willingly hold these assets.

Another type of premia required from investor for holding the certain type of assets is term premia, depending on time to maturity of a given asset. Investors are simply on average risk-averse and holding bonds with 9 years to mature is simply not equivalent to holding repeatedly 3-year bond with the same coupon during those 9 years. The preferred habitat model developed by Vayanos and Vila (2009) and imperfect asset substitution problem (market segmentation) analyzed by Andrés et al. (2004) represent the fraction of various papers studying this type of premia. The ECB during CSPP implementation bought a part of corporate bonds with longer maturities and could have lowered the term premia on corporate bond markets. All three above mentioned types of premia are analyzed in section 4.5: "The Impact of the CSPP on corporate financing".

4.3 Event study analysis

Data and methodology

This section employs event study (ES) methodology to quantify the effects of CSPP-related events (ECB's monetary policy decisions and minutes, Governing Council members' speeches and main CSPP news) on yields of corporate bonds. Event study is frequently used by central banks and monetary policy researchers to tackle the effects of monetary policy, see e.g. Briciu and Lisi (2015), Joyce et al. (2012) or Altavilla et al. (2015). The tailored version of event study is employed in this paper to identify the effects of policy decision from other economic and political events. The similar approach is used e.g. in ECB (2017) for quantifying the effects of the announcements of non-standard measures from 2014–15, in that time with no focus on corporate bonds. Event study analysis considers all important CSPP-relevant events in 2016 and 2017. As for the correct time window for accessing the effect of related events the most common two-day time window was used for each included event, the same length is used e.g. in Krishnamurthy and Vissing-Jorgensen (2011) or Hausken and Ncube (2013). A one-day window would possibly not capture slow reactions of less-liquid bonds and the three-day window could easily misleadingly capture other effects. Furthermore, event study is adjusted for movements caused by major periodic economic releases by estimating adjusting regressions.

Set of base event study events consists only of CSPP-related and CSPP-positive events – it would be unclear how to assess all speeches of ECB's members, sources and market news with hawkish tone, with signs of quantitative easing tapering or lowering the CSPP purchases (not CSPP-positive).[3] Altogether the event set consists of following 52 events of 5 types listed below and captured in timeline in Figure 4.1:

(1) ECB's monetary policy decisions (2 events)

(2) ECB's monetary policy accounts (3 events)

(3) ECB's news with major market impact ("ECB's sources") (8 events)

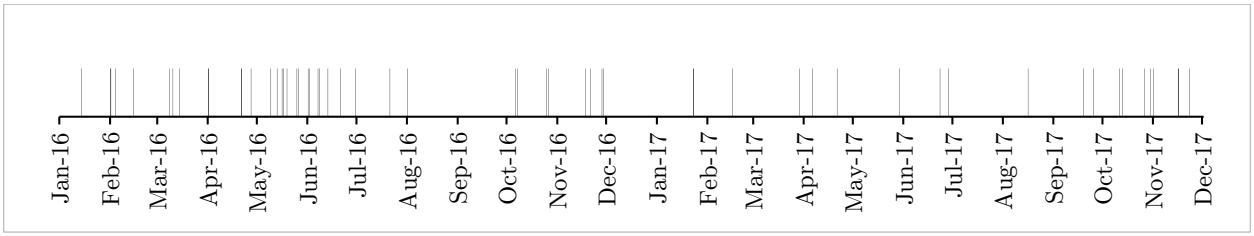
(4) Speeches of Governing Council members about the CSPP (16 events)

(5) Major CSPP-related high impact news from Bloomberg or Thomson-Reuters (23 events).

The first (1) and the second (2) type of events mentioned above naturally include key ECB's decisions regarding the CSPP from March 2016 and October 2017 and corresponding minutes plus the CSPP-promising minutes from January 2016. As for the third type (3), these are unexpected CSPP news from anonymous sources close to the ECB, that usually

[3]Twelve other base event sets were however analyzed to decide appropriateness of chosen event set.

Figure 4.1: CSPP-related events timeline



Note: each vertical line represents an event included in the event study; Source: author's

have the power to increase volatility on markets. The next event type (4) stands for all public speeches of Governing Council members referring in some way to the CSPP. Type (5) represents all highly influential news on CSPP published on Bloomberg or Thomson-Reuters – an extensive search on CSPP-related news was undertaken from all news from 2016–17 and only the major news on the CSPP were selected.[4]

As for major global macroeconomic and geopolitical events in 2016–17 there is fortunately no direct interference with ES windows defined in this paper around selected base events, but effects of these political events can still be expected to affect this ES in the mid- and long-term by entering the other windows but cannot be easily estimated and separated from other acting factors. These geopolitical events are taken into consideration in this paper and also reflected in following VAR analysis: Brexit referendum, UK High Court decision on article 50, U.S. presidential election, Italy constitutional referendum, "sequel" of Greece bailout debate, French presidential election, UK General Election and Catalan regional election.

To fine-tune ES findings and to adjust them for effects of macroeconomic releases, such as GDP, CPI etc.[5], this study employs nonlinear regressions on selected macroeconomic releases on intraday high-frequency data of 2014–17 range and estimates what part of yield change in that day was caused by macroeconomic data releases that fell in the ES time window and what part had a different cause (possibly the CSPP). This simple model estimates an impact of major periodic macroeconomic releases of the U.S., UK, EZ, Germany, France, Italy and Spain that fell into a two-day window around ES events and quantifies their direct impact on bond markets of selected maturities in Germany, France, Italy and Spain. Regressions are based on the surprise factor derived from the actual value of data release and the surveyed value according to the Bloomberg event surprise methodology and

[4]The selection is based on professional bond market-maker expertise.

[5]The complete list of incorporated releases by its home countries: CPI, GDP, PMI manufacturing and employment indicators (for U.S., UK, GE, FR, IT, SP and EC); government bond auctions (for GE, FR, IT and SP); monetary policy rates (for U.S. and UK); durable goods orders, ISM manufacturing and retail sales (for U.S.).

historical intraday movements of futures of sovereign bonds.[6] A bid to cover ratio is used for government bond auctions instead of surprise factor which is not provided for auctions. Highly efficient fixed-income derivatives markets are known to absorb economic releases' surprises fairly quickly, therefore a 3-minute interval was used for each particular event for each release type (e.g. CPI in Germany). Regressions then incorporate the price change between the time of release (T) and ($T + 3$ minutes, which is one beat) as a dependent variable and the Bloomberg-provided surprise factor (bid to cover ratio in case of bond auction) as a regressor.

Formal representation of regressions used in the ES to adjust for the economic releases' impact is based on Bates and Watts (1988) and is written as:

$$y_i = C_i + \theta_{i,1} x_i^{\theta_{i,2}} + \epsilon_i, \tag{4.1}$$

where the dependent variable y_i is a price (yield) change of underlying bonds, C_i is the estimated constant (intercept), x_i is the independent variable representing a release surprise, $\theta_{i,1}$ and $\theta_{i,2}$ are the estimated parameters and ϵ_i is the normally distributed error term. In this case the $C_i = 0$, because of no surprise in economic release, more precisely no deviation from market participants' expectations regarding economic release, cause naturally no price change. The estimated parameters $\theta_{i,1}$ and $\theta_{i,2}$ are estimated in order to constitute an unbiased model – the primary objective is to provide a better data fit with the smallest possible standard errors (SE) of estimated regression with random residuals with no pattern in residual plot. Estimated regressions are of polynomial function shape – no surprise in release is accompanied by no reaction; bigger surprises are accompanied by a bigger reaction of a price change and this applies more or less for all release types.[7] These initial assumptions given the data and its optional handling give us parameter requirements on $\theta_{i,1} > 0$ and $\theta_{i,2} > 1$.[8] Estimated regression functions represent the relation between the dependent price (yield) change and the independent surprise factor derived from an economic release and economic estimates of market participants. Consequent adjusting for effects of macroeconomic releases is then being done by simply taking the value of y_i that belongs to given x_i on estimated function and adjust the ES findings in the given time-window with respect to the price (yield) movement direction.

The same price adjustment could be done by a simple calculus of price changes around the given time interval for the given event, the presented approach however represents a more rigorous way to incorporate this issue. This approach allows us to cover adjustments with

[6] Based on intraday H-F data from Eurex Exchange on Schatz, Bobl, Bund, OAT, Mid-Term OAT, Long-Term BTP and Short-Term BTP Futures.

[7] Since R^2 and p values would not be valid for non-linear regression.

[8] Absolute values of price changes are used to estimate regressions, which is in line with praxis of estimating the relative importance and reactions of the given events, when direction of the price movement doesn't matter. The direction of each price change for all releases were however considered in following ES adjustments based on estimated regressions.

a type of estimated "response function" rather than by a simple price shift caused by every single release. The results of regression-estimated adjustments are however fairly comparable with results otherwise calculated from a simple yield change within a three-minute interval (one beat) around the release and represents only minor fine-tuning adjustment: e.g. an adjustment for CPI in Germany stemming from regression estimates is around -5 bp for 5Y and -3 bp for 10Y government bond yield.[9] The impact of economic releases on corporate non-bank CSPP-eligible bonds is for its simplicity expected to be the same as for the model-estimated impact on sovereign bonds of a corresponding country with the same maturity.

Daily data for the ES itself consist of non-bank corporate bond yields adjusted for individual rating changes of issuers in the given period[10], The Euro Emerging Markets Corporate Plus effective yield sub-index (ICE1) and The Euro High Yield effective yield index (ICE2).[11] The dataset of ECB's CSPP-eligible bond yields consists of over 1,100 specific corporate issues across the Eurozone and the maturity range targeted in 2016–17 by the ECB. For illustrational purposes and to see the whole picture of the Eurozone economy, changes in Euro-Stoxx 50, EUR-USD spot exchange rate and VIX index are analyzed as well.

Results of the ES are further adjusted for overnight index swap rates (OIS) movements – this approach presented and argued in Joyce et al. (2011) gives us a better view of changes in asset prices caused by unconventional monetary policy. Joyce et al. (2011) used the spread between OIS and sovereign bonds yields to separate two effects of monetary policy – the first one that captures a change in expectations about future monetary policy rates and the second one that captures possible changes in term and credit premium. OIS rates as such carry minimal counterparty credit and liquidity risk and fully reflect expectations about future rate path, this fact predestines the OIS rates to be a good proxy for the change in expectations about future monetary policy rates and allows us to quantify the second component of QE announcements that reflect mainly changes in term and credit premium rather than future ECB's rates.

[9] Estimated price movement adjustments for economic release surprises on government bonds of selected countries on average accountable approximately only for 1% of total price movement in given days (e.g. for German bonds it is 1.01% for Schatz, 1.02% for Bobl, 0.99% for Bund and 1.13% for Buxl).

[10] The rating changes in 2016–17 done by S&P, Moody's and Fitch. Data of rated companies were excluded from the dataset in rating days.

[11] Both indices provided by ICE and BofA-ML.

Event study results

The changes in prices/yields of assets around the ES events connected with the CSPP were captured in Tables 4.1 – 4.3. The column "Total change" stands for the total change (sum) in bp (for yields), in pips (for EUR/USD) and in index points (for VIX and EuroStoxx50) in 2016-2017. The column "ES change" expressed in the same scales stands for the sum of changes in two-day windows capturing effects induced by all 52 CSPP-related events covered by this ES.

In the left part of Table 4.1 there are average yield changes – no surprise that usually, the longer the maturity is, the bigger the effect is (e.g. 2Y vs. 20y). Change in the maturities closest to the average ECB's portfolio composition, (which was circa 6 years) in 5-year and in 7-year maturity is both around -40 bp on the short end of the curve, the 2-year yield changed -25 bp and the change on 10-year was -42 bp. The biggest yield changes are present in two event clusters in Q2 2016 and Q4 2017 (see Figure 4.1), which are quarters of the key CSPP decisions. In the right part of Table 4.1, there are the same average yield changes adjusted for OIS movements derived from Eonia changes for given maturities.

The right side of Table 4.1 shows that the change in yields adjusted by OIS of the corresponding maturity is smaller than the unadjusted, which possibly implies that policy of QE, forward guidance and rate decisions are used closely together and in this case the implementation of QE is clearly perceived by markets as "lower rates for longer period". The key CSPP decision in March 2016 was in fact taken together with the ECB's rates change, when the depo rate was lowered by 10 bp. OIS-adjusted change of average yield to maturity (AYTM) in non-bank corporate 5-year bonds, the most purchased maturity, is around -36 bp, which would mean a success of the ECB to send a signal strong enough to make any real difference in asset prices.

Table 4.1: AYTM change by maturity

Tenor [years]	Tot. change	ES change	Tenor [years]	Tot. Change - OIS	ES change - OIS
1	-47.9	-18	1	-43.8	-24.2
2	-64.6	-25.3	2	-66.9	-24.7
3	-60	-33.3	3	-65.8	-31.3
5	-70.6	-44.1	5	-74.8	-35.6
7	-59.3	-39.5	7	-59.2	-26
10	-61.5	-42.2	10	-55.7	-32.7
20	-80.1	-69.2	20	-69.7	-65.1

Source: author's; Units: basis points.

The comparison of maturities and countries is in Table 4.2 for Germany, France, Italy and Spain. Country specific macroeconomic releases are dealt with by the procedure mentioned in first part of this section. Possible longer-lasting geopolitical effects on yields are tackled by the inclusion of the corporate-sovereign bond spread in the right part of Table 4.2 – by comparing the yield spread changes of corporate and its benchmark country sovereign bonds of the same maturity, e.g. French corporates are compared to French government bonds etc. Possible affection by the PSPP could be partially caused by the increase in APPs in March 2016 to €80 bln. starting in April 2016 and the first real CSPP purchases starting in June 2016. Until the March 2016 decision, the PSPP stood approximately for €50 bln., in April 2016 it increased to almost €80 bln. and since June 2016 it was partially replaced by CSPP purchases around €10 bln. a month. No doubt that sovereign bonds had to be to some extent affected by the same March 2016 ECB's decision and the comparison of corporate bonds with its benchmark sovereign bonds is therefore very convenient and it helps us to abstract from the mentioned issues and to focus on solely CSPP-related effects.

From Table 4.2 it is obvious on the spread with benchmark bonds that the effect on CSPP- eligible bonds is partially affected by co-movement of benchmark bonds. It is clearly the case of longer maturities and Italy and Spain. On the other side stands Germany with the completely different pattern – German government bonds have special position in the Eurozone and they are widely recognized as benchmark bonds for the whole area. Constantly high demand for them is connected with collateralization and foreign bond holders' needs and investors' preferences. Even more reduced availability of German government bonds caused by the ECB's PSPP purchases and the repayments of public debt of Germany clearly caused higher pressure on the increase of its prices (decrease of yields) relative to other Eurozone countries.

In Table 4.3 there are captured changes in yields by sector, rating quality and changes in other selected indicators. As for sectors, the biggest percentage from total yield change in 2016–17 induced by the CSPP goes to consumer staples (79%), communications, health care and utilities (around 60%). As for the rating, the effects generally increase with riskiness. The ICE1 Index that tracks emerging markets corporate bonds denominated in EUR, and the ICE2 Index that tracks Euro-denominated below investment grade corporate debt fell significantly by 133 bp and 125 bp respectively. It is clear from these two indices that the impact of the CSPP announcements spilled over to segment of CSPP-ineligible corporate bonds.

Volatility index (VIX) surged considerably around the CSPP-related events, which is quite expected given the unconventional nature of implemented measures and low awareness of markets about the CSPP and its novelty. The EUR-USD rate rose 92 pips and the Euro Stoxx 50 index value on average exert no strong movement pattern. However, in the long-term, in years 2016–17, Euro Stoxx 50 rose almost 600 ip which makes approximately 20% of its value from 1/1/2016. That could be partially caused by investors shifting their portfolios

Table 4.2: AYTM change by country

Simple change			**Spread change with sovereign benchmark bond**		
Tenor (years) by country	Total change	ES change	Tenor (years) by country	Total change	ES change
1 GE	-31.3	-13.5	1 GE	1.3	7.9
1 FR	-57.1	-13.5	1 FR	-30.1	-21.6
1 IT	-25.2	-28.1	1 IT	7.8	-19.6
1 SP	68.6	-153.4	1 SP	101	-184.7
2 GE	-50.4	-0.7	2 GE	-15.2	17.8
2 FR	-54.3	-36.7	2 FR	-29.2	-21.8
2 IT	-54.3	-31.3	2 IT	-16.8	-42.6
2 SP	-71.5	-15	2 SP	-26.3	-11
3 GE	-54	-2.2	3 GE	-24.3	13.3
3 FR	-38.5	-34	3 FR	-18.9	-44.3
3 IT	-74.1	-63.4	3 IT	-51.1	-74.4
3 SP	-66.3	-52	3 SP	-52	-59.7
5 GE	-54.4	2.8	5 GE	-30.5	22.4
5 FR	-52.9	-49.6	5 FR	-34	-45.7
5 IT	-82	-64.6	5 IT	-68.7	-31.3
5 SP	-62.7	-77.2	5 SP	-29.6	-40.2
7 GE	-63	-11.9	7 GE	-42.2	13.5
7 FR	-62.8	-52.6	7 FR	-42.2	-43
7 IT	-64.3	-71.2	7 IT	-61.1	-21.9
7 SP	-36.7	-65.4	7 SP	12.2	-17.9
10 GE	-62.5	-20.7	10 GE	-39.8	10.9
10 FR	-60.4	-44.7	10 FR	-32.7	-29.6
10 IT	-54.7	-88.2	10 IT	-66.3	-38.5
10 SP	-28.8	-107.8	10 SP	5.4	-24.6

Source: author's; Units: basis points.

Table 4.3: AYTM change by sector and rating quality

Sector	Total change	ES change	Portfolio share	Rating quality	Total change	ES change
Comm.	-65.8	-40.7	9.4%	High Grade	-67.4	-30.3
Cons. discret.	-74.1	-21.4	13.8%	Upper Medium Grade	-62.6	-23.9
Cons. staples	-58.1	-45.7	7.8%	Lower Medium Grade	-80.3	-49.1
Energy	-88.8	-53.8	6.8%	Other / Not rated	-22.3	-10.2
Financials	-74	-35	10.5%	**Other Indicators**		
Health care	-42.5	-24.8	3.4%	ICE1 [ip]	-335	-133
Industrials	-55.7	-24	12.7%	ICE2 [ip]	-304	-125
Materials	-67.8	-26.9	8.3%	CBOE VIX [ip]	-14.4	8.9
Technology	-93.1	-35.9	1.6%	EURUSD spot [pips]	843	92
Utilities	-67.3	-38	25.6%	EuroStoxx50 [ip]	573	-16

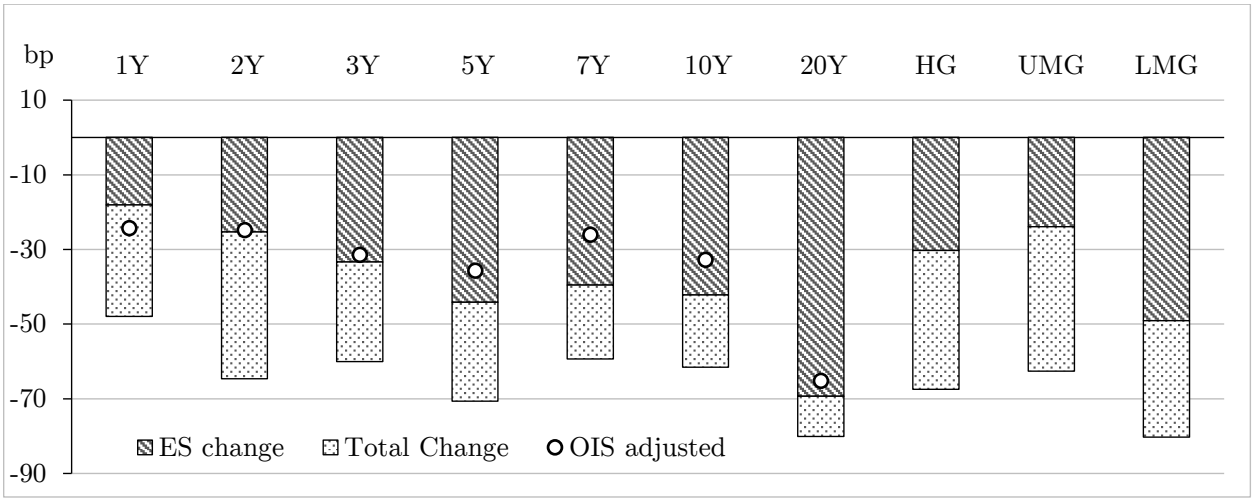
Source: author's; Units: basis points, index points [ip], pips

from fixed-income markets to equity markets and it would support the portfolio rebalancing hypothesis.

Figure 4.2 captures total movement of AYTM of CSPP-eligible bonds, with shaded part directly assignable to ES events and with dot representing the movement adjusted for OIS changes. As for longer maturities and lower ratings, the ES succeeded to capture most of the movement. OIS-adjusted measurement gives us a better idea about the yield change that was caused by APP expansion rather than by change in expected future monetary policy rate. It is clear that expectations of future monetary policy rates reflect the fact that sooner or later the ECB will have to increase its rates – longer maturities exert low OIS change with respect to overall change.

Several interesting facts are noticeable from Figure 4.3, which represents the distribution of the yield changes in the 5Y segment in time. Two important drops in the yield are noticeable around the key ECB's CSPP decisions in March 2016 and October 2017, which clearly states that a message from the ECB was transferred to the markets via the signalling transmission channel. Followed by a drop in June and July 2016, when the ECB actually started to buy bonds on the markets, and its real presence bestirred bond prices and it could actually happen via the portfolio rebalancing channel. The period between October 2016 and June 2017 was marked by ambiguous signals from the EZ economy, several geopolitical turbulences and even by the signs of possible QE tapering. These factors caused pressure on bond yields from both sides and the ECB waited until the situation became more settled. The period between October 2016 and June 2017 was also characterized by a dramatic fall in the expected time to the first hike of ECB's rates from almost 50 months in September

Figure 4.2: AYTM change by maturity and rating

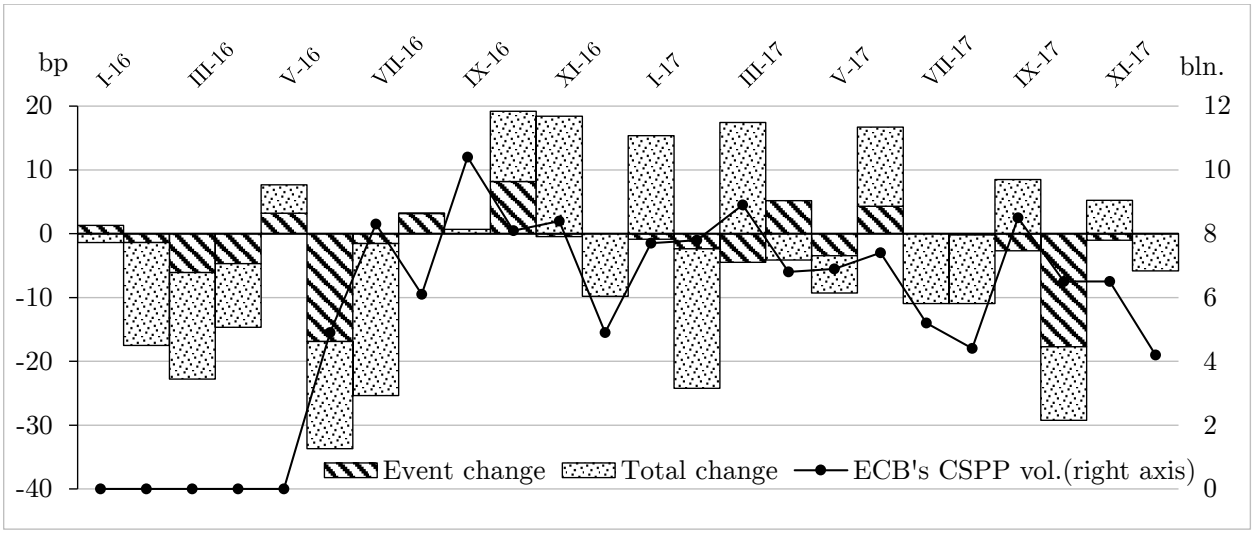


Note: HG stands for high-grade rated bonds, UMG for upper-medium-grade rated bonds and LMG for lower-medium-grade rated bonds; Units: basis points; Source: author's.

2016 to 12 months in April 2017 and remaining low.[12] Furthermore in December 2016 the ECB's decision was perceived less dovish than expected, even though the introduced APP extension was longer than expected (but lower in size) and the reinvestments of the principal payments from the maturing securities purchased under the APP were introduced together with APP deposit rate floor constraint removal. Forward guidance did not do the job well this time and the yields were on the rise. As the economic outlook improved, the signal that asset purchases sent regarding the likely date of the first rate hike becomes increasingly important for anchoring of the medium- to long-term segment of the curve, as being said by Cœuré (2018). The strong signal regarding APP, which was needed in 2016 and which the ECB clearly failed to send, was sent later on in October 2017. However, it is likely, that the stock effect of ECB's CSPP holdings together with the persistent flow of purchases prevented yields from rising even higher during this period.

[12] According to Bloomberg questionnaire inquiry.

Figure 4.3: AYTM change time distribution of 5Y maturity segment



Source: author's; Units: basis points, currency; Currency: EUR.

4.4 VAR-IRFs analysis

In order to discover and quantify a possible relationship among CSPP-incorporating data time series affected by the monetary policy decisions, this analysis uses the vector autoregression model (VAR). This model is being frequently used in studies analyzing monetary policy – see e.g. Bernanke and Kuttner (2004), Gagnon et al. (2010) or Christensen and Rudebusch (2012). VAR is a stochastic process model that can be used to reveal linear interdependencies between time series and to allow bypass of an a priori determination of exogeneity, or endogeneity of variables. Capabilities of VAR modeling, exploited in this paper, are described and advocated e.g. in Stock and Watson (2001). In this study series of maturity-, country-, sector- and company-specific recursive VAR models were constructed together with their impulse-response functions (IRFs) to quantify the strength and the persistence of CSPP-related monetary policy shocks. VARs were also supplemented by Granger-causality tests disclosing dynamics in concerned time series.[13] Constructed VAR models can be under certain conditions perceived as semi-structural as it is advocated in Watson (1994). Recursive VARs constructed in this section construct the error term in each n regression equation to be uncorrelated with the error term in the preceding equation, unlike the reduced form of VAR, by Cholesky factorization of the reduced form VAR covariance matrix, for details see Lütkepohl (1991) or Hamilton (1994). Identifying assumptions taken in the causal interpretation of the equation's correlations make these VARs semi-structural by the proper ordering of the variables in the model equations. For details on identifying assumptions in VAR models see Sims (1986) or Watson (1994). The variable ordering is in this case straightforward with a given set of time series. It is apparent what comes first and what is the causal relation among them, which allows us to impose these ordering restrictions.[14] This paper assumes causal relation from APPs to asset prices and consequently yields in constructed models and not vice versa.

Formally written, the p-lag vector autoregressive VAR(p) model has the form of:

$$y_t = c + \Pi_1 y_{t-1} + \Pi_2 y_{t-2} + \cdots + \Pi_p y_{t-p} + \epsilon_t, \tag{4.2}$$

where y_t is the vector of time-series variables, Π_i are the coefficient matrices and ϵ_t is the serially uncorrelated or independent vector process.[15] Each single equation of this VAR(p) has the same regressors, which are the lagged values of y_t elements. In order to construct IRFs, the VAR(p) must have the triangular structural matrix form:

$$B y_t = c + \Gamma_1 y_{t-1} + \Gamma_2 y_{t-2} + \cdots + \Gamma_p y_{t-p} + \eta_t, \tag{4.3}$$

[13] Granger-causality tests confirmed a priori considered relations among time series used in this study.
[14] First is clearly the monetary policy decision and market reaction follows afterwards.
[15] ϵ_t must have a covariance matrix that is time-invariant.

where B is a lower triangular matrix and η_t is error vector term. This form of VAR(p) is achieved by proper ordering of the variables in the model by co called "recursive causal ordering", where imposed ordering restrictions are made in a way that the contemporaneous value of each variable placed in the model affects only the contemporaneous values of the other, later added, variables but not the values of the variables added before it. Consecutive residual orthogonalization gives us the desired orthogonal impulse response functions (IRFs) that incorporate the graphic representation of the impact of one SD shock of one variable (in this case the monetary policy decision variable) to another (bond yield variable).

Data set for VAR analysis in this section consists of a variety of time series with daily frequency: the time series presented in section 4.3 (average yields to maturity [AYTM] of CSPP-eligible bonds sorted by maturity / country / rating / sector etc., modified time series representing the key ECB's monetary policy actions, OIS rates by maturity, sovereign benchmark bond yields by maturity) extended for the time series representing ECB's CSPP portfolio weekly holdings sorted by various criteria[16] and finally the time series reflecting bond issues of ten selected model companies. Given time series give us a ground to construct dozens of VARs by different criteria: maturity, country, sector or rating of underlaying bonds; therefore, only the most important representative results are presented below.

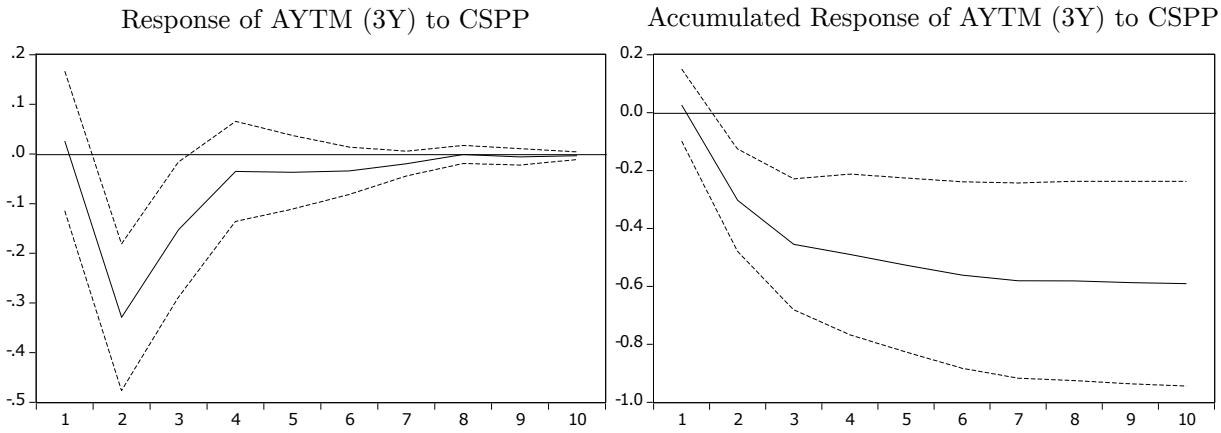
All macroeconomic and political events stated before in section 4.3 (Brexit for example) are omitted from the time series in order not to affect the outcome of VAR analysis. Each constructed VAR[17] consists from only several selected time series, e.g. 3Y VAR model consists from five time series. VAR(3): 3-year corporate AYTM, 3-year government benchmark bond AYTM, 3-year OIS rate, ECB's monetary policy decisions and ECB's bond holding of given 3-year maturity. Other constructed VARs contain the same time series corresponding to its maturity. Lags for endogenous variables were selected according to information criterions and e.g. for 3Y VAR is lag length 3. Data span for all VARs is 01/01/2016-31/12/2017.

The IRFs placed below depict the responses of the selected current and future value of variable to a Cholesky one SD innovation (increase of one SD in one of the VAR errors) $\pm m$ SE, under the assumption that this error will return to zero in following periods and that other errors are zero. The IRF and accumulated response function of the 3-year average bond yield are depicted in Figure 4.4 to illustrate the yield response of a given maturity to one SD innovation in variable capturing ECB's CSPP decisions. IRFs for other treasury maturities are similar in shape as a 3-year sample and differ only in magnitude, therefore only the overall response is enclosed below in Figure 4.5. The response of the AYTM of the corporate sector bonds with 3-year maturity to one SD innovation in ECB's CSPP decision calendar time series is shown in Figure 4.4.

[16] Based on available ISINs of ECB's weekly holdings.

[17] All VAR components were tested for stability and stationarity by standard procedures.

Figure 4.4: IRFs for 3Y AYTM

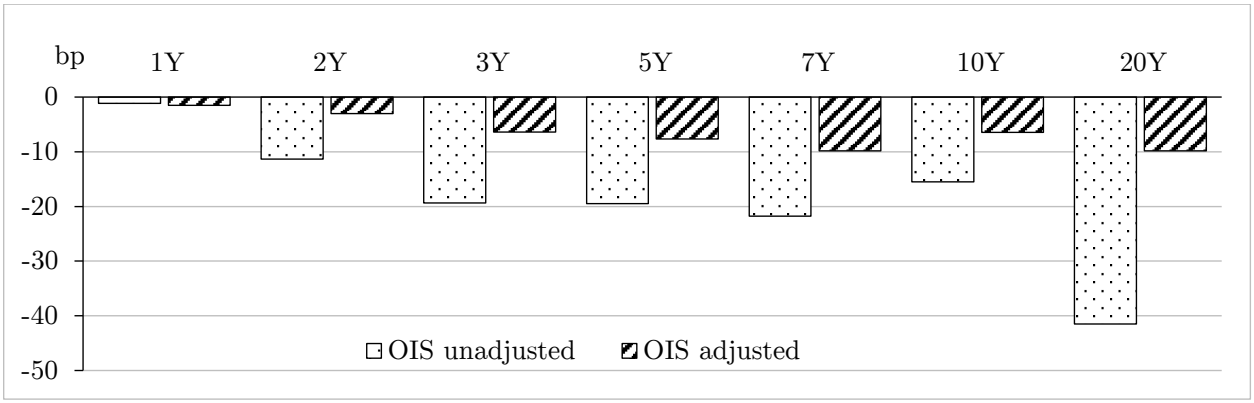


Source: author's model output results (EViews).

In this model case the cumulated response rescaled from one SD shock is around -20 bp in one week after the monetary policy shock similar in size to March 2016 ECB's decision. The response is very quick and quickly fading in approximately 4 days, where most of the response is present – exactly, what would one assume about the reaction of asset yields to monetary policy announcements. All other time series representing changes in AYTM across different maturities, country of issuance, rating and sector follow the same pattern in IRFs, therefore only maximums of cumulative response functions with the reaction time of seven days are depicted and argued in the following figures and comments. The first column in Figure 4.5 represents "raw" change of an average yields of a given maturity, the second represents the same yields adjusted for OIS movements – here it should again provide the better idea about the reaction induced by the decision about the CSPP rather than the changes of the expected future interest rates path. From Figure 4.5 it is evident, that the reaction of OIS-adjusted yields is lower than the unadjusted ones and it is likely that it is caused by the fact that all monetary policy measures (rate changes, APP programme, forward guidance etc.) act together. The strength of the reaction is roughly around -20 bp unadjusted and around -10 bp adjusted in the most important maturities of 3-year to 10-year.

The reaction of AYTM divided by the country of issuance corresponds to the reaction in Figure 4.5 in respect to its country composition – the reaction is stronger for Italy (-36 bp on 5-year), Spain (-22 bp on 5-year) and France (-40 bp on 5-year) and ambiguous for Germany (-2 bp on 5-year). Unlike in section 4.3, the reaction from IRFs analysis is stronger for days around the ECB's CSPP announcements but cannot capture the whole reaction due to a different structure of the time series, which represents only the key events well defined as for length and size of the CSPP purchases.

Figure 4.5: AYTM reaction from IRFs by maturity



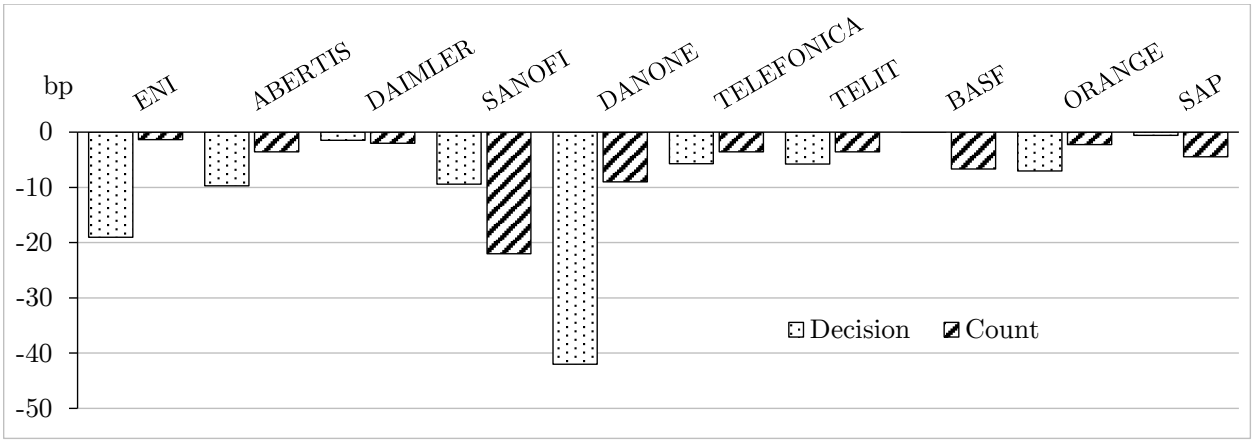
Source: author's; Units: basis points.

For the quantification of effects of the CSPP on micro level, ten model companies from the main Eurozone countries with multiple bond issuances were chosen: Abertis Infraestructuras (SP), BASF (GE), Daimler (GE), Danone (FR), Eni (IT), Orange (FR), Sanofi (FR), SAP (GE), Telecom Italia (IT) and Telefonica Emisiones (SP). Ten synthetic portfolios of above mentioned companies were analyzed for the daily yield changes induced by the main CSPP decisions and for the daily yield changes caused by the inclusion of particular bond issues in the ECB's portfolio. The first approach is the same as in above used IRFs for different maturities, the second one uses the weekly announced ECB's ISIN-based holdings and allows us to analyze the reaction of underlying bond prices to real presence of the ECB on the markets rather than just announcements.[18] The announcement reactions are represented by the first column for each company in Figure 4.6 ("decision" column). Reaction of the yields of synthetic portfolios on additional bond issue bought by the ECB is represented by the second column ("count").

Significant yield reaction on ECB's CSPP announcements is present for the synthetic portfolio of Danone (over -40 bp) and Eni (-20 bp) and fairly limited for Daimler or SAP. The reaction to real ECB's purchases of issues on the market is strong for Sanofi (-20 bp per issue bought), Danone (-10 bp per issue bought) and BASF (-7 bp per issue bought). The following section covers the breakdown of particular characteristics of the corporate financing and changes in this area caused by the introduction and implementation of the CSPP.

[18]This type of analysis is however quite shallow due to lack of precise data – the ECB publishes only weekly held ISINs with no additional information about the nominal amount held. Therefore, only binomial time series for each ISIN expressing presence in ECB's portfolio is used.

Figure 4.6: AYTM reaction from IRFs of selected companies



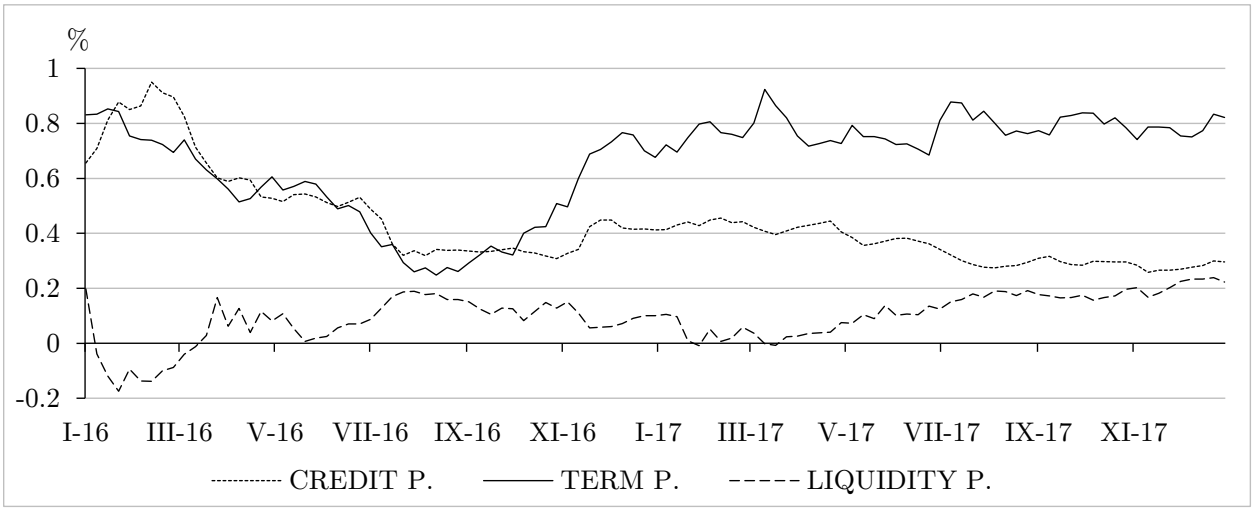
Source: author's; Units: basis points.

4.5 The Impact of the CSPP on corporate financing

Important characteristics of the corporate bond market that may have been affected by the ECB's monetary policy are several types of premia claimed by private investors to hold the corporate bonds – term premium, credit risk premium and liquidity premium. In Figure 4.7 and Figure 4.8, there are depicted the premiums in 2016–17 for both, CSPP-eligible and CSPP-ineligible corporate bonds issued in EUR. Proxied from the average slope of the yield curve for the term premium[19], from yield spread between bonds with higher and lower rating[20] for credit premium and for liquidity premium proxied from composite measure of liquidity composed from market price bid-ask spread and yield spread between issues with different issuance size. Composite measure of liquidity composed from market price bid-ask spread is advocated e.g. in Edwards et al. (2007).

From Figure 4.7 it is clear that the ECB's CSPP announcement at the beginning of 2016 had considerable effect on credit and term premium of CSPP-eligible bonds, where credit premium for CSPP-eligible bonds fell from almost 1% to approximately 0.3% and term premium from 0.8% to 0.3%. Term premium however did not stay on this level and returned to the level close to 0.8%. Liquidity premium did not show any significant reaction to CSPP announcements and stayed for most of the time in the range 0-0.2%.

Figure 4.7: CSPP eligible premia



Source: author's; Units: percent.

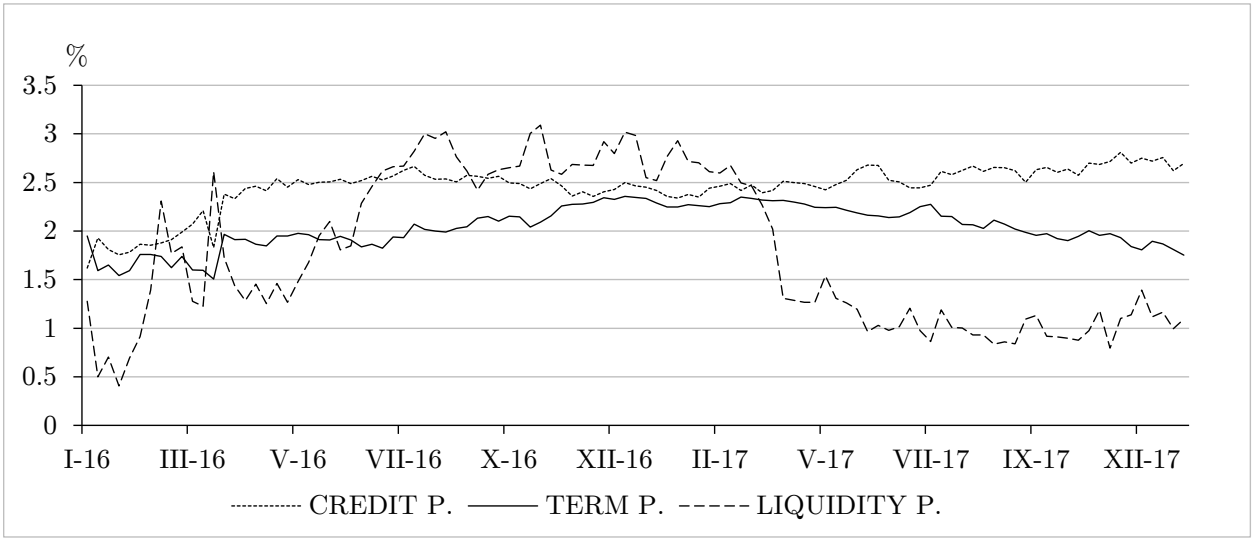
[19]Calculated as 7Y yield minus 2Y yield of A-/A/A+ bonds for Figure 4.7 and from same maturities, but lower ratings (BB-/.../BBB+), for Figure 4.8.

[20]For CSPP- eligible pool from high grade vs. lower medium grade spread and for CSPP-ineligible pool as BBB-/.../AA vs. DD+/.../BB+.

Figure 4.8 represents all other corporate non-financial bonds denominated in EUR and it does not show any similarities in changes of premia with the CSPP-eligible pool. Term and credit premia are almost unchanged through the whole period, liquidity premium is highly volatile in the first third of 2016 but then around April 2017 fell from 2.5% to 1% and stayed resistant since then. It is not likely that the ECB managed to maintain term-premium on low levels, after its initial successful lowering, as ECB's officials would like to see, at least not since the September 2016 ECB's decision, which failed to deliver a strong message, though monetary policy changes were expected by markets.

Development in the markets for corporate financing was quite dynamic in both, conventional bank loan-financing and in more nontraditional bond issuing as well. Availability of bank loans to the corporate sector, especially SMEs, is embodied in the lowering of average loan interest rates. Figure 4.9 shows a constant decrease of an average bank loan interest cost, represented by a cost of borrowing to corporations in the euro area[21], from 2.1% to 1.7% and also the trend of total volume reduction around 15% in 2016–17.

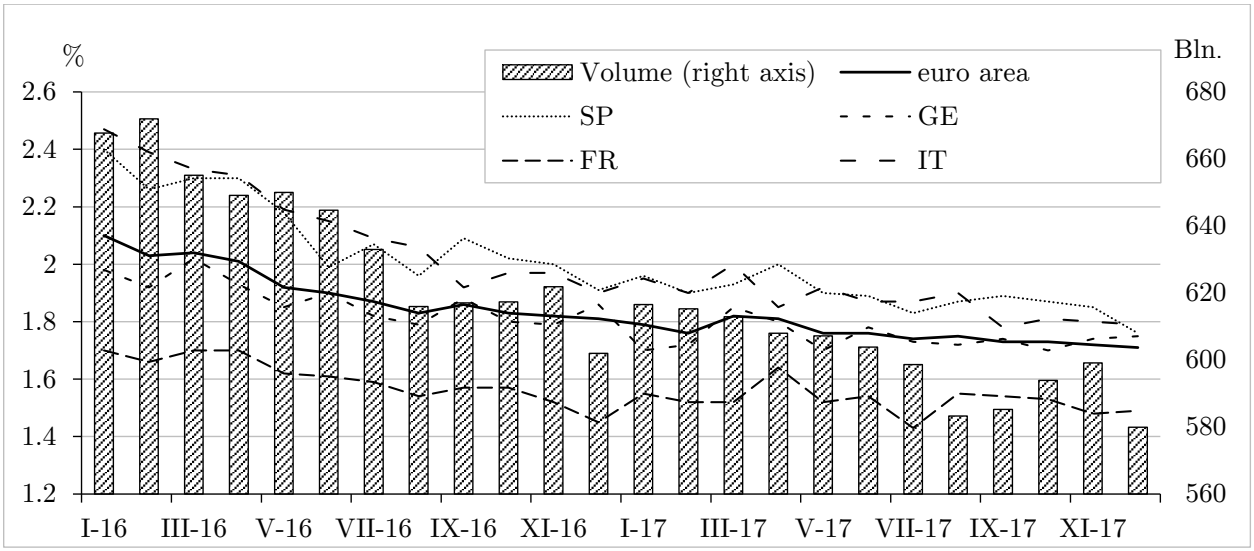
Figure 4.8: CSPP ineligible premia



Source: author's; Units: percent.

[21] Reported by the ECB.

Figure 4.9: Non-financial corporate bank lending in EZ



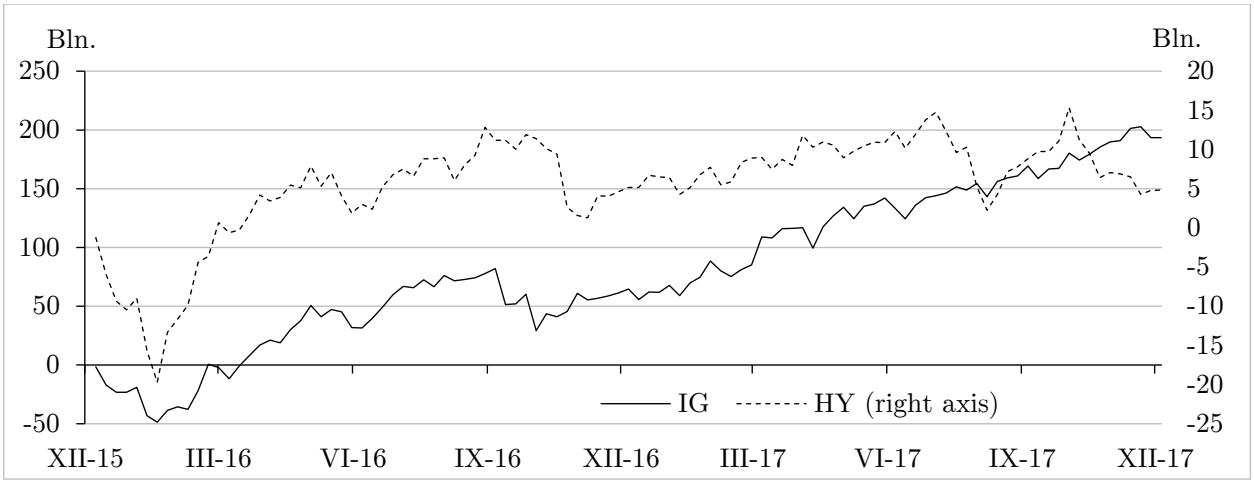
Source: ECB/MFI; Units: percent, currency; Currency: EUR.

In the fixed income segment, the 5-year bond yield fell on average by 70 bp and by almost 40 bp more than national government benchmark bonds (measured for Germany, France, Italy and Spain), which represents a significant decrease of capital acquisition costs by bond issuance. Stable growth of the cumulative volume of bonds issued in both investment grade (IG) and high yield (HY) segment is depicted in Figure 4.10.

From the markets for non-financial corporate bank loans and bonds it is clearly identifiable that the ECB's CSPP had significant effect on the financing of the non-financial corporate sector, especially on the segment of CSPP-eligible issuers. Effects were transferred to the ineligible universe to some extent as well. The trend is clear as for the selected companies from section 4.4, e.g. BASF increased emission of eurobonds in 2016 and even more in 2017 and simultaneously lowered its obligation to banks around 20% between the end of 2015 and 2017.[22] Daimler used bond issuance to a greater extent as well, this time however mainly on the U.S. soil rather than in Europe.[23]

[22]Data from BASF annual reports from 2014–17.
[23]Data from Daimler annual reports from 2015–17.

Figure 4.10: Cumulative non-financial corporate bond issuance



Source: Bloomberg-Barclays; Currency: EUR.

4.6 Conclusions

The CSPP, together with the PSPP, is an important monetary policy tool especially in its segment of corporate non-financial bonds. The CSPP had nonnegligible effects on the yields of targeted assets, especially on CSPP-eligible bonds with transmission to CSPP-ineligible universe. Term and credit premia were unambiguously affected in the eligible universe. In the ineligible universe, it was rather liquidity premium that was affected secondhandly. The event study revealed the strength of CSPP effects on corporate yields on the cross-country range of maturities, ratings and segments. What is important is the adjustment for the movements of the expected path of the ECB's rates represented by the OIS yield curve changes and the adjustment in respect to particular quasi risk-free yields represented by the yield curve of national sovereign bonds. The event study also showed an interesting distribution of yield changes across the given time span and unsurprisingly identified the strongest effects around the key ECB's CSPP decisions. The VAR-IRFs analysis showed the responses and cumulative responses of yields across maturities and countries of the Eurozone to imposed monetary policy shocks of the same size as the one from the March 2016 decision. IRFs also revealed the reaction of the bond issues of ten selected companies on the ECB's monetary policy announcements of the CSPP and real ECB's purchases of these issues. The CSPP affected the real markets of corporate financing and it is possible to identify several possible changes that may be traceable to the CSPP.

Of course, eventually the prices of corporate bonds will fall in the environment of the strong economic recovery and better corporate economic perspectives – improving outlook of present days will naturally drive the yields of bonds higher as expectations of the future ECB's rate path level will rise. Then the question stands what will the ECB do with its holdings of corporate and mainly sovereign bonds? There are already hints that the ECB will walk the path of the swelled balance sheet as it is in the case of the Federal Reserve and change the policy tools towards setting the desirable yields on the benchmark yield curve like the Bank of Japan does. One way or another, the story of quantitative easing in the Eurozone is not over yet.

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Chapter 5

The SER Spread under ECB's Quantitative Easing[1]

Abstract: *This paper discusses the effects of the ECB´s asset purchase programmes (APPs) on the SER spread, while the main focus is given to detailed intraday analysis of the implementation of the Public Sector Purchase Programme (PSPP). The SER spread is perceived as an important indicator of interbank trust in the Eurozone and its elevated level normally signals distortion and mistrust among commercial banks with power to spill over into the whole financial sector. Recent development on interbank markets and especially in monetary policy in the Eurozone could have impaired the ability of the SER spread to act as a proxy for global systemic risk. The SER spread in this study was constructed and calculated using appropriate European financial data and consequent analysis was made on the intraday and high-frequency (H-F) 2015-2017 data. The ECB's APPs, mainly the PSPP, together with other instruments of monetary policy have impacted both legs of the SER spread and this paper tries to identify and quantify the degree of this effect by detailed H-F market data analysis. H-F intraday approach analysis is also being implemented in order to identify which leg of the SER spread was decisive in determining the SER spread change in the first three years of PSPP implementation. Whether it was the "sovereign bond-based leg" directly affected by the ECB's PSPP purchases or the "interbank lending / STIR-based leg (short term interest rate-based leg)". The central finding is that bond-based leg was the SER spread determining leg since the beginning of the PSPP, especially in 2016/2017. The role of the SER spread as an indicator of financial market distress was seriously impaired by the PSPP that undoubtedly caused the shortage of prime sovereign bonds in the Eurozone.*

Keywords: TED Spread, SER Spread, Quantitative Easing, ECB, PSPP

JEL classification: E43, E52, E58, G21

[1]JAKL, J. (2019). The SER Spread under the ECB Quantitative Easing, European Financial and Accounting Journal, Status: accepted for publication. This work was supported by project IGA F1/18/2017 Makrofinanční stabilita a finanční cyklus v zemích s negativní čistou investiční pozicí.

5.1 Introduction

Before the Credit crunch in 2007 not everyone knew what the TED spread was. The Treasury-Eurodollar spread (TED) was originally the spread between three-month (3M) futures contracts on U.S. Treasuries and three-month (3M) Eurodollar, both quoted on the Chicago Mercantile Exchange (CME), till the 1987 stock market crash. Since then, CME dropped the futures on U.S. Treasury bills (T-bills) and the TED is calculated as a difference between the interest rate payed by U.S. Government on 3M cash T-bills and the 3M USD LIBOR rate, which represents the interbank lending market. The TED is referred to as an indicator of global systemic risk e.g. in Bianchi, Drew and Wijeratne (2010), a measure of liquidity freeze, as in Pringle and Carver (2009) or a credit risk indicator as it is referred to in Boudt, Paulus and Rosenthal (2013). In the wake of financial downturn events in the years 2007-2012, the TED spread became frequently mentioned, and widely followed as a key indicator of market distress. In the Eurozone the same corresponding indicator is called the SER spread (Schatz-Euribor spread) and is sometimes inaccurately referred to as the Eurozone TED spread. The SER spread is calculated as a difference between the interest rate payed by the German government on 3M cash T-bills (Bubill), and the 3M Euribor rate, which represents the interbank lending market.[2] The SER spread represents only part of the money market in the Eurozone which is very segmented, yet it represents spread between benchmark sovereign bonds for the whole Eurozone (German bonds), and the most liquid uncollaterized EUR money market (Euribor). And because the Euribor is being traded publicly and virtually any subject can use this market, e.g. for hedging etc., it is crucial Eurozone financial market.

Since 2007 the factors that determine the SER spread have changed significantly and one of the main questions answered in this study is whether the SER spread still carries the same level of information about credit risk in the Eurozone economy. The fact is that since 2007 almost everything connected with TED / SER spreads has changed enormously – monetary policy of the FED and the ECB has changed from direct repo short-end yield curve rate-setting to unconventional Quantitative Easing (QE) and liquidity providing. Interbank money markets (both, collaterized and uncollaterized) have undergone a long structure-changing process and markets for sovereign bond obligations have changed significantly as well. This study is focused on the Eurozone and its SER spread because there is literally none existing research dedicated solely to the SER spread and to the impact of the monetary policy of the ECB on this indicator so far.

[2]Short-term (3M) version of the SER spread, accurately represented by Bubill-Euribor spread, was replaced by the Schatz-Euribor for better informative value. Reasons are fully described elsewhere in this study.

Questions worthy asking, that are answered in this study, are:

- Which leg of the SER spread prevailed in the determination of the SER spread changes during the implementation of the PSPP during 2015-2017 on the intraday basis?
- How could the scarcity of prime government bonds (German bonds) caused by the ECB´s PSPP have affected the market for collateral in the Eurozone, and how was the SER spread consequently affected?
- What are the main factors in the SER spread determination in current market and monetary-policy framework?
- How could the hoarding of excess bank liquidity in the Eurozone, the uncollaterized interbank market trends, and the shortage of prime sovereign bonds, have impacted the SER spread, and is it causing the mitigation of the SER spread's indicative abilities?

The rest of this paper has following structure: the second section introduces the theoretical framework of the SER spread, and changes in the main factors that determined this indicator in the last decade, mainly in monetary policy. The third section describes data used further in this analysis and its limitations, followed by the fourth section with a methodology description of and a presentation of results of the key high-frequency (H-F) intraday analysis of futures markets for German bonds and the 3M Euribor. The fifth section contains a complementary descriptive analysis and overall concluding discussion.

5.2 The SER spread framework

As has been said above, the SED spread (the TER spread as an alternative for the U.S.) is commonly perceived as an indicator of distress in banking sector. However, its nature as a spread means that there are two legs constituting this indicator and these legs can be either affected in the same way by some exogenous factor (e.g. a monetary policy rates change), or they can be affected separately and with a differing magnitude. To be a good indicator of bank distress, it is necessary that it captures the deterioration of interbank markets, or the distrust among commercial MFIs, rather than other factors. There are many other factors and market forces that can suppress the indicative power of the SER spread. For example, this is mentioned in Goodfriend and McCallum (2007), where two categories of shocks are mentioned – factors driven by shocks to the banking sector influencing the STIR-based leg[3], and factors concerning the collateral supply influencing the bond-based leg[4]. Relative changes in the price of collateral available to MFIs is one of the dominant factors that affect the SER spread nowadays, given the extensive APPs of the ECB and the consequent shrinkage of the available pool of prime sovereign bonds. Therefore, distinguishing between the collateral market shock (QE-induced) and banking shock driving factors, provides a better interpretation of the TED or the SER spread as indicators of banking distress. If, for example, the SER spread changes were recently driven by pressures from bond markets, it is reason to believe, that these changes were caused by QE in the Eurozone. There is possibly also a third group of factors that are inseparable from the other factors, and are hard to study, namely the manipulative actions connected to the London Interbank Offered Rate (LIBOR) and consequent scandal.

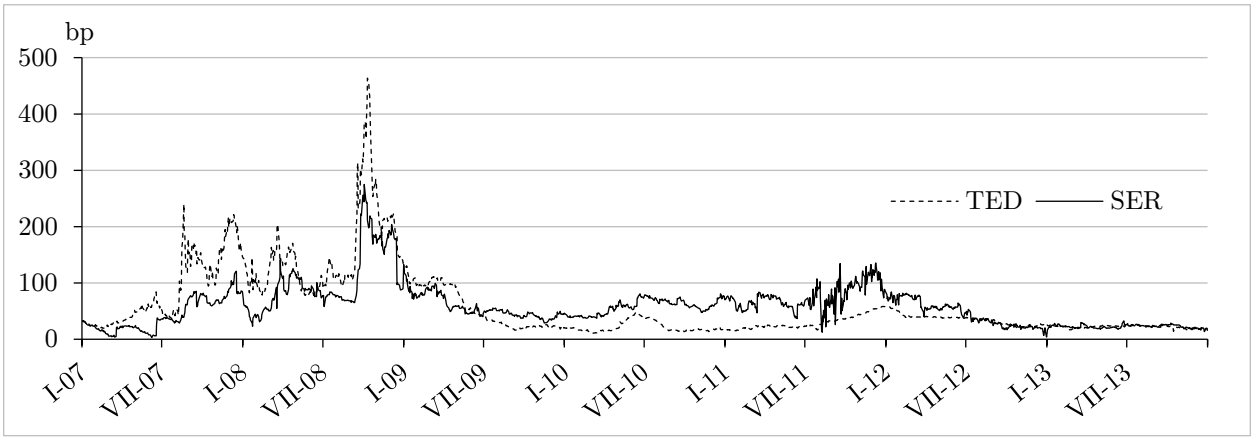
In Figure 5.1 and Figure 5.2 below, the TED and the SER spreads during 2007-2013 and 2014-2018 are depicted. Each figure represents a fairly different picture – the first displays the years of the Great Recession, when both spreads, interconnected in todays globalized world, reached their peaks during the elevated distress in the financial sector, and also the period of the European debt crisis, peaking in 2011/2012. Part of this period between 2007-2009 could be characterized by the anchoring role of the sovereign bonds (bond-based leg) on the SER spread, and the rather changing conditions on the commercial banking side (STIR-based leg). A different pattern is characteristic for the European debt crisis, with elevated yields of sovereign bonds in Europe, but this is another story, beyond the scope of this analysis. The second figure is much calmer as for magnitudes of the TED and the SER spreads and is characterized by a long-lasting period of stable monetary policy rates that were anchoring the STIR-based leg of the SER spread, and the rather disturbed result on

[3]Short-term interest rates (STIR).

[4]In this paper, collateral purposes are mentioned and used in wider dimensions – not only for repo purposes but also for interbank collateral purposes, legal reasons and other similar occasions when MFIs are motivated to hold and operate with high-liquid prime sovereign bonds.

the side of the bond-based leg – disturbed by the unconventional asset-purchasing actions in the ECB's QE monetary policy.

Figure 5.1: The TED and the SER spreads in 2007-2013



Source: FED, ECB, CME and Eurex Exchange, author's; Units: basis points.

The part of the ECB's unconventional monetary policy, using outright purchases (QE), began already in 2009 with the Covered Bond Purchase Programme (CBPP1)[5] with a total value of €60 billion, ending in 2010. In 2010, the Eurosystem started the Securities Markets Programme (SMP)[6] with a total value of €60 billion. The second Covered Bond Purchase Programme (CBPP2) followed soon after in 2011 and 2012 with a total value of €16 billion of purchased bonds. In 2014 the Eurosystem's national central banks started the Asset Backed Securities Purchase Programme (ABSPP) and the third Covered Bonds Purchase Programme (CBPP3). In March 2015 the Public Sector Purchase Programme (PSPP), the largest asset purchase programme aimed for sovereign bonds, was launched. And finally, in June 2016 the last APP programme so far was started – the Corporate Sector Purchase Programme (CSPP) aimed at commercial non-financial bonds. A crucial programme of the ECB for purposes of this analysis is the PSPP, which is by far the largest QE programme ever realized by the ECB, exceeding 80% of all ECB's securities held for monetary policy purposes since early 2015.[7] It was originally planned for 18 months but was extended several times until the end of 2018. And most importantly, it was tailored and aimed at the secondary market of sovereign euro-denominated bonds issued in the Eurozone. The ECB in its March 2015 Decision explicitly mentioned the PSPP as a measure taken in order to battle downward drift in actual and expected euro area inflation, and to give a push to *"lower than expected*

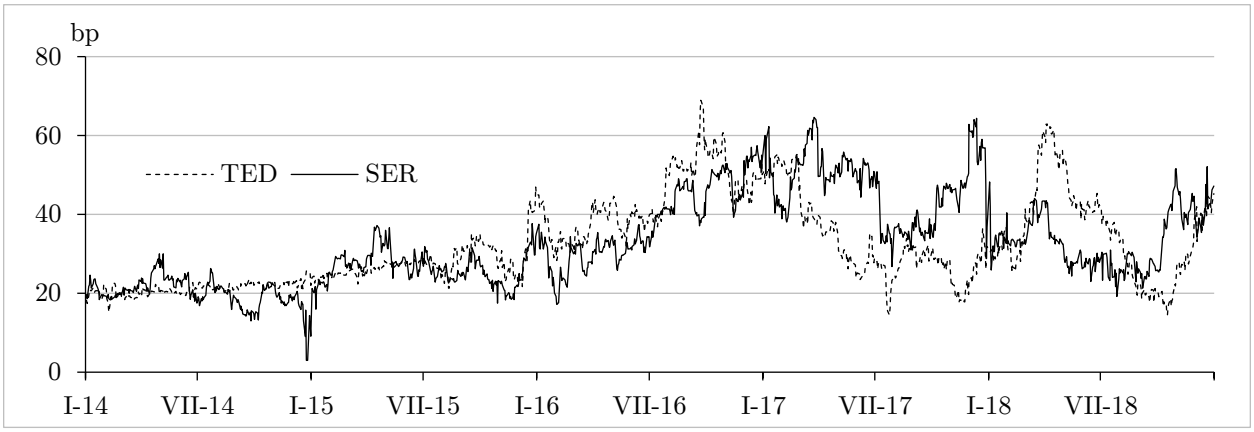
[5] Aimed at the euro-denominated covered bonds issued in the euro area, same as two following waves of the CBPP.

[6] Aimed at the euro-area public and private debt securities markets.

[7] With total ECB's holdings approximately around €2,200 bln. in December 2018.

monetary stimulus from adopted monetary policy measures". In 2019 the ECB entered a new phase of asset purchase programmes, where only reinvestments are realized, but net purchases are discontinued.[8]

Figure 5.2: The TED and the SER spreads in 2014-2018



Source: FED, ECB, CME and Eurex Exchange, author's; Units: basis points.

The part of unconventional policies of the ECB consisting from asset purchases, namely sovereign euro-denominated bonds under the PSPP, led to various effects, and some of them may have been contradictory. The PSPP was officially designated to ease financial and borrowing conditions of non-financial corporations and households in the Eurozone. The role of the PSPP, to work mainly through the portfolio balance channel, leading from asset purchases to the final policy goal of price stability, is repeatedly emphasized by the ECB and explicitly mentioned, see e.g. Cœuré (2017). But the potentially negative effects are presented with less enthusiasm. The alternation of the function of sovereign bonds as a collateral and high-liquid asset, and the demotivation of the Eurozone policymakers to implement fiscal austerity measures, are two of them. The officially unspoken effect of the PSPP was in the first place the lowering of funding costs of the federal governments in the Eurozone.

The positive results of the PSPP are for example uncovered by Paludkiewicz (2018); he makes an examination of granular data from the Germany, when PSPP-compressed bond yields led the Eurozone MFIs to rebalance their portfolios from securities bond holdings toward credit portfolios. While the decrease of interest rates on newly issued loans was lower than the decrease in bond yields, his results indicate that banks increased their

[8] On 13th December 2018, the Governing Council of the ECB decided to *"... continue reinvesting, in full, the principal payments from maturing securities purchased under the APP for an extended period of time past the date when it starts raising the key ECB interest rates, and in any case for as long as necessary to maintain favourable liquidity conditions and an ample degree of monetary accommodation".*

lending to non-financial firms and households in response to the lowering of bond yields, and adequately decreased their bond holdings, especially those with the highest drop in yields. This means that commercial banks were more willing to offer loans and yet the SER spread was widening through the bond-based leg. Since August 2012, there has also been the phenomenon of growing excess liquidity of MFIs, that comes inevitably with contemporary ECB's monetary policy – liquidity providing programmes (LTROs) together with asset purchases (for newly ECB-created interbank liquidity) and changes in quality of ECB's collateral repo requirements contributed vastly to this current state of affairs. In this state of excess overall interbank liquidity, there is a general willingness to permit interbank lending but given the excess liquidity there is no need to borrow that much. This should, on the contrary, lower the SER spread through the STIR-based leg due to lower pressure on the interbank market. Various empirical studies examine the liquidity-driven rebalancing channel of MFIs, see e.g. Kandrac and Schlusche (2017) or Carpinelli and Crosignani (2017), and the yield-induced rebalancing channel, see e.g. Albertazzi et al. (2018) or Tischer (2018).

Under the PSPP, the Deutsche Bundesbank (DB) (2018) purchased till the end of 2017 roughly around a quarter of the total outstanding volume of German federal bonds (sometimes generally called Bunds) and induced major changes in the holders' structure.[9] The holders' structure of German bonds is very broad because of its benchmark position among European sovereign bonds and securities in general. The main Eurosystem counterparts were non-European foreign subjects, followed by the euro area MFIs. The holders' structure by residency from before, after the PSPP years 2014 – 2017, was changed significantly: non-euro area countries lowered their shares from 59.8% to 44.6%, German subjects tripled their holdings from 11.6% to 34.4%; that was, however, entirely caused by Deutsche Bundesbank's asset purchases (of which DB was 0% to 23.5%). Other euro area countries lowered their holdings from 20.6% to 16.5%, and other subjects with unclear residency accounted for 8% in 2014 and 4.5% at the end of 2017.[10]

An undesired side effect of PSPP may have been embodied in the increased scarcity of PSPP-targeted securities and consequently the lower market liquidity with cash bonds, caused by the constriction of sovereign bond markets, i.e. Eurosystem asset holdings were purchased to hold, not to trade. MFIs Bund bond holdings were crowded out by DB's purchases and MFI holdings changed from 5% of the total outstanding amount in 2014 to just 0.7% which is a significant decrease (-86% change). Other financial Eurozone investors also lowered their Bund holdings, but rather insignificantly – from 20.6% in 2014 to 20.1% in 2017. The important role of foreign countries Bund holders as a counterpart to the ECB arose probably from sales of China's public sector assets in this period, when Chinese foreign exchange reserves shrank by $700 billion, as it is mentioned in the Deutsche Bundesbank

[9] On December 2017, the Bundesbank holdings accounted for 24% of the total outstanding amount of German federal bonds (€263 billion worth).

[10] Statistics provided by Deutsche Finanzagentur.

(2018). The estimated change to free float of tradable German bonds shrunk to less than 40% of the total in December 2017. MFIs have, unlike other investors, access to the ECB's deposit facility, which can be a cheaper and more convenient alternative to sovereign bonds in these days, at least since the introduction of the cash collateral option by the ECB in December 2016 (see ECB decision from 8th December 2016). Because the ECB's deposit facility rate (which is currently -0.4% and negative since June 2014) exceeds the yield of 2-year German federal bonds since March 2015, it is at least from a yield-bearing perspective a better option than the holding of short-end Bunds. This fact is probably the cause of the MFIs Bund portfolio reduction; however, regulatory requirements, and the need to hold highly liquid assets for interbank collateral purposes, and other reasons make German bonds more than a simple investment with consequences to its price elasticity (respective inelasticity). The regulatory environment of Basel III, the European Market Infrastructure Regulation (EMIR) and other regulations, put on Eurozone institutional investors, could have induced a stronger and relatively price-inelastic demand for short-term and mid-term sovereign bonds, see the DB (2018). This effect is, however, opposed by the contradictory effect of the excess liquidity of MFIs being held at its Eurosystem central bank. The striking difference between the Eonia swap rate and the yield on the 2-year German Schatz, reaching over 60 bp in early 2017, represents the so-called "scarcity premium", which is referred to by the DB (2018) and can be used as a proxy to measure relative scarcity of freely traded German securities.

As mentioned above, ECB's holdings were not designed to be traded but rather to be held and to withdraw targeted assets from their markets – this could lead to shrinkage of market liquidity (defined by traded volume) as a side effect. This was unlike the FED in its first wave of QE that started in 2008, when asset purchases (mainly MBS) were designed to put frozen dysfunctional markets back into motion. Bund secondary market is mainly OTC, and transactions outside the membership of the Bund Issues Auction Group administrated by Deutsche Finanzagentur are publicly unknown. The given group, however, traded less than €5,000 billion in 2017, while in 2005 it was €7,000 billion, and the outstanding total volume increased circa one half during this period.

Janks and Mönch (2018) from the Deutsche Bundesbank, contemplating the European repo market where German sovereign bonds have become scarce since 2015, and the concept of a "specialness spread"[11], analyzed the distortion effect of the PSPP. The German Bund is no longer being used as a general collateral in the degree that it was before the PSPP implementation. Repo market, and reverse repo short-term purchases, are mainly motivated by short position obligations, arbitrary transactions or liquidity provisions. They admit that "specialness is actually a phenomenon that should only occasionally arise for isolated securities" and that "specialness has been more the rule rather than the exception for German sovereign bonds in recent years." The high unaccommodated demand for German bonds

[11]Which they defined as the difference between the ECB's deposit facility rate and the specific collateral repo rate of a given bond.

was also associated with increased price volatility, while financial intermediaries tried to retain German sovereign bonds. Bunds are being considered safe and liquid, and financial intermediaries prefer not to repo them, especially during the regulatory reporting dates as mentioned by the BIS (2013a) or (2013b).

Janks and Mönch (2018) also contemplated about the ECB's securities lending facility, that was introduced in April 2015, and its purpose is to mitigate a possible squeeze on bond markets, where PSPP-induced demand would exceed supply, and where consequent price rise of the given bonds, effectively withdrawing them from daily use on repo and collateral markets, due to their unavailability and high cost.[12] The ECB also adopted a cash collateral option in December 2016 for its repos (with certain limitations), and tried to battle the rising scarcity of highly valuated sovereign bonds. The PSPP securities lending balances reached its highs in December 2017, when the average balance on the loans was under €70 billion. These actions, mainly the introduction of a cash collateral option, probably lead to the mitigation of bond repo market pressures, but the overall effect is disputable. The important fact to notice from Bindseil (2014) is that most bank assets are not refinanced through the central bank, in the euro area it is roughly just around 2%. MFIs also tend to use the least liquid eligible assets[13] as collateral for the central bank and the sudden reduction of asset liquidity or a tightening of a collateral framework can destabilize short-term liabilities of commercial banks. While the ECB's repo collateral requirements were lowered regarding quality of collateral in recent years in the Eurozone, the available quantity of high liquid and safe sovereign bonds across the Eurozone was undoubtedly reduced, and the overall resultant effect on the SER spread is therefore unclear.

Unconventional monetary policy of asset purchases implemented by the ECB could have impaired the ability of the SER spread to act as a proxy for global systemic risk. The SER spread is in model scenario mentioned as an indicator of elevated financial systemic risk, with overall higher default risk of financial intermediaries, this however would not be true in the PSPP times when obviously widening of the SER spread was caused by demand-driven price rise on European sovereign bond markets. Following sections contain description of the data and methodology, H-F analysis of intraday SER-constituting data, complementary descriptive analysis and overall concluding discussion.

[12]The ECB made securities purchased under the PSPP and later under the CSPP available for lending in a decentralized manner by Eurosystem central banks since 2nd April 2015.

[13]In Eurozone in 2010 government bonds constituted cca 50% of eligible assets from total assets and yet the usage ratio of government bonds was only around 6% in contrast to ABS usage ratio of 38%. See Bindseil (2014).

5.3 Data and data handling

The following section 5.4 contains essential part of this paper – a high-frequency (H-F) analysis of the SER spread, based on a detailed analysis of both constituting legs (bond-based and STIR-based leg). Data for the detailed analysis of the PSPP and OTC bond markets is virtually unavailable or available at an insufficient frequency; therefore, ultra H-F futures data (exhaustive trade-by-trade from market data feed) were acquired from two exchanges. The Eurex Exchange (Deutsche Börse AG) is the source of data for German bond futures, and the London International Financial Futures and Options Exchange (LIFFE) is the source of data for Euribor[14]. Ultra H-F data obtained from data sources was for convenience sake aggregated in 5-second intervals, which is an optimal interval for analyzing price changes on given markets.[15] For complementary analysis, where H-F would not provide better insight, daily data was used, namely for correlation analysis between German bonds with various maturities and descriptive statistics. Sources for daily data are the same as for H-F data extended for the Deutsche Finanzagentur, the ECB and Bloomberg.

The underlying Euribor data was also adjusted for flipper activity[16], which would otherwise reduce data quality and usability. The underlying data was originally used for the analysis of possible arbitrary trade opportunities caused by unsynchronized (time discrepancy) repricing of the underlying legs of the SER spread.

As mentioned above, data for detailed analysis of the PSPP and OTC bond markets is virtually unavailable; this is in the first place a reason to use the type of analysis presented in this paper, rather than more conventional direct methods. Data regarding the QE of the Eurosystem, such as the PSPP, is confidential, and only aggregated and low frequency data is available. There is, for instance, no direct way how to find out when Deutsche Bundesbank (or other PSPP-authorized member banks of the Eurosystem) operated on bond markets. The interbank OTC money markets and OTC bond markets data are decentralized and very highly valuated and usually not provided (at least not at a sufficient frequency). Therefore, analysis undertaken in this section uses proxy data for its better availability and H-F character. Proxy data for the STIR-based leg comes from LIFFE[17] Euribor futures

[14]The reason why Euribor is used instead of Euro LIBOR interest rates, as it is usually used for computation of the TED spread (US LIBOR), is that LIBOR is constructed over few selected constituent MFIs and Euribor is constructed over much broader constituent base. Euribor is also used as a benchmark reference rate for financial contracts in the Eurozone and is publicly traded on exchange on H-F basis. Euro LIBOR interest rates data are on the contrary not provided on high-frequency and not traded publicly on any exchange, therefore analysis based on LIBOR-OIS spread or LIBOR-Repo rate would not be beneficial.

[15]Given the fact that this paper does not aim to undergone trade-by-trade analysis. This kind of analysis would be interesting if the ECB would ever published detailed information about its purchase (ISIN, day and hour of purchase etc.), this is however unlikely going to happen.

[16]Illegal activity belonging to market manipulations, when subject alter the market conditions for a short period of time (usually by size of market order) by false signals and consequently carry out trades for its own benefit.

[17]London International Financial Futures and Options Exchange (LIFFE).

contracts, and proxy data for the bond-based leg from the Eurex Exchange Schatz futures contract (FGBS). Euribor futures is cash settled futures based on the European Money Markets Institute (EMMI) EURIBOR rate for three month deposits, and the Eurex Exchange Schatz futures is futures whose underlying instrument is short-term debt instrument issued by the Federal Republic of Germany. There are several strong reasons to believe that futures market data is convenient to act as a proxy: all OTC transactions are immediately reflected by OTC market participants on futures markets for hedging or arbitrage purposes[18], futures contracts are standardized as for maturity, futures are settled on cheapest-to-deliver (CDT) basis, and the bond futures market is widely perceived as a leading price formation element.

The original SER spread (as it was presented in previous sections) is in this section replaced by its variation with a longer maturity, which was necessary in order to strip several Euribor expirations with different maturities to correspond with Schatz futures (which has 1.75 to 2.25 remaining term in years).[19] The calculation of the SER spread in this section, therefore, incorporates the German cash bond (Schatz) hedged by a strip or bundle of STIR futures (Euribor). In fact, it is a designated trade where quarterly cash flows of 3M STIR futures are hedged by cash flows of given cash bonds.

The sequence of the mathematical determination of the SER spread in general is as follows:

- Construct the implied coupon-paying generic bond from STIR futures (Euribor for the SER spread, or Eurodollar for the TED spread), which has the same characteristics as a corresponding cash bond. This implied generic bond is constructed using interest rates computed from the prices of STIR futures.
- The constructed implied generic bond then has the same credit rating as a strip from given STIR futures.
- The difference of the interest rate of the constructed implied generic bond (its implied yield), and the interest rate of the actual cash bond (yield of cheapest to deliver [CTD] cash bond)[20], is the SER spread.

The procedure described above in general terms requires many partial operations that make this procedure quite complex, and its formal description would be too space-demanding, therefore, only a brief text description follows in the next paragraph. For all general financial mathematic procedures used in this paper, in this case with the focus on fixed income and STIR derivatives, see Choundhry (2003), Choundhry (2006), Aikin (2012) and Aikin (2006) or a variety of other relevant financial mathematics publications on the given issue.

[18] E.g. correlation coefficient value for Schatz futures and generic 3M Germany Bubill in 2014-2017 is 0.97.

[19] For the TED spread it would require the same procedure – strip Eurodollar expirations or Eurodollar bundle to the corresponding U.S. Treasury cash bond.

[20] U.S. 2-year bond for the TED spread and 2-year Schatz for the SER spread.

For convenience, the CTD[21] cash bonds were chosen, from the available set of cash bonds in this analysis, for the computation of implied prices and yields of STIR contracts. Cash flows of the CTD cash bond for each day were deployed on corresponding cash flows of STIR contracts. The yield curve of spot interest rates was used to compute interpolated interest rates valid for the STUB period, which is the period before the operationality of the first STIR contract of the used strip. Accrued interest was used to find the correct yield, by deducting it from the so-called dirty price bond. The conversion factor and gross basis were employed to transform the price of given bond futures to the price of a synthetic generic cash bond. The net basis based on days to delivery, accrued to delivery, and spot interest rate, were then used to estimate the price of the cash bond more accurately.

[21] $CTD = CurrentBondPrice - SettlementPrice * ConversionFactor$

5.4 Intraday high-frequency SER spread's analysis

The high-frequency (H-F) intraday analysis of the SER spread can, unlike the interday analysis, reveal many things that would otherwise remain hidden. H-F for instance shows detailed traffic on individual markets for government bonds and interbank market – volatility changes and peaks during the trading hours, intraday traded volumes, and many other market characteristics that would not be uncovered using daily aggregated data. Therefore, in this section, the H-F approach was undertaken to reveal possible causality among the two legs constituting the SER spread, which is crucial in order to identify the possible impact of the PSPP on the SER spread. The accompanying phenomenon, indicating a strong impact of the ECB´s PSPP on the SER spread, would be the dominance of the bond leg on the SER spread's changes during the PSPP implementation period. Causality would simply, in this case, go from the bond markets to the SER spread, and consequently continue to the STIR markets, and this order of sequence would be observable on H-F data. Normally each leg of the SER spread is accountable for a fair share of the initiative role in the SER spread induced changes – change in one leg (e.g. in STIR leg) is transferred to other leg (e.g. bond leg) and vice versa, and there is no strong pattern or even prevalence of which comes first and which follows, respectively which leg is initiator, and which is follower. There is also reason to believe that during the PSPP implementation and presence of the ECB on the bond markets, the SER spread changes induced by the bond-base leg would not be fully accommodated by the STIR-based leg. Market participants would simply perceive changes on the bond markets to be long lasting and fundamentally founded.[22]

The SER spread's changes induced by change on the bond leg were in deed not entirely accommodated by the change on the STIR-based leg, which is also observable on data with lower frequency (daily, weekly, etc.). Changes on the STIR-based leg (Euribor-based) did not offset the changes on the bond-based leg, which naturally led to the increase of the SER spread, this time with no real connection to elevation in global systemic risk, interbank liquidity contractions, or MFI credit default risk increase, as it was during the Great Recession.

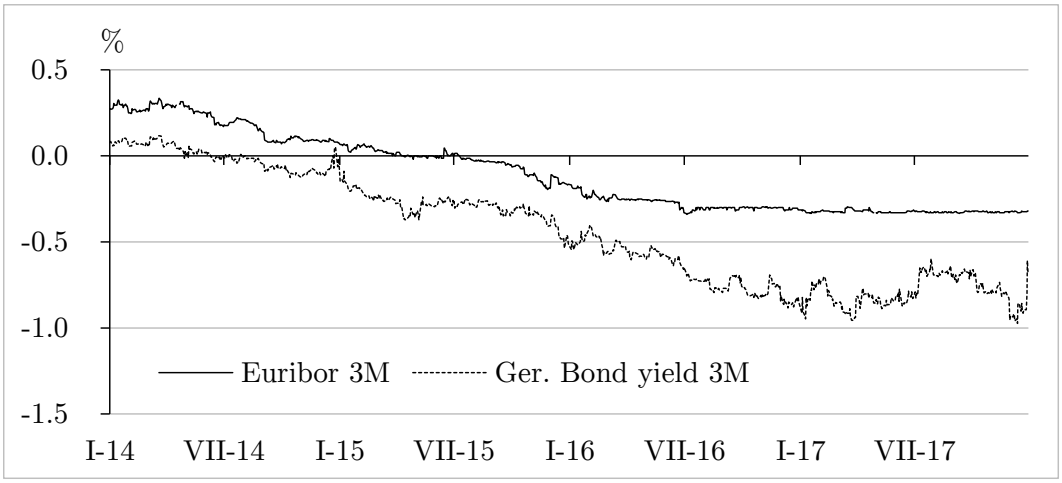
The SER spread's indicative power could have been therefore suppressed by its otherwise more stable constituent, the bond-based leg. The real impact of the PSPP on the SER spread, however, could not be identified simply by looking at the Euribor rate and the yield of the German Schatz since 2015 as it is captured in Figure 5.3. It gives us only information

[22]This could be theoretically caused by several reasons different for each leg. For the bond-based leg, movement not to be accommodated by the STIR-based leg, can for instance cause a fundamental change in the demand or supply side at sovereign debt markets. When e.g. the federal budget of some country exerts a surplus, and the total outstanding amount of its debt is being reduced. On the STIR-based leg, it could be caused by a change in the regulatory framework, collateral framework, or the newly established ECB's liquidity facilities. The ECB is currently considering a tiered deposit rate, which would mean that some banks would be exempted from paying the ECB the 0.40% annual charge on their excess reserves, see e.g. Koranyi, Siebelt and Canepa (2019).

about the steadiness of Euribor, and the fluctuation of the Schatz yield, especially in 2016 and 2017, while the real cause of this fluctuation remains unidentified. One way to uncover the possible role of the PSPP without exhaustively identifying all the other factors forcing German yields lower is to focus solely on identifying the presence of a leading initiative role of the bond leg, which must have been caused by a strongly elevated demand for the given bonds on related markets. Other factors that would be able to shake the SER spread through the bond-based leg, e.g. a change in the sovereign rating of Germany, would not exert this pattern of repricing on bond markets through a series of many repricing episodes.

Speaking of German government bonds, they were not subject to a sovereign rating (or rating outlook) changes for long time; the last time that major rating agencies published Germany rating outlook changes was for Moody's Aaa stable (in February 28th, 2014), for S&P AAA stable (in January 13th, 2012) and for Fitch AAA stable (in November 21st, 2011). During the European debt crisis (peaking in 2011-2012), the German bonds were the main relatively safe target of investors during the risk-off sale of less sound sovereign bonds. Germany as a country also benefits from a positive fiscal development, and has been constantly lowering its debt-to-GDP ratio since 2012.[23] This relative lower availability of German sovereign bonds undoubtedly has an impact on the SER spread, but this is rather indirectly through lower issuance of new bonds rather than buybacks of existing debt; the secondary market is therefore influenced only indirectly through slow changes in the relative size of the available bond pool. This gap between the supply and demand on the German bond market is however quickly widening due to the fact that nominal incomes and interest rates are rising in general, and sovereign bond issuance is being reduced.

Figure 5.3: Euribor 3M rate and German generic 3M yield



Source: LIFFE, Deutsche Finanzagentur; Units: percent.

[23] As reported by Bundesministerium der Finanzen.

Clusterization

The Gaussian Finite Mixture Modeling (GFMM) approach was used for clusterization of three components of analyzed data using the R (programming language) package *mclust*, which is a package that allows modelling of data as a Gaussian finite mixture with different covariance structures and different numbers of mixture components. Model-based clustering is in general described in more detail in Fraley and Raftery (2002), and in model-based cases using the *mclust* package in Scrucca et al (2016). Clusterization undertaken in this paper follows these mentioned sources, and uses a modified version of the VVV model described in Scrucca et al (2016). In general terms, the GFMM can be described in the following terms:

$x = \{x_1, x_2, \ldots, x_n\}$ is a sample of n independent identically distributed observations specified by a probability density function via a FMM with G components in the form of

$$f(x_i; \Psi) = \sum_{k=1}^{G} \pi_k f_k(x_i; \theta_k), \tag{5.1}$$

where $\Psi = \{\pi_1, \ldots, \pi_G, \theta_1, \ldots, \theta_G\}$ are the parameters of the mixture model, and where $f_k(x_i; \theta_k)$ is the k-th component density for the observation x_i with a vector of parameters θ_k. $(\pi_1, \ldots, \pi_G)$ are the mixing probabilities (that sum up to 1) and G is the number of mixture components. G is assumed to be fixed, therefore the estimation of Ψ would be done by estimating the log-likelihood function $\ell(\Psi; x_1, \ldots, x_n) = \Sigma_{i=1}^{n} \log(f(x_i; \Psi))$ respectively the MLE by the expectation–maximization (EM) algorithm.

The Gaussian mixture model (GMM), which assumes a multivariate Gaussian distribution for each component $f_k(x_i; \theta_k) \sim N(\mu_k, \Sigma_k)$, was employed in this study in a way that identified clusters as ellipsoidal, centered at the mean vector μ_k and with different geometric features (volume, shape, orientation) determined by the different covariance matrix Σ_k. $\Sigma_k = \lambda_k D_k A_k D_k$, where scalar λ_k controls the volume, A_k is a diagonal matrix specifying the shape of the ellipsoid, and D_k is an orthogonal matrix which determines the orientation of the ellipsoid. Therefore, the volume, shape and orientation of the covariances can be constrained to be the same or to deviate between groups of clusters. Model VVV with different geometric characteristics was chosen for its best fit in our case, where $\Sigma_k = \lambda_k D_k A_k D_k$, distribution is ellipsoidal, and volumes / shapes / orientation are variable across clusters.

Generally, the number of mixing components, and the covariance parameterization, are selected using the Bayesian Information Criterion (BIC), which is not necessary in this analysis, given the nature of the data, where it is possible to easily identify three clusters per se. Optional arguments of the R *mclust* package allow exact specifications for G – the number of components, and the model covariances parameterization. In this analysis the EM algorithm for maximum likelihood estimation of multivariate mixture models was used to identify three clusters, whose characteristics were a priori specified. The identified component cluster [1] represents the linear dependency between a constituent leg and the SER spread,

and was a priori defined as a component with the highest variance (Gaussian cluster with covariance matrix corresponding to a long, thin diagonal ellipsoid)[24]. The second identified component cluster [2] was a priori defined as a component around the y-axis (Gaussian cluster with covariance matrix corresponding to a long, thin, vertical ellipsoid around y-axis), and the third component cluster [3] captures the rest of observations that are rather randomly distributed.

Limitations of the model data arise from the fact that all three clusters overlap around the x-axis-y-axis intercept and it is not possible to separate them with high accuracy between clusters.[25] Though it represents only a minor problem, since it does not alter the estimated slope of the fitted line in cluster [1], and gives us no strong information, since this area around coordinates [0,0] contains only observations capturing very small movements of the leg against the SER spread itself. It can, however, alter the distribution among clusters listed in Table 5.1, because this area often (in some days) contains the majority of observations.

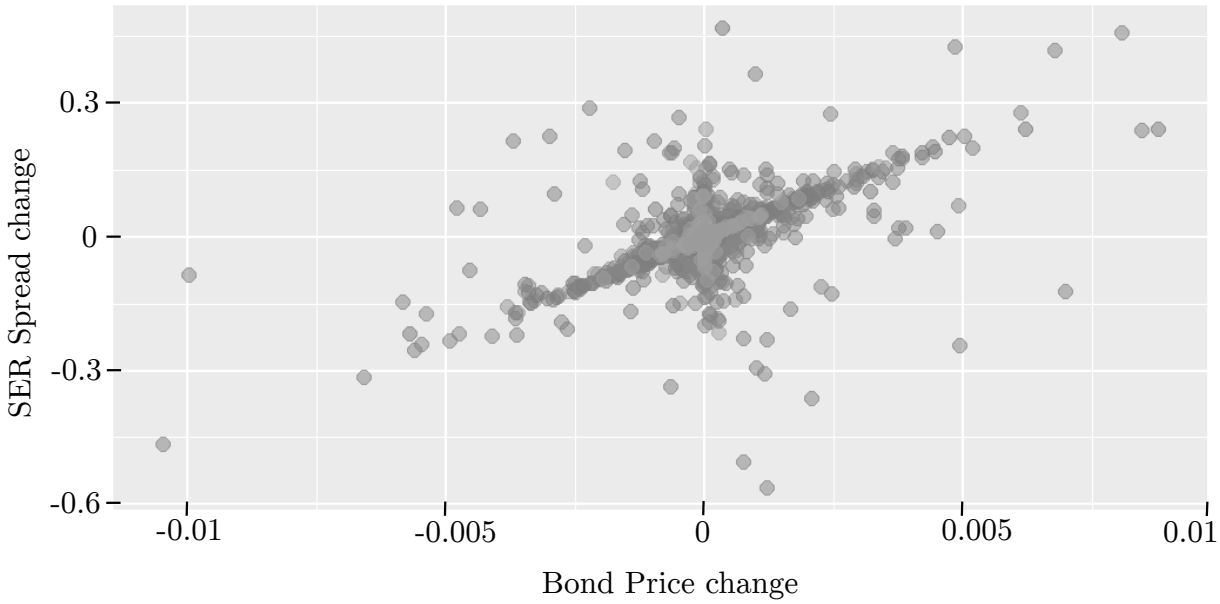
Analysis results

The following scatter plots of model outputs (plots made from intraday movements) in Figures 5.4 and 5.5 for 22$^{\text{nd}}$ of January 2015 and Figures 5.6 and 5.7 for 15$^{\text{th}}$ of December 2016 are graphic representations of 5-second shots of selected representative days. The first scatter plot in Figure 5.4 depicts the relationship between the cash bond price change in % of par value (x-axis), and the change of the SER spread in basis points (y-axis). The second scatter plot in Figure 5.5 depicts the same relationship between the yield of the constructed synthetic implied bond in basis points (x-axis), and the change of the SER spread in basis points (y-axis). Each presented scatter plot contains approximately ten thousand observations/points; both scatter plots are H-F intraday from 22$^{\text{nd}}$ of January 2015, when the PSPP was introduced (planned to start in March 2015) by the ECB and monetary policy rates were unchanged. This decision was widely anticipated. This particular day was chosen for its representative look which is characteristic for the anticipation-period before the implementation of the PSPP (end of 2014 and beginning of 2015) and ended on this very day, and for its non-biasedness, which could otherwise be caused by a lack of liquidity, or the presence of major geopolitical events.

[24] With negative slope for bond-based leg yield change and with positive slope for STIR-based leg yield change.

[25] Derived density distribution was used to determine observation home clusters in intercept.

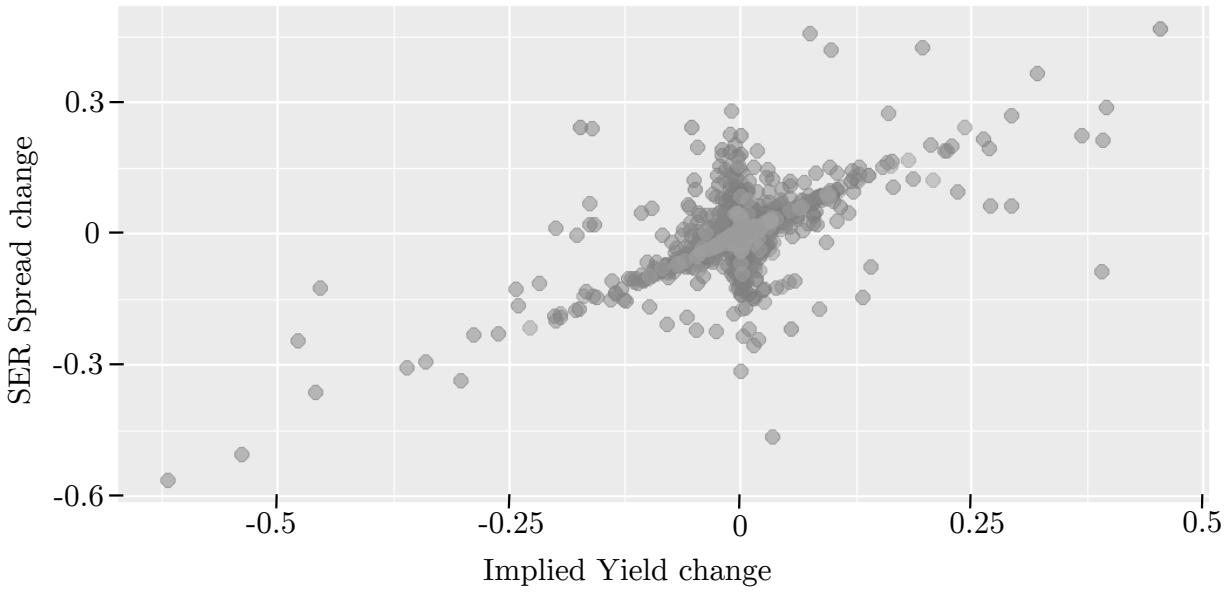
Figure 5.4: Cash bond price in relation to the SER spread before the PSPP [changes]



Source: author's; Date: 22nd of January 2015; Units: basis points for the SER spread, % of par value for bond price.

From the plots, it is clear that no leg of the SER spread is yet dominant in its impact on the SER spread's change, and though there is a traceable linear dependence cluster on both plots, there is still a majority of points suggesting a random quantity with two-dimensional normal distribution with $\rho = 0$. These scatter plots still have a strong component that could be identified as statistically independent, and was present significantly till the PSPP introduction. Statistical independency of both variables is especially characteristic for "normal" times before the period when asset purchases started to be anticipated (for 2013 and part of 2014), when there was no major leading force in the bond or STIR markets that would cause in the long run (days / weeks / months) some easily measurable change of the SER spread.

Figure 5.5: Implied yield in relation to the SER spread before the PSPP [changes]



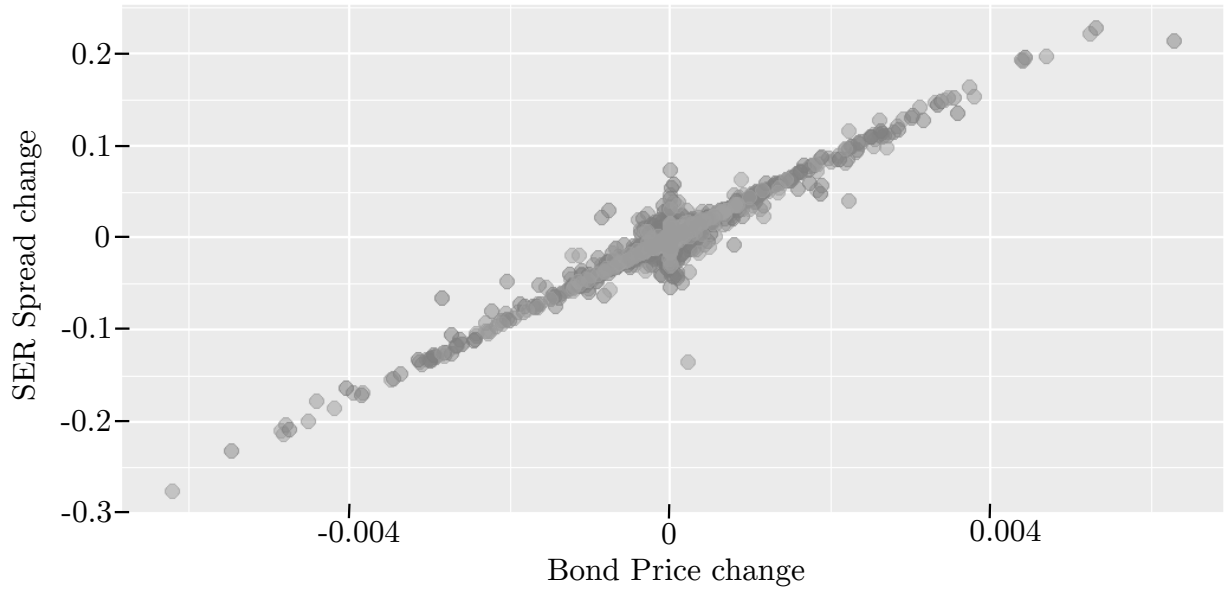
Source: author's; Date: 22nd of January 2015; Units: basis points for the SER spread, basis points for implied STIR yield.

The situation is quite different for the times during the PSPP implementation as is visible on scatter plots in Figure 5.6 and Figure 5.7, which represent a common, non-exceptional day from the analyzed period 03/2015 - 05/2017 under the influence of the PSPP. These are the same type of plots made from intraday movements on 15th of December 2015. Both plots are now quite different from each other, and it's clearer that movement in the cash bond price is accompanied by a linear change in the SER spread. The same cannot be doubtlessly said about the movement on the STIR-based leg (yield of constructed synthetic implied bond). There are still some contours of a weak linear dependency – some changes in the SER spread were still induced by change on the STIR-based leg. Nevertheless, the majority of these observations are either random (statistically independent), or showing a strange relationship, whereby a change in the SER spread was not at all accompanied by a change in the yield of the constructed synthetic implied bond. These situations are probably caused by either a lock-in of very stable packs / bundles of the underlying STIR (Euribor in this case), or more frequently and importantly when the SER spread's change was induced solely by the bond-based leg movement that was unaccommodated by the STIR-based leg movement.

For both cases, as for other days during the analyzed time period, the direct relationship between both legs on the used time-interval of 5 seconds exhibits a cross shaped relationship – a yield change on the bond-based leg caused no change on the STIR-based leg, and vice versa. It either means that a 5-second interval is too short to reprice change on the first leg

to the second one, or more probably that the relationship between both legs was somehow compromised in the given time period, and that market participants were reluctant to mirror changes from the first leg to the second one. Normally it would be a tempting arbitrage opportunity.

Figure 5.6: Cash bond price in relation to the SER spread during the PSPP [changes]

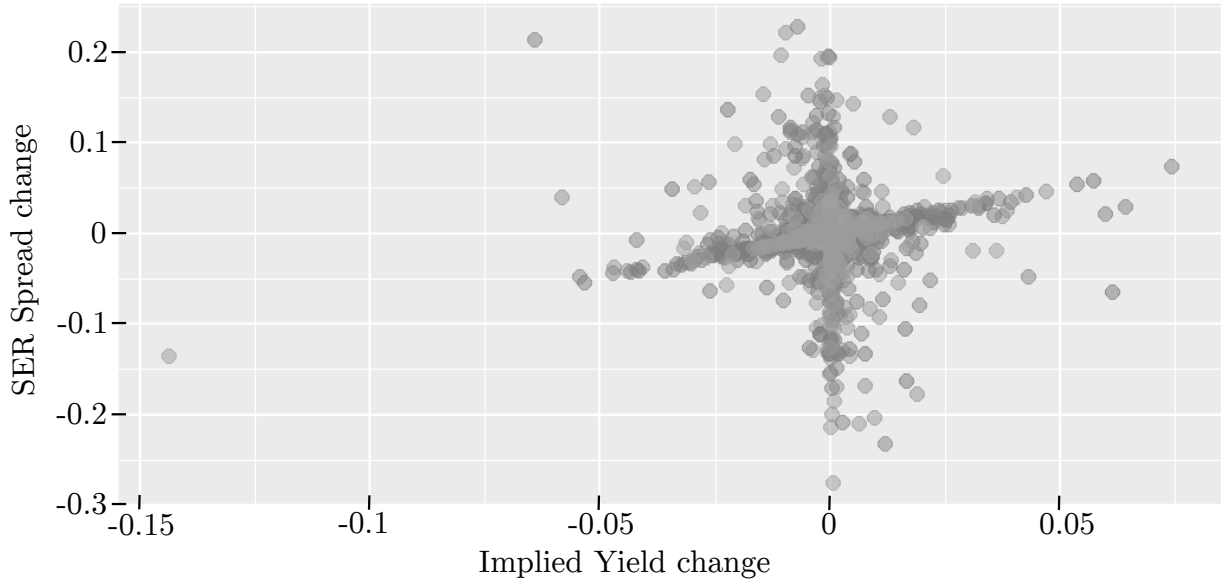


Source: author's; Date: 15th of December 2016; Units: basis points for the SER, % of par value for bond price.

The following Figures 5.8 and 5.9 represent an exemplary model day that is more or less characteristic for the analyzed time period. Figure 5.8 depicts the clustered relationship between the bond-based leg yield change and the SER spread's change, and Figure 5.9 depicts the clustered relationship between the STIR-based leg yield change and the SER spread's change. On H-F data for 15th of December 2016[26], the scatter plots in Figures 5.8 and 5.9 were constructed by clustering methods (described in preceding section), and all observations were categorized as one of the three identified components – [1] the component that represents the linear dependency of the yield change of the given SER spread's leg, [2] the component that contains all the observations that are on the vertical line around the y-axes, and [3] the independent component that represents other observations with no apparent

[26]Regular day with no major macroeconomic event release, monetary policy decision, geopolitical factor or market liquidity irregularities in the Eurozone.

Figure 5.7: Implied yield in relation to the SER spread during the PSPP [changes]

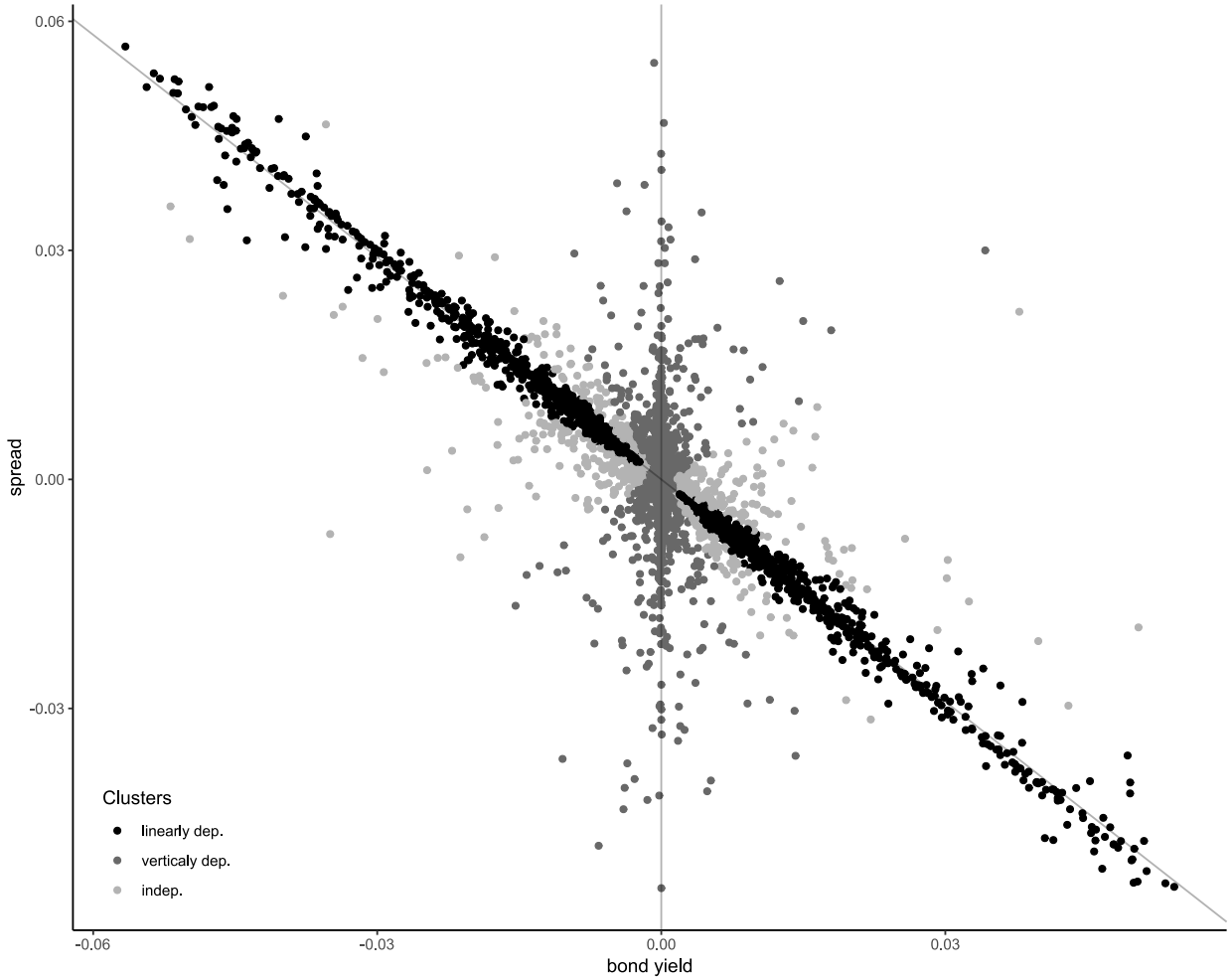


Source: author's; Date: 15th of December 2016; Units: basis points for the SER spread, basis points for implied STIR yield.

dependency between the SER spread's leg yield change and the SER spread's change.[27] Especially important are component [1] and component [2]. Component [1] is strong for the bond-based leg and weak for the STIR-based leg, by which it is possible to interpret that the SER spread's changes and the bond-based leg yield change is highly correlated, and that the bond-based leg has had a very strong dominance during the given period in determining the SER spread, unlike the STIR-based leg. Since we are speaking about "spread", it is possible to directly speak about causality between the bond-based leg and the SER spread. Component [2] is on the contrary strong in the STIR-based leg and, as mentioned before, it was probably caused by either lock-in of the underlying STIR, or situations when the SER spread's changes were induced solely by the bond-based leg and were unaccommodated by the STIR-based leg. This would suggest that market participants perceived the change in the SER spread as backed up fundamentally, and did not mirror it to the Euribor.

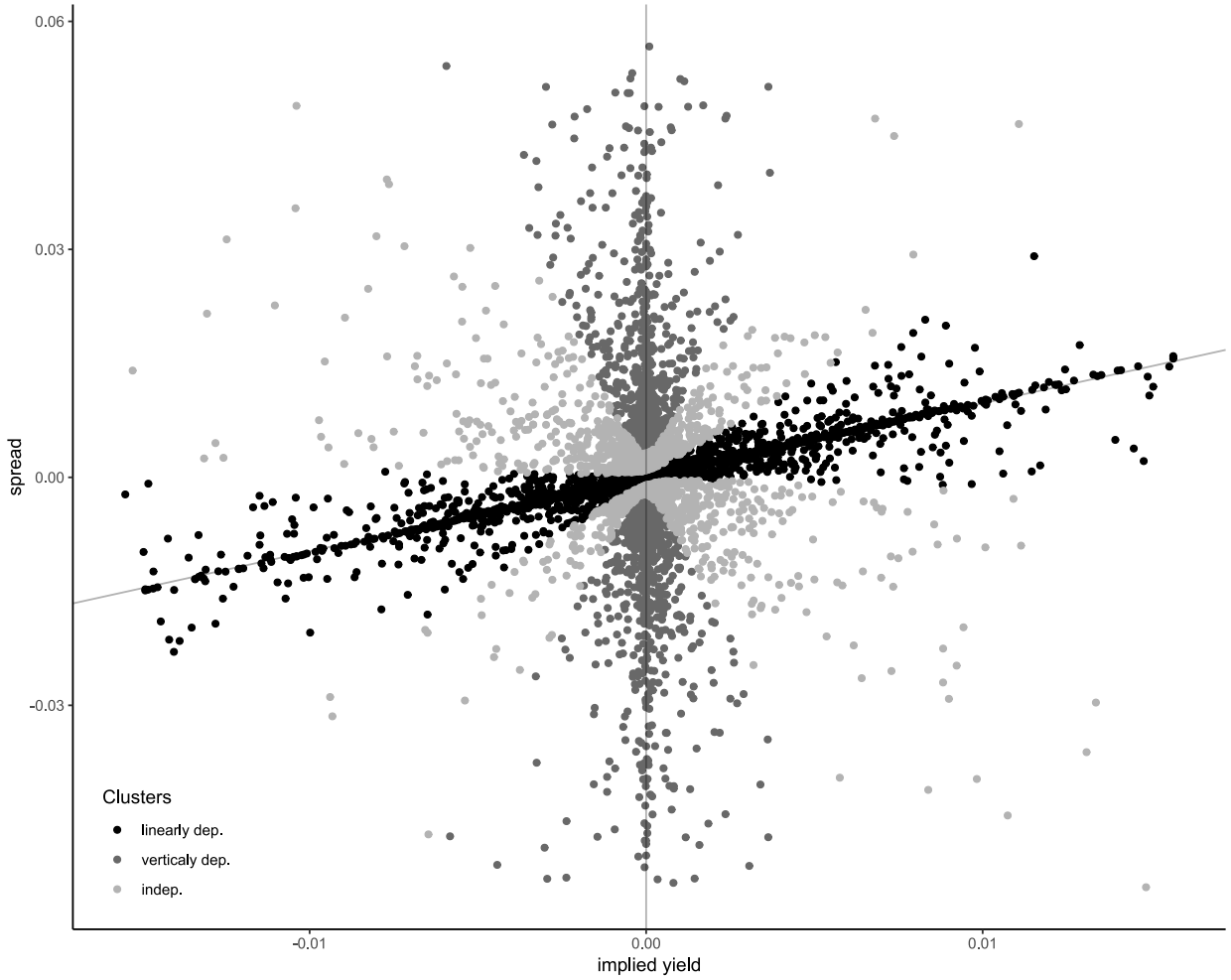
[27]The used method is only approximative, and used in order to include only component [1] and [2] observations that clearly belong to that given category. The division of observations close to the center of the intercept of all components can be therefore slightly biased, however a reasonable assumption is that the bias is rather small and not result-changing.

Figure 5.8: Clustering of the cash bond yield in relation to the SER spread [changes]



Source: author's; Date: 15th of December 2016; Units: basis points.

Figure 5.9: Clustering of the implied yield (STIR) in relation to the SER spread [changes]



Source: author's; Date: 15th of December 2016; Units: basis points.

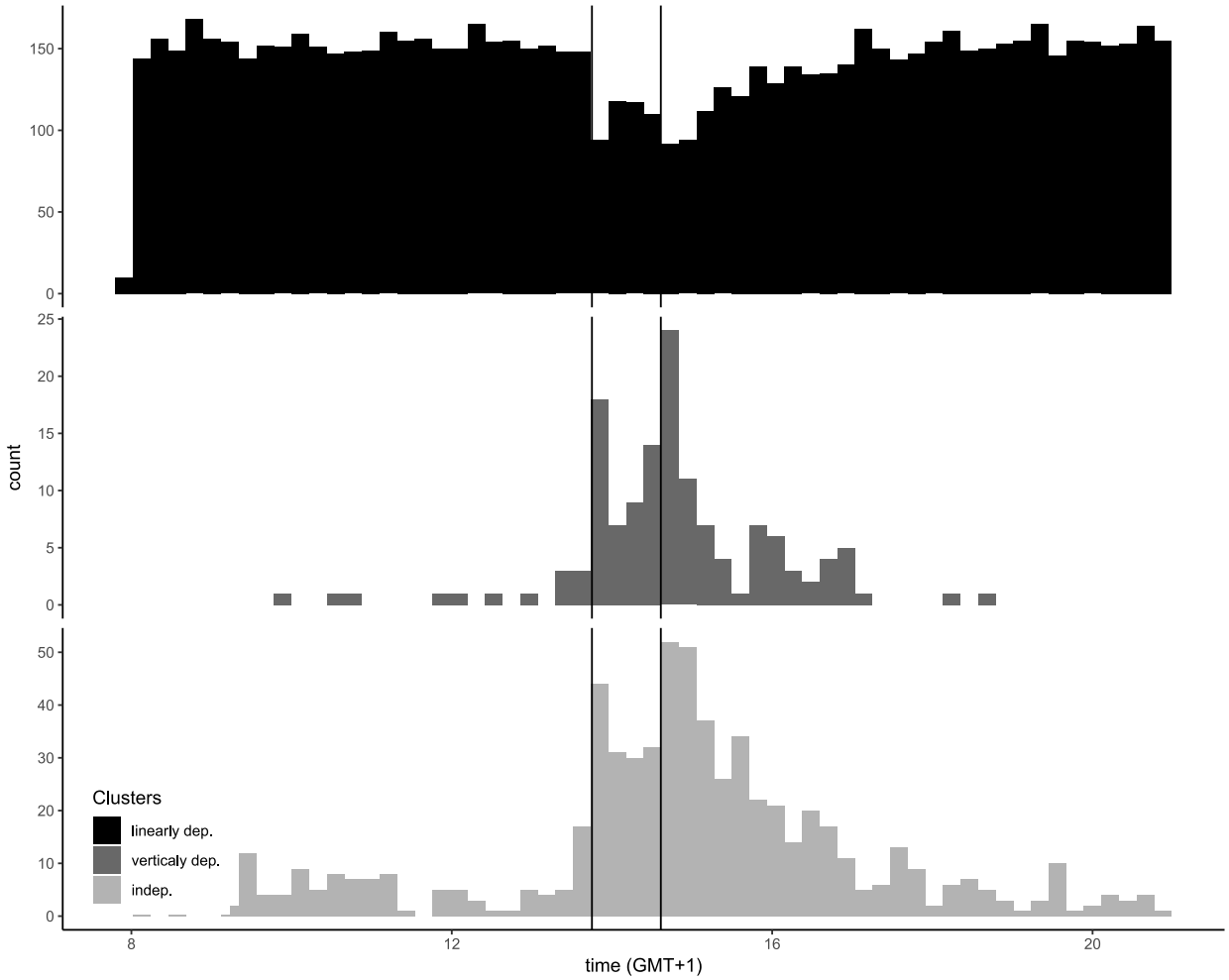
The same clustering approach was applied using several other dates, with approximately a quarter year time-lapse between them, to capture the process dynamics, and its output statistics are in Table 5.1. It is apparent that the slope of the line fitted through component [1], representing the bond yield change vs the SER spread's change, is fairly stable through time, and that this component includes the majority of observations, as for the bond-based leg in 2017. This would suggest a dominance of the bond-based leg over the STIR-based leg in determining the SER spread in 2017 (SER spread's change was induced only by the bond-based leg, not by both legs together moving in the same direction), while for the STIR-based leg it is characteristic in 2017 that component [2] includes the majority of observations, which probably means that the STIR-based leg had very little influence on determining the SER spread. The slope of the fitted line through component [1] of the bond-based leg is also very close to -1, which could be interpreted as meaning that these observations were not accompanied by an opposite-direction movement of the STIR-based leg.

Table 5.1: Descriptive statistics of selected days from 2016-2017

Date	Leg	Comp.	Obs./ tot. obs.	↑ Yield: SER bp change	↓ Yield: SER bp change	SD leg	SD SER	Slope
6/14/16	Bond	(1)	1899 / 8626	-15.59	**18.17**	3.42E-02	3.38E-02	**-0.986**
		(2)	5936 / 8626	-0.35	0.61	1.33E-03	4.62E-03	∞
6/14/16	STIR	(1)	951 /8626	2.84	-2.9	1.20E-02	1.17E-02	**0.924**
		(2)	532 /8626	-2.18	2.62	9.59E-04	5.95E-02	∞
9/29/16	Bond	(1)	2214 / 8626	-8.45	**9.21**	2.02E-02	1.99E-02	**-0.983**
		(2)	447 / 8626	0.74	-0.34	1.15E-03	1.88E-02	∞
9/29/16	STIR	(1)	373 /8626	2.02	-1.6	2.16E-02	2.07E-02	**0.956**
		(2)	617 /8626	-2.17	3.17	8.19E-04	3.67E-02	∞
12/15/16	Bond	(1)	2571 / 9345	-23.2	**23.74**	3.55E-02	3.45E-02	**-0.971**
		(2)	5814 / 9345	-0.54	0.54	1.22E-03	5.27E-03	∞
12/15/16	STIR	(1)	5789 / 9345	5.7	-5.8	5.74E-03	5.60E-03	**0.912**
		(2)	1841 / 9345	-6.8	6.02	1.52E-03	3.92E-02	∞
3/1/17	Bond	(1)	7953 / 9345	-33.82	**28.91**	2.65E-02	2.61E-02	**-0.984**
		(2)	1338 / 9345	-1.39	1.17	4.85E-03	1.43E-02	∞
3/1/17	STIR	(1)	1075 / 9345	4.47	-4.58	1.49E-02	1.57E-02	**0.933**
		(2)	8187 / 9345	-9.76	4.64	1.40E-03	2.57E-02	∞
5/18/17	Bond	(1)	7812 / 8626	-37.4	**36.93**	2.37E-02	2.25E-02	**-0.941**
		(2)	714 / 8626	-0.27	0.67	7.55E-03	2.72E-02	∞
5/18/17	STIR	(1)	758 / 8626	6.57	-6.17	2.65E-02	2.63E-02	**0.947**
		(2)	7443 / 8626	-9.56	8.79	1.95E-03	2.24E-02	∞

Source: author's; Note: ↑/↓ Yield: SER spread bp change is sum of all SER spread changes while leg yield went ↑/↓.

Figure 5.10: Time distribution of bond leg clusters



Source: author's; Date: 8th of December 2016

In Figure 5.10 above, an interesting episode is captured – the time distribution of individual clusters through 8th of December 2016, when the ECB released a decision regarding its monetary policy, and held a press conference. Monetary policy rates were not changed; however, the ECB in its decision prolonged APPs, introduced a reinvestment framework for APPs, securities lending facility, and allowed the use of cash reserves as a repo collateral.

From time distribution of the SER spread's changes it is clear that before the decision, the markets followed a pattern where the bond (Bund) directly influenced the SER spread, and this movement is not offset by Euribor (see component [1]). Around the time of the decision and press conference, and for some time after, markets exerted a different pattern, a rather uncertain one caused by not knowing the outcome of the ECB decision, when components [2] and [3] would gain some strength. However, around 5:00 PM markets started to follow

the same pattern as they had followed the whole forenoon, when it was clear that the ECB would hold the same direction of monetary policy and would not be willing to taper its asset purchases any time soon.

This altogether provides some indirect evidence about the real effect of the ECB's PSPP on the SER spread – at least it can be said that the strong or unaccommodated demand for German bonds that caused prices to rise, and consequently to cause the widening of the SER spread, was not caused by forces that would affect both legs, and it effectively eliminates many possible causes. For instance, a change in the ECB's rate policy would affect both legs in the same direction, and the SER spread would remain unchanged.

Complementary descriptive analysis

Some indicative power can also be attributed to a simple descriptive statistic – the 30-day moving average of standard deviations (SD) of 3M Euribor and 3M German Bubill prices, as depicted in Table 5.2, were elevated especially during the Great Recession years of 2008-2009, but were fairly comparable for both underlying instruments. For the two following periods of the European debt crisis (2011-2012), and the calm period before the PSPP introduction, SDs were still very similar for both underlying instruments. The same, however, cannot be said about period during the PSPP implementation (2015-2017), displayed in the Figure 5.11, where the SD of 3M German Bubill prices almost quadrupled the SD of 3M Euribor. This period is without doubt characterized by higher German bond price volatility.

Table 5.2: The 30D moving average SD of 3M Euribor and 3M German Bubill prices

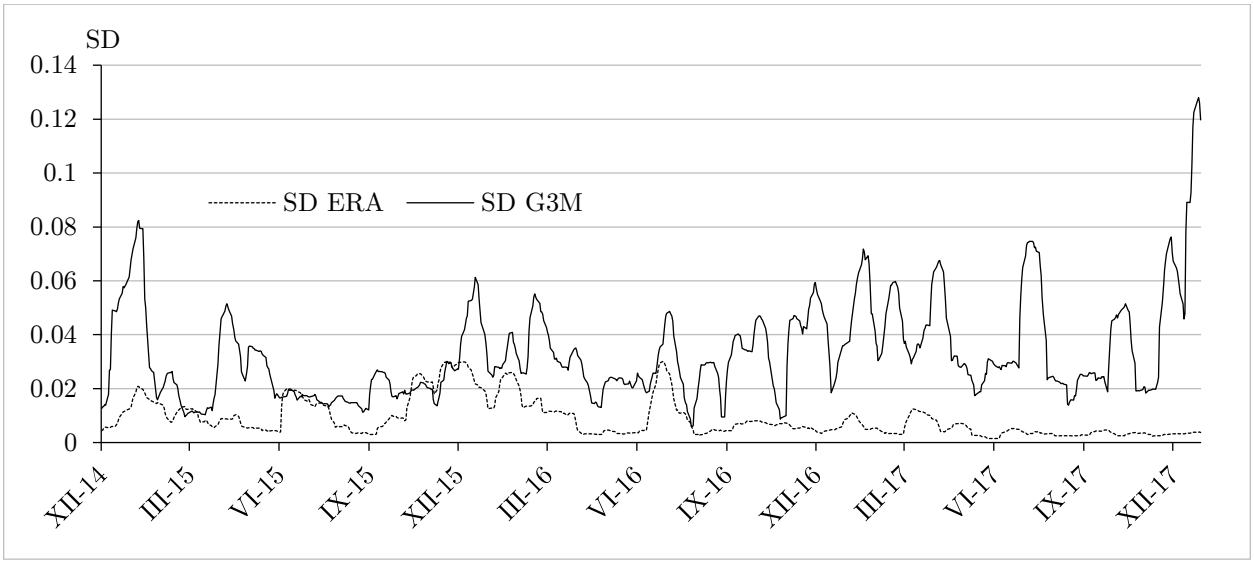
	2008-2009	**2011-2012**	**2013-2014**	**2015-2017**
3M Euribor	0.095402	0.054078	0.018862	0.008958
3M GE Gov. Bond	0.104255	0.069199	0.015057	0.033179

Source: author's; Units: units of underlying contracts.

Intraday standard deviations of both legs and the SER spread in time windows of 3, 5 and 10-minute intervals were constructed for all trading days in 01/2015 - 05/2017. An intraday SER spread's SD carries no easily interpreted information, but in relation to the intraday SD of its legs, reveals the fact that an increase in the SD on both legs at the same time does not necessarily increase the SD of the SER spread; only an unaccommodated movement of one leg would usually be transferred to an increase in the SD of the spread between them.

Another meaningful way is to look at the price correlation of different German cash bonds with various remaining maturities, this gives us the information about the yield curve of the federal debt of Germany. Correlations naturally react swiftly and strongly to any change in market expectations regarding the ECB's QE policy and its intentions to engage in asset purchasing. Price correlations in the spectrum of German sovereign bonds are depicted in

Figure 5.11: The 30D moving average SD of 3M Euribor and 3M German bond yields



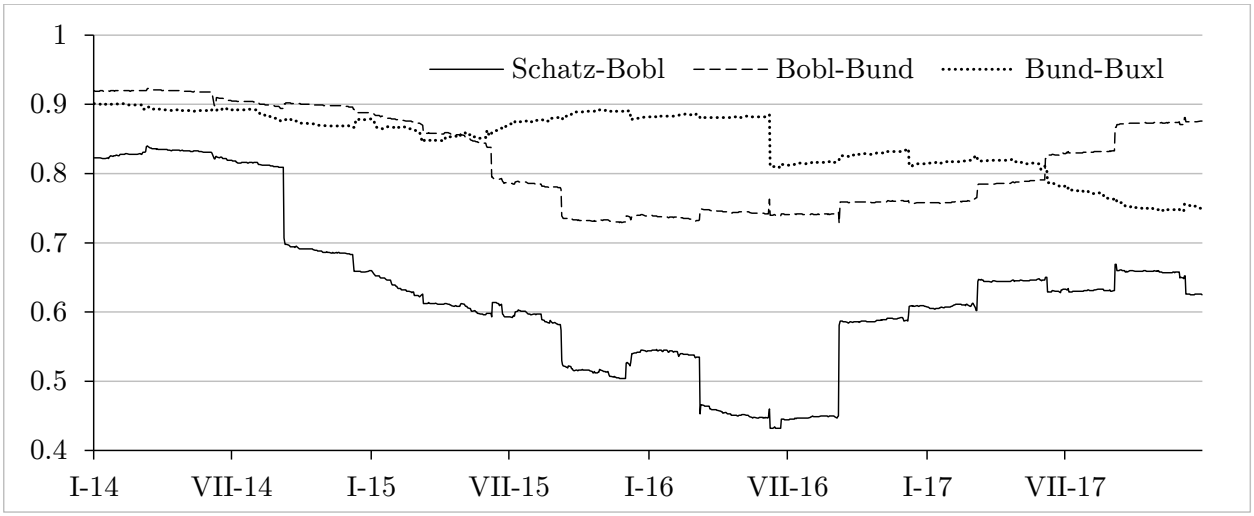
Source: Bloomberg / LIFFE, Deutsche Finanzagentur; Span: 12/2014 - 12/2017.

Figure 5.12. Four main groups of bonds issued by the Federal Republic of Germany are represented: the Schatz (remaining term in years 1.75 to 2.25), the Bobl (remaining term in years 4.5 to 5.5), the Bund (remaining term in years 8.5 to 10.5), and the Buxl (remaining term in years 24 to 36), all traded on the Eurex Exchange in Germany. The ECB's PSPP weighted average remaining maturity of purchased German bonds was very close to the 7 years prior to December 2018. This part of the yield curve is represented by Bund, and is by far the most traded contract among German bonds. Figure 5.12 captures correlations between given bond maturities, and was heavily affected by all important ECB's decisions about its QE policy, and this is visible on several jumps around decision dates. The base logic behind price correlation changes is that when the ECB targeted certain yield curve part of sovereign bonds for asset purchases, created significant pressure on its prices that was not fully transferred to other parts of the yield curve (long-end). In 2016 and 2017, the often disputed tendency in European fixed income markets was squeeze on German bonds, when a diminishing free float of tradable German bonds emerged, see e.g. Ashworth (2017) or Garzarelli and Cena (2015). The same logic stands behind Operation Twist, announced by the FED in 2011, which caused the yield curve to flatten by reinvesting SOMA bond holdings into bonds with longer maturity, see e.g. Swanson (2011).

There was a relatively calm period prior to the 09/2014 rate cut, and introduction of the third Covered bond purchase programme (CBPP3)[28], increase of the issue share limit

[28]See monetary policy decisions of ECB from 4th of September 2014.

Figure 5.12: Price correlations of the German bonds across maturity portfolio



Source: Bloomberg / Eurex Exchange, Deutsche Finanzagentur; Span: 01/2014 - 12/2017.

for purchased assets via the PSPP in September 2015[29], and rate cut, expansion of APPs and introduction of the Corporate Sector Purchase Programme (CSPP) and the second Targeted longer-term refinancing operations (TLTRO II) in March 2016.[30] Interesting is the sudden jump in the correlation of the short-end yield in September 2016, when no monetary policy change was implemented, but came later on in December, and the markets strongly expected a change in asset purchase policy, see Murray, Powell and Sbaihi (2016). On the other hand, a strongly anticipated major changes of monetary policy, as the one announced in December 2016, were accompanied only by a minor price correlation change on the Schatz-Bobl (increase) and the Bund-Buxl (decrease), when the ECB announced another extension of APPs, lowered its eligibility criteria and introduced cash collateral for PSPP securities lending facilities.[31]

Figure 5.13 below is a special, non-standard, tailored representation of selected "special" days from within the analyzed period 01/2015 - 05/2017, that were exceptional because of some deviation from the general characteristic: either by the cumulative change of the SER spread (MaxDiff) exceeding 1 bp, or by a one-time change of the SER spread (MaxChange) exceeding 0.5 bp or maximal intraday SD (MaxSD) of the SER spread exceeding 0.5 bp. This graphic representation of leg prevalence gives us a picture of a gradual rise of the importance of the bond-based leg over the STIR-based leg, as the PSPP continued and the ECB accumulated holdings consisting of sovereign bonds. The x-axis in Figure 5.13 is

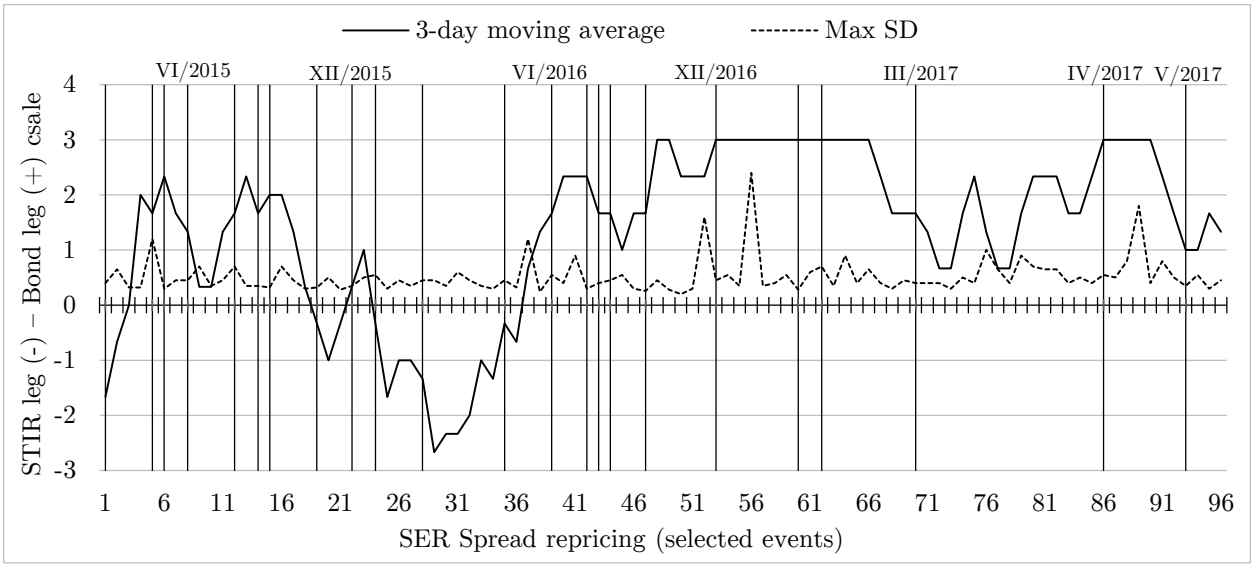
[29] See monetary policy decisions of ECB from 3rd of September 2015.
[30] See monetary policy decisions of ECB from 10th of March 2016.
[31] See monetary policy decisions of ECB from 8th of December 2016 and press release where Eurosystem introduced cash collateral for PSPP securities lending facilities.

nonlinear in time because of the uneven time distribution of selected "special" days from the dataset. The y-axis represents the average count of the daily occurrence of the biggest three SER spread's changes, induced either by the bond-based leg or the STIR-based leg. The separation of one group from the other was done by equation 5.2, below.

$$\text{separation} = \left\{ \frac{|i^{impl.}|}{|i^{impl.}| + |i^{bond}|}; \frac{|i^{bond}|}{|i^{impl.}| + |i^{bond}|} \right\}, \tag{5.2}$$

where i stands for change in the given leg specified in the upper index, and which lies within the interval [0,1]. Basically, the SER spread changes only, when both legs moved in the same direction (one moved more than the other), or when one of the legs did not move with the other, are captured in the calculation.[32] The SER spread's changes, which were characterized by the movement of both legs in opposite directions, were excluded because of their ambiguity. One important finding from the analyzed period was in causality direction – price changes on the STIR-based leg were usually followed by price change on the bond-based leg and not otherwise. This is literally the technical reason why the SER spread widened, while prices of German bonds rose, and this price movement was not mirrored on the STIR-based leg.

Figure 5.13: The SER spreads during selected days – 3 top changes moving average leg dominance



Source: author's; Note: no occurrence of abnormal repricing of the SER spread occurred in the following months: 2015 (February, April, August), 2016 (April, May, August).

[32] Pair {0;1} or {1;0}.

All analysis presented above provides indirect evidence of strong market pressures that highly affected markets for German government bonds and had undoubtedly a strong effect on the widening of the SER spread as well. The unavailability of relevant intraday data about ECB's purchases, and the OTC nature of cash bond markets, unfortunately do not allow to carry out a more direct and straightforward kind of statistical analysis, that would provide direct evidence rather than indirect.

The overall analysis of H-F data uncovered several interesting facts about the SER spread:

- In 2017, the SER spread reached its peak level, not seen since the 2012 European debt crisis, and its rising tendency is traceable since the end of 2014 and the beginning of 2015. During that time some kind of ECB's QE asset purchase programme was highly anticipated.
- The bond-based leg constituting the SER spread (constituting together with the STIR-based leg) is accountable for the majority of the SER spread's changes, and they were not followed by the STIR-based leg. Especially the biggest repricing events / days in 2016 and 2017 were driven by this leg. This period corresponds with a squeeze on the prime euro-denominated sovereign bond market in the Eurozone, especially on German bonds.
- During 2015 and the beginning of 2016, the STIR-based leg of the SER spread was still accountable for a nonnegligible share of the SER spread's change, but this share gradually fell.

5.5 Conclusions

In this paper the H-F clustering analysis and the complementary descriptive analysis uncovered a relationship between the SER spread, and its constituting legs – the first based on short-term German government bonds, and the second based on the Euribor rate. The undertaken analysis is by its nature only indirect, yet capable of uncovering a connection between the ECB's monetary policy, especially the PSPP, and the SER spread. A direct analysis of the PSPP purchases and their connection to the SER spread would require granular, ideally H-F data, that is not provided by the Eurosystem. Weekly, monthly or ISIN-derived data capturing the Eurosystem asset purchases, would not be sufficient to undertake a more direct analysis, until the time of availability of exact data, when it will be possible to match purchases of the Eurosystem to market trade-by-trade data.

The H-F analysis answered questions stated in the first section of this paper, and uncovered several interesting facts about the SER spread and its constituting legs that would otherwise have remained hidden. The central finding is that the bond-based leg has been the SER spread's determining leg, since the beginning (or even since the anchoring of market anticipation) of the PSPP programme, and this role even intensified later on in 2016/2017 when the squeeze on prime bond markets hit its yields hard. Unlike in the preceding times, when no leg had had such an overwhelmingly leading role in determining the SER spread. The role of the SER spread as an indicator of financial market distress was seriously impaired, and its recent elevations give us completely different information than it would have in the case of a STIR-based leg dominance. The PSPP undoubtedly caused the shortage of prime sovereign bonds in the Eurozone, and despite (possibly because of) the securities lending facility and the ECB's collateral requirements has changed, it led MFIs and other institutional investors to significantly reduce their holdings of German bonds. Among the factors that impact the bond-based leg of the SER spread, is not only the unconventional monetary policy of the ECB, but also the shrinking federal debt of Germany caused by the budget surpluses in recent years, and the changing collateral framework, and last but not least, the slowly changing preferences of domestic and foreign investors regarding composition, riskiness and maturity of their investment portfolios. The STIR-based leg of the SER spread is currently very stable, and the reality of abundant excess bank liquidity, effective functionality of the interbank money market, ECB's liquidity-providing programmes, and the future prospect of still very dovish monetary policy contribute together to this current state.

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Chapter 6

Conclusions of this doctoral thesis

The partial contributions of each paper constituent to this thesis to the QE monetary policy knowledge base is stated below. Each paper has a different theme, and, the methods I used in one of them may differ from the methods I used in other ones, yet all four papers form together a coherent and inter-complementary research that studies QE monetary policy. The FED's QE was approached in a more aggregated level as a single concluded episode, then the ECB's APPs were studied separately on a PSPP and CSPP basis, with their overlappings on a micro level, and then finally the analysis of the PSPP impact on the SER spread and German government bonds represents detailed analysis of separate markets on a high-frequency basis. The conclusions of each paper constituting this thesis follow underneath:

Jakl, J. (2017). ***The Impact of Quantitative Easing on Purchased Asset Yields, its Persistency and Overlap*****, Journal of Central Banking Theory and Practice, Vol. 6, No. 2, pp. 77-99.**

Announcements of the FED's asset purchases had a significant effect on all targeted assets, mainly during the first wave of QE (QE1), when this unconventional monetary policy was completely new, and market subjects were not yet familiar with it, and were cautiously expecting its introduction. The strongest impact of asset purchases is observable in the segment of MBS, while the MBS market was under serious distress, torn by mistrust in the concept of securitization. The Maturity Extension Program, where the FED reinvested part of its portfolio of bonds with short maturity into bonds with long maturity, caused a relative shift in yield decrease from the short-term bonds to the long-term bonds. Yields of bonds with longer maturity decreased mainly due to QE-induced reduction of term premiums. The asset purchase programmes of the FED had also an impact on other than purchased assets, while for example the direct effects of purchases on government bond markets spilled over into the corporate bond segment. The initial effect of yield decrease gradually moved from the segment of government bonds and MBS to other segments like corporate bonds that were not bought under the APP programmes. The third wave of QE (QE3), in fact, caused

more or less only yield changes in segments that represent the investment alternatives to QE-targeted assets, what would speak for validity of the portfolio-rebalancing channel. The yield decrease of U.S. government bonds was undoubtedly caused not only by the FED's QE policy, but also by a series of global risk-offs and shifts in investment portfolios towards less risky assets. The European debt crisis was one of the events that may have caused an elevated demand for U.S. federal bonds, and together with the QE policy, caused a yield decrease that was observed.

Jakl, J. (2019). *The True Nature of the Portfolio Balance Channel of Quantitative Easing Policy*, Review of Economic Perspectives, Vol. 19, No. 2, pp. 95-117.

The regression model used in the paper and the counterfactual analysis results provide some evidence of the presence and the nature of the so-called portfolio balance channel during the PSPP implementation. All types of investors reshuffled their portfolios, selling government bonds to the Eurosystem, and buying different types of assets, mostly corporate bonds and equities (listed shares) and equity fund shares. The analysis showed that investors are quite willing to sell government bonds, particularly foreign investors and MFIs. The relative increase in MFI holdings of alternative assets was smaller for corporate bonds and equities, compared with the decrease in government bond holdings. The counterfactual analysis showed that the closest alternative-investment asset classes – corporate bonds and equities, were verifiably bought more than they would have been in the case of a non-PSPP scenario. There is an exception for corporate bonds bought in Germany, which is most likely given by Germany's exceptional position as a government and corporate bond benchmark country with the most high-rated issues in both the government and the private sector. The same pattern of reallocations from the government bonds to corporate bond holdings applies also for non-residents, the very important counterpart of the Eurosystem. This segment of foreign investors, however, cannot be analyzed in more detail due to missing holdings data, and the unknown structure of their assets abroad. Household's equity holdings may have decreased due to the PSPP; it could have been the result of locking in the equity profit arising from the increase in equity prices. This could be the consequence of the ECB's asset purchases as well, and it's not necessarily against the model expectations. The PSPP led to the portfolio reallocations towards riskier assets, and it remains an open question whether the benefits of lower funding costs across the Eurozone, caused by the ECB's asset purchases, are justifiable facing the higher risk exposure of investors in the Eurozone.

Jakl, J. (2019). ***The Outreach and Effects of the ECB Corporate Sector Purchase Programme*****, Prague Economic Papers, Status: accepted for publication / not yet published.**

The analysis in this paper uncovered the strength and time distribution of the impact of the Corporate Sector Purchase Programme undertaken by the ECB. a detailed picture of the effects of the CSPP implementations, in all their phases, covers phase before the announcement, about the time of the CSPP announcement, before the first realized purchases, during the purchasing time itself, and after when the effects caused by the ECB's amendments of asset purchase programmes were realized. a tailored event study made it possible to distinguish the impact of the CSPP from the other events with possible impact on corporate bond yields that do not relate to monetary policy. The analysis quantifies by two distinct methods, by the event study and by the VAR-IRFs analysis, the yield changes in corporate sector bonds that may have been caused by the CSPP, and doing so in both universes. The CSPP-eligible bond universe, and the CSPP-ineligible universe. Quantification is multicriterial by distinction of country of issuance, remaining maturity, issuance rating and sector of issuer. The VAR-IRFs analysis uncovered the micro-level impact of the CSPP on bond emissions of selected Eurozone companies. The inclusion of a particular ISIN to the Eurosystem CSPP-related holdings, was accompanied not only by a yield decrease in the given emission, but also by a yield decrease in other emissions of the given companies. The impact of the no-QE-related monetary policy on expected future interest rates was identified and quantified, and separated by the methodological apparatus used to measure the impact of the QE monetary policy. This separation allowed me to distinguish the impact of QE from the effects caused by other forms of monetary policy (i.e. forward guidance and the setting of monetary policy rates – mainly the ECB's depo rate). By analyzing the relationship between yield changes in corporate bonds and their national sovereign bonds, which usually play the role of the "benchmark" bonds, the estimation of the impact of the ECB's CSPP was enhanced. The national-specific fiscal- and political-related events may have affected the bond yields in the economy, and this approach allows me to control for it. Credit, liquidity and term premia over time were estimated for segments of CSPP-eligible and CSPP-ineligible corporate bonds, and the ECB's QE monetary policy was discussed in relation to their changes. The model results and the ensuing discussion suggests that the CSPP had significant nonnegligible effects on the funding of the non-bank corporate segment, the corporate bond emissions, and on the real costs of the funding of the corporate sector in the Eurozone.

Jakl, J. (2019). *The SER Spread under the ECB Quantitative Easing*, European Financial and Accounting Journal, Status: accepted for publication / not yet published.

The high-frequency clustering analysis and complementary descriptive analysis revealed in this paper the relationship between the SER spread and its constituting legs, the first leg based on short-term German government bonds and the second leg based on the Euribor rate, and how it changed as a reaction to the ECB's PSPP. The central finding is that the bond-based leg has been the SER spread's determining leg since the beginning of or even since the anchoring of the market anticipation of the PSPP, and that this role had even intensified later on in 2016/2017 when the squeeze on the prime bond markets hit its yields hard. The role of the SER spread as an indicator of financial market distress was seriously impaired and its recent elevations give us completely different picture than would have been given in the case of STIR-based leg dominance. The PSPP undoubtedly caused the shortage of prime sovereign bonds in the Eurozone, and despite (because of) the implementation of the securities lending facility and the ECB's collateral requirements changes, MFIs and other institutional investors were lead to significantly reduce their holdings of German bonds. The STIR-based leg of the SER spread is currently very stable, and the reality of abundant excess bank liquidity, the effective functionality of the interbank money market, the ECB's liquidity-providing programmes, and the future prospect of a continuing very dovish monetary policy, all contribute together to this current state. Among the factors that impact the bond-based leg of the SER spread is, not only an unconventional ECB's monetary policy, but also the shrinking of the federal debt of Germany, caused by budget surpluses in the recent years. Other factors are a changing collateral framework, and last but not least, a slowly changing preferences of domestic and foreign investors regarding composition, riskiness and maturity of their investment portfolios.

The overall contribution of this thesis to the QE monetary policy knowledge base, and to the understanding of this relatively new and unconventional monetary policy rests in answering the research questions stated in the introductory section of this paper, and in the other findings that came out from my analysis undertaken in the four thesis-constituent papers. The possible effects of the Federal Reserve's QE monetary policy on various asset segments were identified, and quantified for the intensity and persistence of the impact. The detailed event study uncovered the different nature of each QE wave, and the Maturity Extension Program undertaken by the FED in the years 2008-2014; and quantified their impact on yields of targeted assets, and on assets that are being considered as investment alternatives. The VAR-IRFs analysis uncovered the shape of the response function to monetary policy shocks, and the magnitude and time persistency of these shocks in various asset segments. The revealed nature of the FED's QE policy is in line with economic theory predicating a strong role of the portfolio rebalancing channel and the signalling channel.

Similar analysis was undertaken to uncover effects of the ECB's QE monetary policy, consisting mainly from the PSPP and the CSPP, where both programmes were analyzed in detail. The results of the undertaken analysis suggest a possible presence of the portfolio balance channel, and the signalling channel, acting as the main transmission channels present in the transmission mechanism of the QE policy in the Eurozone. Sectoral aggregated results for portfolio rebalancing induced by the PSPP were estimated, and the counterfactual analysis showed what the reality may have looked like, and how the QE policy possibly altered the situation on asset markets. The ISIN-based analysis showed the impact of the ECB's CSPP on the various non-bank, corporate bond segments in the Eurozone, and the consequent analysis uncovered the impact of this programme on the micro-level funding of selected non-bank, corporate companies, and its possible effect on the development of corporate financing markets. The VAR-IRFs analysis also uncovered the shape of the response function of bonds to the ECB's monetary policy shocks, and the magnitude and time persistency of these shocks in the segment of non-bank, corporate bonds.

The analysis undertaken in order to uncover a possible impact of the ECB's QE monetary policy on the financial distress indicator in the Eurozone, the SER spread, showed that the PSPP heavily affected markets for prime sovereign bonds in the Eurozone, and that the role of the SER spread as a financial distress indicator was seriously impaired. a detailed high-frequency cluster analysis also uncovered the behavioral patterns of market participants in German government bond markets, and the changing roles of both legs constituting the SER spread due to ECB's monetary policy.

The convenient way in which to continue the above-presented research would be to focus on the possible negatives and disadvantages of the QE monetary policy. The research presented in this thesis by various means uncovered the capabilities of the QE monetary policy in the U.S. and the Eurozone, and the fact that it was effective in bringing the long-term interest rates down, even under the condition of zero lower bound. Important questions to ask in connection to QE policy in general are: What are the overall costs compared to the overall benefits of the QE policy? Is it justifiable to transfer risks that should normally be borne by the corporate sector to the central bank via QE monetary policy? Does QE policy really demotivate fiscal policy-makers from maintaining balanced budgets and from acting responsibly with fiscal prudence? And finally, the question about the limitations of a monetary policy operating radius, that may be limited for now for the central banks that have undertaken QE policy, and whose balance sheets are overflowing with sovereign and corporate bonds and/or asset-backed securities. These questions are nonetheless immensely difficult to answer while QE monetary policy is affecting all segments of the economy, working globally, and while the quantification and overall assessment of all QE costs and benefits, and the comparison of the utility they bear, and to whom, is a rather political issue that requires a political decision.

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"All this have I proved by wisdom:
I said, I will be wise; but it was far from me.
That which is far off, and exceeding deep,
who can find it out?."

Ecclesiastes 7:23-24