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Eva Kranebitter BSc

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## List of Abbreviations

ABSPP……………………………..……………..……. asset-backed securities purchase program

AIC……………………………..……………………..…………… Akaike's information criterion

APP……………………………..…..………………..………… expanded asset purchase program

bps……………………………..……………………………………………..………..basis points

CBPP………………………..…………………………………covered bond purchase program

CPI………………………..………………………………………..………….consumer price index

CSPP…………………………………………………………corporate sector purchase program

DSGE model……………………..…..…………dynamic stochastic general equilibrium model

ECB………………………………..…………………………..…….European Central Bank

EONIA………………………………………..……………………..….euro overnight index average

ESCB………………………………………………..……………. European System of Central Banks

EU…………………………………………………..………………………………European Union

EUR………………………………………………………..…………………………………..……. euro

Fed……………………………………………………………..………….Federal Reserve System

FOMC……………………………………..……………………Federal Open Market Committee

FPE……………………………………………………………..……………. final prediction error

FTO…………………………………………………………..……...………fine-tuning operations

GARCH model…………..…. generalized autoregressive conditional heteroscedasticity model

GBP…………………………..…………………………………………………………….pound sterling

GDP……………………………..………………………………..…………….. gross domestic product

HICP……………………………..…..……………..…………harmonized consumer price index

IS-LM model………………...….Investment-Saving/Liquidity preference-Money supply model

LSAPP…………………………..……………………..…..large-scale asset purchase program

LTRO…………………………………..…………………longer-term refinancing operations

MBS……………………………………………..…………………..…….mortgage-backed securities

MRO…………………………………..………………..……..main refinancing operations

p.ex………………………………………..……………………………………..per exemple

PSPP…………………………………………………...…………public sector purchase program

SMP…………………………………………………….…………securities markets program

SSM……………………………………………….………...…single supervisory mechanism

TLTRO………………………………...…………..targeted longer-term refinancing operations

USA…………………………………...………..……………….…….United States of America

USD……………………………………….………………..……………United States dollar

VAR model……………………………..……..……..……………… vector auto-regression model

VEC model……………………………..……..………..…………Vector error correction model

# 1 Introduction

Lately the European Central Bank's monetary policy and especially its asset purchase programs have received extensive attention not only from banking experts but also from customers not specifically interested in the banking sector. Monetary policy influences us in several ways. It determines the interest rates we get paid when depositing cash in a bank and the interest rates we have to pay when applying for a loan to finance consumption and housing. Additionally, it also has major effects on business production, asset prices and inflation rates. Hence, quantitative easing has an impact on banks, companies and customers alike. This topic should be of interest to each and every citizen of the Eurozone and even beyond. The ECB's asset purchase programs are not innovative in its idea. Large-scale asset purchase programs have been implemented before, p.ex. QE1 to 3 by the Federal Reserve System.

The objective of this master thesis is to investigate the effectiveness of European and US-American quantitative easing programs and to compare them. Effectiveness is defined as reaching a persistent inflation rate of slightly below 2%. Thus, this thesis aims at answering the question whether quantitative easing programs in the euro area and in the US have contributed to reaching this target. Empirical literature was analyzed to determine the effects of the programs implemented by the Federal Reserve System. These programs were terminated already and the full impact should be visible in most current studies. The consequences of the still active European Central Bank's programs are determined by applying a vector error correction model on most current figures. Furthermore, the effects of different transmission channels are examined by analyzing and comparing empirical literature. In general, the impact of US-American programs seem to be more sizeable on financial as well as macroeconomic variables. This may be explained by the fact that the US-American programs were implemented at times of high financial stress, when quantitative easing is said to unfold its full impact. Secondly, trust issues and dispersion in the financial system of the euro area may have contributed to the limited effects of local large-scale asset purchase programs.

The master thesis is structured as follows. Chapter 2 gives an introduction to monetary policy and its two forms: conventional and unconventional measures. Special emphasis is put on the transmission channels of quantitative easing on which the hypotheses are based. The next section focuses on the structure of the Federal Reserve System. It outlines the monetary policy implemented by the Fed and analyzes its quantitative easing programs. In Chapter 3 the same is done for the European Central Bank. The first part of section four deals with the theoretical and empirical models used to analyze the impact of European quantitative easing programs on the harmonized consumer price index. The second part then summarizes the main findings. In Chapter 6 the two programs are compared before the thesis is concluded in section 7.

## 2 Monetary policy

In a perfect economy without market frictions prices are fixed. They clear markets, thus prices form in a way that aggregate supply meets aggregate demand. However, in a free economy prices fluctuate. These fluctuations are produced by and simultaneously influence the behavior of the economy. Aggregate demand consists of consumption, investment and the use of resources by the government. If real aggregate demand changes, hence changes are independent of the quantity of money, economy reacts by altering the output and thus adjusting aggregate supply accordingly. These changes are reflected in price movements. Leaving money supply unchanged, increases in the aggregate output are restricted on the upper-bound. If demand changes and prices fluctuate without being accompanied by respective changes in production, these price movements are an indication of inflation (deflation) caused by excess (shortage of) demand. The primary goal of monetary policy is to control inflationary and prevent deflationary movements without inhibiting natural adjustments in the economy. In other words central banks use monetary policy to prevent economies from sliding into hyperinflation or recession. An effective monetary policy continuously supplies an appropriate amount of money to enable a sustained growth rate. As the need for money is hard to determine, national banks can only try to forecast the approximate amount of money needed by the economy (Bernstein, 1958, p. 88ff.). A sustained growth rate is directly linked to stable prices. Unstable prices raise concerns in individuals of being confronted with inflation and as a result with future asset erosion. Individuals start safeguarding against possible losses in purchasing power instead of saving. This has a direct negative effect on business investment but also indirectly hampers investment through limiting credit availability. Deflation, on the other hand, increases the debt burden of household and business when controlled for the decline in prices. Thus, monetary policy does not only pursue the goal of continuous economic growth but also of stable prices (Federal Reserve System, 2018a).

Central banks can guide the general price level by influencing the interbank money market rate (federal funds rate in the US, main refinancing rate in the euro area). They do so by controlling the money supply. Farmer (2012) in his core monetary model explains that the targeted policy rate is based on an interest rate that would be pursued in an economy with an inflation rate of zero. This zero-inflation target is then adjusted by reaction coefficients for inflation and economic growth. Apparently this is a stark simplification of how policy rates are actually determined but it helps understanding the main driving factors of monetary policy. Influencing interest rates is a possibility to counteract the cyclical patterns bank credit availability is following. If inflationary sequences are guided by expansionary granting of credit and the economy faces the risk of overheating, central banks can reduce the demand for credit through increasing the target rate. This is achieved by taking money out of the economy and thus pursuing a contractionary stance of monetary policy. On the other hand, central banks can boost the availability of credit at the beginning of a recovery from restricted credit availability by lowering the target rate and thus implementing expansionary monetary policy (Bernstein, 1958, p. 94ff.). The induced decrease in the interbank interest rate causes a reduction in the bank's costs. Banks tend to pass these cost savings on to their customers through lowering other market interest rates (Yu, 2016). Thus, changes in the target rate have direct effects on short-term interest rates, also called money market rates in a wider sense. These short-term changes are then gradually transmitted to medium- and longer-term interest rates like the interest rates on corporate bonds and consumer loans. However, these effects happen with a time lag and are highly dependent on people's expectations about future developments in monetary policy. Hence, effects on long-term interest rates will usually be smaller than immediate effects on short-term rates. Central banks try to control effects on longer-term interest rates by choosing the maturity and the type of the assets purchased wisely (Federal Reserve System, 2018a).

## 2.1 Conventional forms of monetary policy

Central banks do not determine interest rates directly. They set a target for the overnight interest rate on the interbank money market and pursue this target by primarily altering the money supply through open market operations. These operations are conducted in the form of reverse transactions (Smaghi, 2009). When carrying out open market operations, central banks buy (sell) pre-specified securities on the open market from (to) certain securities dealers. Funds are then not credited (debited) on the dealer's account directly, but on the account that the bank of this primary dealer is holding at the central bank. The bank will then pass on the benefits (costs) to the dealer. Funds that are parked on the account a bank is holding with the central bank are called reserve balances. An open market purchase would hence lead to an increase of these reserve balances. As a result banks would be willing to lend excess reserves to other banks at more favorable conditions, putting downward pressure on the interbank money market rate and other short-term interest rates. An open market sale, on the other hand, would reduce reserve balances, leading to an increase in the interbank money market rate. The central banks have to determine the quantitative necessity of open market purchases to achieve the retention of the target interbank rate (Federal Reserve System, 2018a). Thus, in so-called conventional policy measures central banks neither actively lend to the private sector or the government nor are they involved in outright purchases of securities. They solely interact with banks and do not directly interfere in the economy. (Smaghi, 2009). Open market operations can be initiated by the central bank itself or by other financial institutions. If a commercial bank is facing increasing demand for business loans, it can finance its needs for resources through selling investments p.ex. government bonds. On the one hand, buyers can be banks with excess reserves or private individuals. In this case reserves of the banking system remain unchanged. On the other hand, if central banks act as buyers, reserves of the banking system and thus money supply is increased. In this case action is always taken by the commercial bank which is in need of funds (Bernstein, 1958, p. 92).

Besides open market operations, central banks can control the supply of money themselves without engaging in the markets through altering reserve requirements (Bernstein, 1958, p. 93f.). In order to prevent illiquidity central banks determine a fraction of deposit liabilities that a depository institution has to hold either in cash in its bank vault or on its account with the central bank, this is referred to as the reserve requirements. If the bank finds itself in a reserve squeeze, it can lend overnight from other banks that have excess reserves in the federal funds market. This lending and borrowing is then directly reflected on their reserve balances (Federal Reserve System, 2018a). Central banks also set interest rates on excess balances. In times of financial stress central banks can lower these interest rates to discourage parking of money on central bank accounts.

Last but not least, discount window lending is used as the third and last conventional monetary policy tool. If a depository institution is in need of overnight funding that cannot be serviced at the interbank market, the central bank may step in and lend to the institution directly. Originally the central bank made a loan through purchasing commercial loans at a price less than its face value and thus at a discount. This is why the interest rate offered by the central bank is still called discount rate or base rate even though today credit by the central bank is mostly given in exchange for collateral pledged by the borrower. Usually central banks set interest rates on discount window loans above interbank market rates. This way they want to ensure that the interbank market remains the first source of accommodation and that discount window lending is used in cases of emergency only (Federal Reserve System, 2018a). During the financial crises discount window lending experienced increasing importance as interbank markets seized due to trust issues. Central banks expanded its lending to prevent banks from going bust resulting from illiquidity.

As described above, monetary policy has direct effects on interest rates and liquidity. However, it also indirectly influences currency exchange rates, asset prices and wealth. These indirect effects give central banks the possibility to influence economic growth, employment and inflation. Corresponding to these effects, different channels through which monetary policy works can be distinguished.

The mechanism of affecting the economy through pursuing a target for the interbank money market rate is known as the interest rate channel and forms the linchpin of the traditional Keynesian IS-LM model. When considering the IS-LM model one has to pay attention to the fact that spending decisions are rather based on real interest rates and not on nominal ones which can be influenced by the central bank. Expansionary monetary policy leads to an increase in nominal short-term interest rates but also in real ones through inducing inflation. These changes have a spillover effect on long-term interest rates because of sticky prices (Mishkin, 1996). To understand the model the concept of term premia needs to be introduced. Risk-averse investors prefer buying short-term securities. For buying longer-term assets they demand a premium that grows over the investment horizon. This mark-up is known as the term or risk premium. In other words, the term premium is the compensation that an investor demands for bearing the risk of larger price swings that is attributed to longer maturity bonds. Secondly, the interest rate term structure is determined by expectations. Long-term interest rates are the average of expected future short-term interest rates plus a term premium component (Yu, 2016). Furthermore, to understand basic macroeconomic connections it is essential to distinguish current from expected future inflation rates. The current inflation rate sets yesterday's price of goods in relation to today's value of exactly the same good. Thus, current inflation measures the changes in value that lie in the past. The expected future inflation rate measures potential future changes. It expresses the relative price of today's goods in terms of the expected value tomorrow. Central banks react to current inflation rates while investors form decisions based on the expected future inflation rates. However, these inflation rates are not independent, they are highly interconnected. Thus, shaping investor's expectations about future real interest rates is always dependent on the current inflation rate and their expected future inflation rate (Farmer, 2012). If central banks can truthfully signalize their intentions of keeping nominal interest rates low, investors may expect future inflation to be low and thus real short-term interest rates to remain low as well. Combining the two theories, real long-term interest rates as an average of expected real short-term rates plus term premium will decrease as well. This will lead to an increase in investment spending and thus will result in an increase in aggregate demand which induces a rise in output as described above. A main drawback of the classical IS-LM model is that it focuses on one general price level rather than distinguishing asset prices (Mishkin, 1996). Secondly, the long-run neutrality of money implies that while changes in the monetary base can influence real variables like real income and unemployment in the short-run, in the long-run changes in the money quantity only affect the general level of prices. Thus, longer-term economic growth can only be achieved by maintaining prices at a stable level (European Central Bank, 2018a).

Internationalization and globalization have raised the awareness for the importance of exchange rates on economic decisions. In addition to the traditional interest rate channel, monetary policy also works through the exchange rate channel. Expansionary monetary policy results in a decrease of real interest rates (Mishkin, 1996). As a result, national assets loose attractiveness to foreign investors. Thus, foreign investors invest less in assets denominated in this currency, leading the currency to depreciate in foreign exchange markets. On the other hand, a fall in the value of this currency also has positive effects on the international commodity trading position. A lower value of a currency also lowers prices that foreigners have to pay for goods and services of this nation compared to their domestic ones. As well, national inhabitants would have to pay more for foreign products, giving them an incentive to buy domestic goods and services. Thus, depreciation of a currency boost exports and reduces imports. This rise in net exports would result in an increase of aggregate output and thus economic growth (Federal Reserve System, 2018a).

Furthermore, long-term interest rates influence equity prices. First of all, stocks serve as alternative investment opportunities to long-term bonds. Thus, if longer-term interest rates fall, investors may substitute these investments by purchasing stocks. This switch from safe long-term investments like government bonds to riskier investments like stocks can also be driven by investor's expectations that low long-term interest rates will boost economy and thus profits in the future. Either way, increasing stock purchases drive up stock prices (Federal Reserve System, 2018a). Tobin's q theory of investments states that firms will only make new investments if their market value divided by the replacement cost of capital is high. If firms issue equity during these times investments are relatively cheap. They can finance a lot of new equipment and goods while issuing only small amounts of equity. On the other hand if market value is low relative to replacement cost of capital, new investments would be expensive. Thus rising demand for equity would result in higher stock prices and an increase in the issuance of stock. This would then further stimulate investment undertaken by firms and thus increase aggregate output (Mishkin, 1996). Secondly, as almost every society member owns stocks either directly or indirectly through investing in investment funds, changes in stock prices have effects on consumers' financial wealth. An increase in the lifetime resources of consumers is likely to induce an increase in consumption driving up output once again (Federal Reserve System, 2018a).

If consumers are still worried about future developments, they may choose saving over consumption. In this case expansionary monetary policy increases bank deposits leaving banks with the possibility to grant higher quantities of loans. Deposits will partly be used to finance corporate loans and thus leading to an increase in investment spending. Alternatively, more optimistic consumers may obtain loans to finance consumption plans. Either way aggregate output rises once again. Mishkin (1995) describes this mechanism as the bank lending channel. He also points out that the role of banks in financing is declining. Furthermore, deposits are no longer the main source of funds to grant loans. Thus, the actual importance of this channel on the overall transmission mechanism is questionable.

## 2.2 Unconventional forms of monetary policy

Conventional tools only work when real interest rates are changing. The classical IS-LM model predicts that conventional monetary policy may work even though nominal short-term interest rates already hit the zero lower bound. If money supply is increased, the expected price level and thus the expected inflation increase as well. Hence, even though nominal interest rates are fixed at zero, real interest rates can be expected to fall and thus the intended increase in investments spending and output may still be achieved. Therefore expectations of a booming economy become a self-fulfilling prophecy. However, if the expected future inflation rate is zero and nominal interest rates already hit the zero lower bound, real interest rates coincide with nominal interest rates which will remain at the zero blocking conventional monetary instruments in their functioning. Financial crises are often the reason why expected inflation rates converge towards zero. During financial crises the economy faces increasing asymmetric information problems as uncertainty about payoffs from debt contracts rises. On the one hand, this uncertainty makes it harder for banks to distinguish good from bad projects and thus impeding bank lending and leading to an economic contraction. On the other hand, depositors may be afraid of their bank giving out bad loans and thus will withdraw their money. If the economy is affected by exceptionally high levels of uncertainty and the population has lost its trust into the banking system, masses of depositors are likely to run on banks to get back their funds. During these so-called bank runs banks may not have enough liquid assets to service all people who want to withdraw and thus slide into a bank failure. Declining deposits and a diminishing number of banks further worsen the drop in economic activity (Mishkin, 1996). Economic contraction is usually associated with economic recession and thus with low levels of expected inflation. Hence, if short-term interest rates are set to zero and economic shocks are too powerful, conventional actions may not suffice to improve the market participants' expectations of the future inflation rate. Conventional may then be complemented by unconventional monetary policy measures to increase expected inflation and thus lowering real interest rates.

"*In general, unconventional measures can be defined as those policies that directly target the cost and availability of external finance to banks, households and non-financial companies. These sources of finance can be in the form of central bank liquidity, loans, fixed-income securities or equity. […] Unconventional measures may be seen as an attempt to reduce the spreads between various forms of external finance, thereby affecting asset prices and the flow of funds in the economy*" (Smaghi, 2009).

Unconventional measures can take form of a broad range of different tools. What they all have in common is that unconventional measures are usually taken when the policy rate already hits or is close to zero. The bank has then three options to still stimulate the economy. First of all it can assure investors that money market rates will remain low. Secondly, it can influence the availability of securities and their prices in the market through specifically buying them and changing the composition of the central bank's balance sheet. Lastly, it can expand its balance sheet beyond conventional levels (Bernanke & Reinhart, 2004).

The central bank can specifically target certain market segments by buying commercial papers, corporate bonds or asset-backed securities. This policy is known as *credit easing*. Central banks have to consider differences in financing across countries. The effectiveness of credit easing is highly contingent on the importance of this specific market in financing in the private sector. It is noteworthy that these purchases are outright and hence central banks do business directly with the private sector. Central banks need to carefully consider which assets they want to buy as they have a direct impact on the riskiness of the central banks' balance sheet and thus threaten the independence of the central bank. Furthermore, if central banks engage in markets directly, they have to assess the impact on the specific sector to avoid distortions in the allocation of money among different sized companies in the sector and hence preventing large firms from gaining any privileges (Smaghi, 2009).

In contrast to credit easing, when implementing *quantitative easing*, the central bank does not interact with the private sector directly. It engages in massive open market operations, trading assets with longer maturities with other banks. These programs are known as large-scale asset purchase programs (LSAPP). The effects of this instrument are twofold. First, when buying long-term government bonds, prices of these securities rise and thus yields decline. As government bonds serve as benchmarks when pricing privately issued securities, yields on these assets fall as well. Secondly, conditional on a decline in long-term interest rates, investors will seek alternative investment opportunities. Thus, aggregate demand rises further and stabilizes crises-torn prices. The main problem of quantitative easing is that central banks interact with banks. Thus, they do not have any control over the flow of funds. Provision of funds by the central bank target stimulating the private sector. If the banks now decide to keep the money as a liquidity buffer instead of providing new loans, the target of this policy is not achieved. This is commonly known as the liquidity trap of asset purchases. Central banks try to incentivize the banks not to keep the funds within the financial sector by parking it at the central bank through lowering interest rates on excess reserves. Therefore, quantitative easing is mainly used when interest rates already hit the zero lower-bound while credit easing can also be conducted while interest rates are still positive (Smaghi, 2009).

Besides direct credit and quantitative easing, the central bank can also engage in indirect easing. The two direct policies above imply that a central bank acquires the asset from the other party. Thus, it directly holds the assets on its balance sheet, making it subject to the risk of the asset. Another possibility would be to lend to banks against collateral rather than purchasing assets. However, this measure can only be effective if the central bank lends on longer maturities and commits to pursuing this program over a longer period of time (Smaghi, 2009).

## 2.3 Channels of quantitative easing

Quantitative easing targets increasing domestic GDP and inflation. It works through different transmission channels. These channels are summarized in Figure 1 and the most important ones will be discussed in more detail in this chapter.

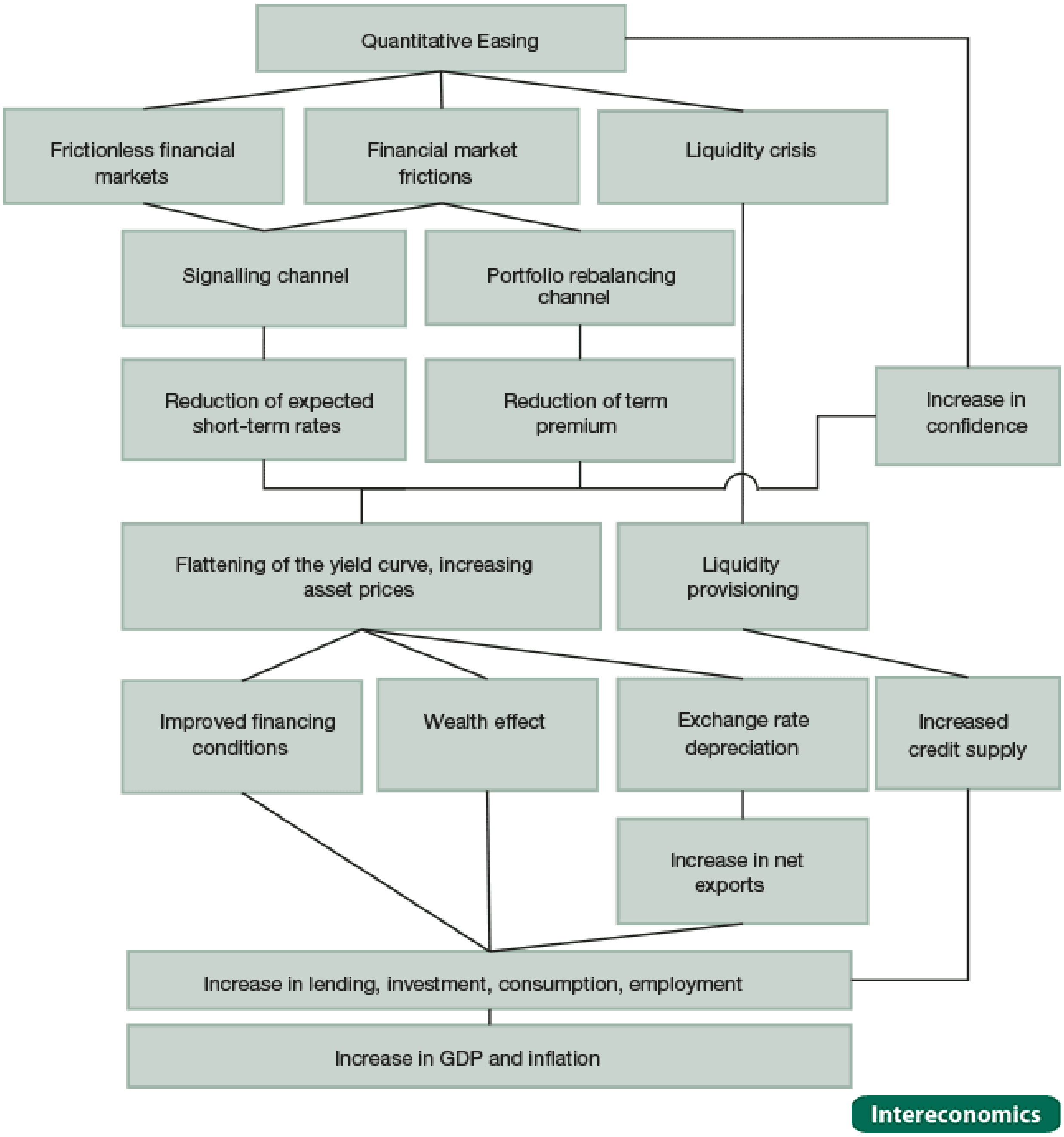


**Figure 1: Transmission channels of quantitative easing. Source: Gern et al. (2015)**

As described above, open market operations are a tool that can be used to control the overall supply of money and reserves. Quantitative easing programs are an extreme form of open market operations. They expand the monetary base and the size of the central bank's balance sheet beyond conventional levels. In other words they accommodate markets by excessively providing liquidity. Thus, the first channel through which quantitative easing programs operate is called the liquidity channel. Feeding the market with liquidity leads credit supply to increase. This then causes an increase in investment spending and thus in the price level. (Bernanke & Reinhardt, 2004; Krishnamurthy & Vissing-Jorgensen, 2011).

***Hypothesis 1:*** *Large-scale asset purchase programs lead to an increase in the general price level and thus spur inflation.*

Secondly, a central bank cannot only change the size of its balance sheet but also the composition and its maturity structure. To understand the portfolio rebalancing channel the concept of the preferred-habitat model needs to be introduced. In standard economic theory, prices of goods are formed contingent on the willingness of investors to substitute consumption across time. Market segmentation theory, however, says that investors have different maturity preferences. When investing, investors only consider assets of their preferred maturity, referred to as the preferred habitat. Thus, markets are fragmented and the interest rate for a certain maturity is determined by demand and supply for this maturity and is independent of other maturities. Thus, it is solely influenced by the corresponding preferred habitat clientele. In a market that consists of preferred habitat clientele only, maturity markets and the term structure would experience extreme segmentation. Arbitrageurs, who seek risk-free arbitrage opportunities while being able to invest in all maturities, integrate these markets. Arbitrageurs react to shocks in expected future interest rates through buying and selling assets of different maturities. These carry trades constitute the mechanism that allows them to align asset yields with changes in expectations (Vayanos & Vila, 2009). A more general way of explaining differences in assets would be by simply introducing market frictions. In a perfect market securities can be seen as perfect substitutes. In a segmented market assets differ in their risk characteristics but also in their liquidity. Thus, different kinds of securities are imperfect substitutes. Therefore, the term premium of a security does not necessarily rise linearly with its maturity. Neither does its demand, supply and price (Deutsche Bundesbank, 2016). Market frictions are a requirement for the second channel, the portfolio rebalancing channel, to work. Only if short-term bonds are imperfect substitutes for long-term bonds, large-scale asset purchases can alter yield curves. Massive purchases reduce availability and drive up prices of longer-term bonds, reducing their yields and thus the term premium (Gern, et al., 2015).

***Hypothesis 2:*** *Large-scale asset purchase programs induce a reduction of yields on long-term nominal assets that increases with the maturity of the asset. Thus, quantitative easing leads to a flattening of the yield curve.*

Long-term interest rates are formed based on expectations about future developments of short-term interest rates as well as inflation. Thus, central banks can affect prices for long-term investments through shaping expectations of the future path of money market rates. They can guide expectations through two forms of commitment. Commitments can either be unconditional, meaning that central banks will conduct pre-specified monetary policy measures within a fixed period until a certain date is reached. Commitments can also be conditional and thus contingent on the state of the economy. Either way, commitments made by central banks have to be credible to be able to influence expectations formed by market participants. Simply promising to keep short-term interest rates low may not suffice to alter expectations as central banks do not have the power to set these rates directly. However, they can actively set interest rates on reserve balances. Making commitments about the future path of these interest rates may be more effective in guaranteeing that quantitative easing programs are perceived as permanent and thus shape expectations (Bernanke & Reinhart, 2004). On the other hand, credibility of the commitment is also influenced by the size of the program. Ordinary open market operations can be too small to effect expectations about inflation. Quantitative easing programs on the other hand include large quantities of asset purchases, increasing the credibility and the impact on expectations. This tool of unconventional monetary policy can also be defined as forward guidance. In practice quantitative easing and forward guidance are mostly used in combination. Thus, in literature one important channel through which quantitative easing works is the signaling channel which refers to forward guidance as well (Gern, et al., 2015).

***Hypothesis 3:*** *If the central bank can credibly commit to pursuing a low-interest rate environment, large-scale asset purchase programs accompanied by forward guidance lead investors to expect the price level and inflation to rise.*

So the three main channels through which quantitative easing works are the liquidity provision channel, the portfolio rebalancing channel and the signaling channel. These channels induce an increase in credit supply and a flattening of the yield curve. While talking about the general impacts of monetary policy and the channels of conventional monetary policy, some positive effects of low long-term interest rates on the economy have already been pointed out. These channels are also applicable to quantitative easing. A short revision of the different channels will be given without going into detail.

LSAPPs reduce yields of domestic assets making them less attractive to foreign investors. As a result they reduce demand for the domestic currency which leads to a depreciation of the currency. Subsequently domestic goods become cheaper and domestically as well as internationally more attractive. Thus, the exchange rate channel has positive effects on domestic aggregate demand and net exports (Gern, et al., 2015).

***Hypothesis 4:*** *Large-scale asset purchase programs cause the home currency to depreciate in the international market.*

The liquidity channel leads the general price level to increase which further spurs economic activity. The bank capital channel is based on the increase of commercial banks' capital stock due to increasing prices. This will further stimulate the provision of credit. Its counterpart on the borrower's side is called the balance sheet channel. Increasing prices give rise to the borrower's capital. This then reduces the credit default risk and hence the accounted risk premium leading to a rise in investments and demand for credit once again (Deutsche Bundesbank, 2016). Another channel that needs to be mentioned is that quantitative easing also affects fiscal policy. Government debt bears a current or future tax liability on the inhabitants of the respective country. If expansionary policy is perceived as being permanent, then interest rates on new government bonds are expected to decline. Furthermore an increase in demand for government bonds will drive up prices and reduce yields on government bonds. These two factors leave the public with a lower expected tax burden. Thus long-lasting quantitative easing programs can also lead to expansionary fiscal policy (Bernanke & Reinhart, 2004).

### 2.4 Risks of quantitative easing programs

While the benefits of quantitative easing programs are relatively clear, the costs that they induce are diffuse and thus hard to determine in foresight as well as in hindsight. First of all, quantitative easing is implemented at the zero lower bound and targets an ultra-low interest rate environment for an extended period of time. These low interest rates encourage loosening credit conditions. They limit the cost of defaulting debtors to banks. Thus, banks have a lower incentive to carefully look into its customers' creditworthiness. They may be tempted to seek risk-taking behavior and continue financing bad projects due to high possible gains. This effect is amplified by securitization, by weak banking supervision and the longer this stance of monetary policy is maintained. Maddaloni and Peydró (2011) show that pursuance of a low short-term interest rate environment over an extended period of time contributed to triggering the financial and possible the real and fiscal crises. As short-term interbank financing is more important in the euro area, the Eurozone was hit harder by financial turmoil than the US. Artificially low interest rate environments have distortionary effects on investment decisions as well. Quantitative easing does not only foster risk-taking behavior on the creditor's side but also on the debtor's side. Low yields cause investors to heavily invest in riskier assets to extract gains from the market. This yield-seeking behavior makes them more susceptible to interest rate changes and market volatility (Yu, 2016). In the US for example the booming in the housing market that happened prior to the financial crises had its origins in exceptionally low mortgage rates.

Besides this misallocation of capital, quantitative easing constitutes major interventions of the central bank in the economy. These interferences may block natural adjustment processes. They may keep the economy from taking corrective steps itself. Financial crises indicate that structural reforms are necessary. Quantitative easing programs reduce financial stress, buying the government time to enforce changes. They cloud the urgency of reforms and will delay or even prevent the implementation of reforms (Gern, et al., 2015).

What also needs to be mentioned is that government bond purchasing programs carry the risk of losses for the central bank itself. Large-scale government bond purchases will increase prices for these types of assets. Central banks will have to spend large amounts of funds to sustain quantitative easing programs. If the programs were effectively conducted, exiting them will cause long-term interest rates to rise again entailing a decline in current government bond prices. Thus, central banks face the risk of having to bear severe losses (Smaghi, 2009).

Fourth, quantitative easing also threatens monetary policy's credibility and independence from fiscal policy. By buying large amounts of national government bonds, central banks become the main creditor of their home governments. Financing conditions on sovereign debt are no longer tied to the soundness of the country. They become decoupled from capital market conditions. Fiscal policymakers may be tempted to put pressure on central banks to retain favorable conditions (Deutsche Bundesbank, 2016) .

Last but not least, exiting unconventional monetary policy poses a challenge as well. Many theories exist on how to normalize monetary policy but few central banks have gone through experiences with exit strategies (Gern, et al., 2015). The first decision that needs to be made is when to unwind from monetary policy accommodation. The obvious answer would be when initial targets were achieved. However, as mentioned before considerable risks increase with the duration of the extra monetary stimulus. Thus, it may be advisable to exit quantitative easing earlier when the achievement of these goals is advancing at a slower pace than expected. Central banks need to clarify whether markets are still in need of non-standard measures. Additionally, raising the policy rate incorporates the risk of distorting investment decisions and discouraging savers to purchase longer-term assets. Thus, before unwinding the central bank needs to be sure that the confidence in the financial system has been restored. The second question concerns the how. The sequence and the speed of the exiting process are important determinants that impact sustainability of measures taken. Smaghi (2009) claims the ideal sequence to be rolling back unconventional monetary policy operations before increasing interest rates. With regards to the speed of exiting quantitative easing, a trade-off between unwinding too slow and thus imposing a severe threat to price stability and speeding up the process and imposing capital losses on lenders and on the central bank itself exists. Key institutions have to find a balance tailor-made to the affected economy. In general Smaghi emphasizes the need of the central bank to clearly communicate its plans and actions to the public.

# 3 Quantitative easing in the US

## 3.1 The Federal Reserve System

In the following chapter the central bank of the US and its quantitative easing programs are presented. The central bank of the US is known as the Federal Reserve System (Fed). It performs five functions: Conducting monetary policy, helping the stability of the financial system, supervising and regulating financial institutions, fostering payment and settlement system safety and efficiency and promoting consumer protection and community development (Federal Reserve System, 2018b). It is constituted by three separate entities all of them serving the public interest. Firstly, the Board of Governors as an agency of the federal government reports to and is supervised by the Congress. The seven members of the board are responsible for governing the Fed's operations and guiding the fulfillment of the overall goals (Federal Reserve System, 2018c).

The US follows a decentralized approach to central banking. It was divided into twelve districts to implement this principle. A federal reserve bank was established for all of the districts and was entrusted with the operating business of the Fed. Reserve banks work independently. However, they are overseen by the Board of Governors. For a commercial bank to become part of the Federal Reserve System, it needs to acquire stock in its district's reserve bank (Federal Reserve System, 2018b). These stocks cannot be sold or traded. The core function of the reserve banks is to supervise and examine certain financial institutions, to provide key financial services to them and lend to depository institutions (Federal Reserve System, 2018c).

As the US-American financial system grew more complex over time, monetary policy conducted by each and every reserve bank itself became inscrutable, requiring higher levels of collaboration among these banks. In general reserve banks follow the trend of increasing coordination and collaboration in the offering of financial services and in their pricing. Additionally, interaction was partly facilitated by establishing the third key entity, the Federal Open Market Committee (FOMC) in the midst of the 30s during the Federal Reserve Act (Federal Reserve System, 2018c). The FOMC consists of the members of the Board of Governors and the presidents of the reserve banks, which bring in information concerning the industrial sectors (Federal Reserve System, 2018b). The FOMC is mainly responsible for the national monetary policy. It pursues three main goals: "*[…] maximum employment, stable prices, and moderate long-term interest rates*" (Federal Reserve System, 2018a). While the ECB mainly concentrates on inflation targeting, the FOMC defined its goals in a broader way. However, stable prices are also associated with a 2% inflation rate and the FOMC officially commits to pursuing this threshold. As employment level is largely determined by other factors in addition to monetary policy, the FOMC has not defined a specific target unemployment rate. However, a general economic outlook and implications for labor market conditions are presented in its quaterly "Summary of Economic Projections". Together with the annual update on its monetary policy goals, firstly publicly elaborated on in the "Statement on Longer-Run Goals and Monetary Policy Strategy" in 2012, the quarterly reports form the linchpin of the FOMC's forward guidance (Federal Reserve System, 2018a). The FOMC holds quarterly meetings to specify future conduct of monetary policy. These meetings focus on discussing three main topics. First of all the FOMC has to elaborate on the evolvement of the US economy in the short and medium-term. In order to do so a broad range of information is collected before the meeting takes place. Based on the analysis of this information and statistical models, economic forecasts can be made. Sometimes external experts are consulted as well. This preparation work is done by the participants individually. Each and every member has to present his/her findings. The main target of assessing past operations and making predictions about future economic developments is to answer the second important question: What are the appropriate monetary policy measures that should be implemented to assure the fulfillment of the Fed’s three main goals in the future. While all participants are strongly encouraged to take part in the discussions, decision power is limited to the voting members, namely the members of the Board of Governors, the president of the Federal Reserve Bank of New York and four other presidents of reserve banks. These four mandates are rotating on a yearly basis. Last but not least, after decisions over monetary policy tools have been taken, the FOMC also consults over how to communicate economic expectations and policy decisions to the public. Since 1994 a summary of the decisions, plans and their main driving factors has been published in the postmeeting statement. Detailed meeting minutes are publicly accessable approximately three weeks after FOMC meetings. Besides these publications the Federal Reserve Chair has to give testimonies to the congressional committes twice a year. Furthermore policymakers regularly hold public speeches and good communication channels with other organizations are fostered as well (Federal Reserve System, 2018a).

## 3.2 US-American monetary policy

The tools through which the FOMC conducts monetary policy have evolved over time. Before the financial crises of 2007 the FOMC used to concentrate on a conventional monetary policy approach, which is called traditional monetary policy by the Fed itself. The tools mainly consisted of buying and selling securities that were secured by the US government on the open market (Federal Reserve System, 2018a). These transactions are referred to as open market operations with the goal of giving direction to interest rates and economic growth. Open market operations are specifically implemented to pursue a predetermined target for the federal funds rate, the US-American interbank market rate. The Federal Reserve is authorized to accept a certain range of securities only, which is clearly defined in section 14 of the Federal Reserve Act. Two types of Federal Reserve open market operations can be distinguished. Permanent open market operations are outright purchases or sales reflected on the system open market account. During and after the financial crises these transactions were the main tool to flatten yield curves and stabilize economy. Temporary open market operations are used to accommodate short-term and transitory reserve needs. These operations include repurchase agreements (repos) and reverse repurchase agreements (reverse repos). Under a repo (reverse repo), the Fed buys (sells) a security while committing to resell (repurchase) it in the future. Open market operations in the US are conducted by the Open Market Desk in New York (Federal Reserve System, 2018d).

Besides open market operations the FOMC also uses two other conventional tools. The FOMC sets minimum reserve requirements. Since 2008 the Fed pays interest rates on these reserve balances. It also pays interest on excess balances, which do not serve any regulatory purposes. However, these two interest rates differ. Thus, by changing the interest rate on excess reserves, the Fed can boost or erode attractiveness of holding excess reserves. This leaves the FOMC with another tool to achieve its target federal funds rate (Federal Reserve System, 2018a).

Last but not least, federal reserve banks can lend to banks directly through discount window lending. In the US three different types of discount window lending exist. First of all sound depository institutions can request primary credit. This type of loan helps to overcome very short-term funding needs and should not be used as a permanent source of funding. Depository institutions which are not eligible to receive primary credit but meet the requirements of discount window borrowing in general can request secondary credit. As institutions receiving secondary credit are less sound, conditions are also less favorable and thus the primary credit rate is typically 50 basis points below the secondary credit rate. Last but not least, if depository institutions' funding needs follow seasonal patterns rather than singular occurences like in touristic or agricultural areas, these institutions may apply for seasonal credits. Seasonal loans are not restricted to short-term lending, but can be made use of during booming periods. Conditions for seasonal credit are dependent on market rates. Discount window lending rates in general are set by reserve banks independently but are supervised by the Board (Federal Reserve System, 2018a).

During the financial crises the Federal Reserve System like other central banks increased discount window lending to resolve liquidity squeezes. In addition it launched several unconditional monetary policy programs to cope with problems caused by the crises. Dollar liquidity swap arrangements serve as an example for these programs. The Fed made arrangements with other central banks to solve dollar funding issues abroad. In exchange for foreign currencies it provided foreign central banks with US dollars that they could distribute locally. Several other emergency lending facilities were established to address funding shortages coming from non-depository institutions not eligible to discount window lending (Federal Reserve System, 2018a).

All major central banks including the Fed relied on monetary easing. They established a near-zero target for the federal funds rate during the beginning of the financial crises in late 2008, leaving open market operations as primary conventional monetary tool ineffective. So towards the end of 2008 the Fed started switching to unconventional measures. It launched a series of LSAPPs complemented by improved and continuous communication of its intentions and targets. This so-called forward guidance was conducted to keep the public informed and thus rebuild trust and confidence in the US-American banking system. Therefore, since 2007 along with the post-FOMC-meeting statements, quarterly 'Summaries of Economic Projections' have been published providing the reader with more information on the macroeconomic developments and an assessment of monetary policy. For seven years now these publications have been accompanied by press briefings (Federal Reserve System, 2018a).

### 3.3 US-American quantitative easing programs

In late 2008 the Federal Reserve System slowly became aware of the serious consequences that the financial crises was entailing. It recognized that the US economy was facing a dramatic slowdown and reacted swiftly. It aggressively lowered its federal funds target rate. In spite of this, it adapted its monetary policy and started complementing conventional by unconventional monetary policy measures. One of these was implementing a series of LSAPPs from late 2008 to October 2014. The range of securities bought by the Fed was restricted to long-term US government bonds and longer-term securities issued or guaranteed by government-sponsored agencies (Federal Reserve System, 2015).

In December 2008 the Federal Reserve System started its first quantitative easing initiative by buying in total $1,250 billion of mortgage backed securities (MBS) from the government-sponsored agencies Fannie Mae and Freddie Mac as well as from the Federal Home Loan Banks. This first round of quantitative easing (QE1) was maintained until August 2010. In spite of this program, during the peak of financial turmoil between March and October 2009 the Fed purchased $300 billion of longer-term Treasury securities to stabilize the private credit markets. The second round (QE2) took place from November 2010 to June 2011. It consisted of buying additional $600 billion of long-term Treasury securities. Afterwards, the Operational Twist targeted the portfolio maturity extension, increasing the average maturity of the bank's treasury portfolio. It was launched in September 2011 when the FOMC announced the exchange of $400 billion of Treasury securities with maturities of 6 years to 30 years against securities of an equivalent value with remaining maturities of less than 3 years until the end of June 2012. This program was then extended till the end of 2012 incorporating the extension of the maturity of securities worth another $267 billion. The last LSAPP (QE3) was implemented in September 2012. MBS in the amount of $40 billion per month were announced to be purchased open-ended. In spite of this, from January 2013 onwards longer-term Treasury securities were bought at a pace of $45 billion per month. Following the improvement of US-American labor market conditions and the increase in inflation, in December 2013 the FOMC announced its plan to slowly exit its large-scale asset purchase programs and to normalize its monetary policy.  In October 2014 US-American quantitative easing programs were officially terminated (Federal Reserve System, 2018d).

The continuous improvement of economic conditions and outlook enabled the initiation of monetary policy normalization in December 2015. Back then the FOMC raised its target federal funds rate for the first time since the financial crises had hit global economy. This target is pursued solely by changing the interest rate paid on excess reserve balances. Additionally the FOMC is allowed to use an overnight reverse repo facility if necessary. The normalization is still ongoing and consists of two main parts. First of all, the FOMC gradually increases the target rate as well as the deposit rate on reserve balances at a pace tailor-made to the development of the US economy (Federal Reserve System, 2017). On May 22th 2018 the FOMC raised the target federal funds rate to a range of 1.50% to 1.75% (Federal Reserve System, 2018d). Since October 2017 the Fed focuses on the second part of normalizing the stance of monetary policy, reducing the Fed's securities holdings. Reductions are primarily implemented by abandoning principal reinvestments received from securities held by the Fed. The sale of securities themselves is not anticipated for the present but could be considered it economic conditions warrant it. In line with this reduction reserve balances will continually fall as well, which still poses a challenge to the Federal Reserve (Federal Reserve System, 2017).

### 3.4 Evaluation of US-American quantitative easing

The quantitative easing programs of the Federal Reserve have been the linchpin of many studies, forecasting the effects in foresight as well as evaluating them in hindsight. Overall scientific literature agrees upon that in general the Fed's quantitative easing programs were effective in lowering long-term bond yields with impacts of the programs declining chronologically. However, the magnitudes of these changes differ. Cumulative changes in the 10-year Treasury bond across the QE1 period range from -91bps when using an event study (Gagnon, et al., 2010) over -50bps when implementing two-stage least squares for Treasury securities purchases only (D'Amico & King, 2013) to -35bps (D'Amico, et al., 2012). QE2 caused a decline of approximately -45bps (D'Amico, et al., 2012) to -21bps (Meaning & Zhu, 2011). In foresight the decline of the Operational Twist was estimated to amount to -85bps (Meaning & Zhu, 2012). QE3 was forecasted to raise the 10-year Treasury yield by 13bps instead of reducing it (Nellis & College, 2013). Building on the work from Gagnon et al. (2010) and Krishnamurthy and Vissing-Jorgensen (2011), Nellis and College (2013) take up an extreme position. They claim that QE1 was effective in reducing Treasury and MBS bond yields while the impact of QE2 and QE3 can be regarded as negligible. Wright (2012) points out that induced changes in interest rates faded out fairly fast. He raises the question whether these declines were indeed driven by the Federal Reserve's actions. Another interpretation would be that markets overreacted to news regarding monetary policy updates. What is more, he also shows that the effects on long-term Treasury bonds are the biggest. Changes in shorter-term Treasury security yields are negligible. Effects on corporate bond yields are approximately half of the effect on the 10-year Treasury bonds.

Weale and Wieladek (2016) claim the impact on the term premium through the portfolio rebalancing channel to be visible in changes of the 20 and 30-year government bond yields. The signaling channel, on the other hand, is reflected in short-term swap rates. In their study they find evidence of reactions of long-term bond yields to asset purchase programs while short-term swap rates did not react. Thus, Weale and Wieladek attribute effects of US-American LSAPPs primarily to the drop in term premia and claim the portfolio rebalance channel to be dominant. While these findings were confirmed by Gagnon et al. (2010), Bauer and Rudebusch (2014), on the other hand, found significant evidence that effects were caused by decreasing expected future short-term interest rates and thus transmission is mainly achieved by the signaling channel. In alignment with this, Christensen and Rudebusch (2012) also attribute the effects of QE1 mainly to transmission through the signaling channel. They use an event study and locate eight key announcements. Furthermore, an empirical dynamic term structure model helps them to decompose yield changes into effects caused by changes in expectations and the term premium component. Two thirds of the decline in the 10-year Treasury yield during QE1 can be explained by reductions in expected future target rates. Only one third can be attributed to a decline in term premiums. However, applying the same model to data from the UK shows that after QE announcements yields decline due to changes in the term premium. Hence, through which channels quantitative easing programs work is largely determined by financial market structure and policy communication. While the Federal Reserve heavily relies on forward guidance, the Bank of England's willingness to share information on future policy plans is more restrained. Thus, the signaling channel is dominant in the US while it is less salient in the UK.

Krishnamurthy and Vissing-Jorgensen (2011) add to this discussion by decomposing the overall impact of QE1 and QE2 on various interest rates into effects of seven different channels. In their event studies, they split up the portfolio-rebalancing channel into its effects through duration risk, prepayment risk, default risk, degree of extreme safety and liquidity. When analyzing QE1 they focus on five event dates while for QE2 they could only detect two relevant dates. Overall both quantitative easing programs were effective in reducing nominal interest rates on medium- and long-term bonds. However, differences occur depending on the type of bond. The effects on safe assets like Treasury and agency bonds were higher, indicating that the liquidity channel for these bonds was offset by the safety effect. As market segmentation theory suggest for extremely safe assets a unique clientele exists. Large-scale asset purchase programs reduce the availability of these assets. Investors which have a preferred-habitat for these bonds bid up prices for remaining safe assets and hence reduce yields. However, contradicting the idea of the duration risk channel, this clientele does not substitute the safe assets by riskier assets of the same maturity. Hence, quantitative easing reduces yields on safe assets by increasing the safety premium. For riskier assets like MBS or low-rated corporate bonds QE1 mainly worked through reducing the default risk and the prepayment risk premium. No evidence for these channels could be found when analyzing data on QE2. The lack of evidence for these channels can be explained by the fact that during QE2 Treasury bonds were bought only. Announcements during QE1 shifted back anticipated increases in interest rates by 6.3 months. The effects of QE2, on the other hand, were much smaller and postponed expected increases by 2.1 months only. In general, the effects of QE1 and QE2 seem to be mainly driven by the signaling channel. However, the impact of this channel is decreasing over time. Both quantitative easing programs significantly increase inflation expectations and decrease inflation uncertainty. However, effects of QE1 are larger once again. While QE1 increased expected future inflation over the 10-year horizon by 96bps to 146bps, QE2 only raised expectations by 5bps to 16bps. Comparing these changes to effects on nominal interest rates, Krishnamurthy and Vissing-Jorgensen claim the effects of the quantitative easing programs on real interest rates to be even higher than on nominal rates. To sum up, Krishnamurthy and Vissing-Jorgensen show that US-American quantitative easing was effective in lowering nominal and real interest rates. However, their main contribution is that the magnitude differs across bond types. When implementing monetary policy central banks should not solely concentrate on Treasury rates as these changes are mainly driven by safety effects. Investors will not change their preferred habitat and will not substitute safe by risky assets. Thus, yields on Treasuries and other safe bonds will be reduced but mortgage and lower-grade corporate bonds will not be affected by the induced policy shocks. This threatens the targeted goal of revitalizing economy as nominal interest rates on mortgages and lower-grade corporate bonds are most relevant to households and corporations. Focusing on buying safe assets only reduces the effects of unconventional programs to the signaling effect and thus limits overall effectiveness.

D'Amico et al. (2012) use regression procedures on pre-crises data to confirm that US-American LSAPPs indeed lowered long-term Treasury yields. Building on the work of Krishnamurthy and Vissing-Jorgensen (2011), D'Amico et al. differentiate between effects through the signaling, the duration and the scarcity channel. The latter one coincides with the safety channel described above. They show that fluctuations in the short-term yields are mainly caused by changes in expectations. In contrast to this, longer-term yields are driven by the term-premium. Their work claims that QE1 reduced long-term Treasury yields by 35bps while QE2 caused a decline of approximately 45bps. D'Amico et al. attribute these changes in long-term yields largely to the scarcity and the duration channels rather than the signaling channel. Taking into consideration that the amount of assets purchased under QE2 almost doubled the amount bought under QE1, the impact that QE2 had on Treasury yields is smaller. Overall the estimated amounts are considerable larger compared to other studies as D'Amico et al. used pre-LSAPP period data. Furthermore, QE1 and QE2 reduced the average duration of privately held outstanding Treasury debt by approximately 0.12 years each. Thus, the Fed would have to start massive interventions in the market to remove a significant amount of duration beyond the 10-year maturity. D'Amico et al. confirm that LSAPPs are an effective monetary policy tool to reduce Treasury yields. While Krishnamurthy and Vissing-Jorgensen (2011) claim that changes in Treasury yields induced by QE1 can be primarily attributed to the safety channel, D'Amico et al. (2012) point at the significance of the duration channel.

Besides effects on financial variables, the second bulk of literature investigates the impact of quantitative easing on macroeconomic aggregates. Baumeister and Benati (2013) conclude that when the zero lower bound of the policy rate is binding, a long-term yield spread compression has stimulating effects on output growth and inflation. They use a time-varying parameter structural VAR model to investigate macroeconomic effects within the context of the Great Recession from 2007 to 2009. According to their study QE1 was effective in mitigating the risk of deflation and GDP collapses. Chen et al. (2012) quantify the impact of QE2 by using a DSGE model. Annualized effects of QE2 on GDP amounted to 13bps and the impact on inflation is claimed to be 3bps. They emphasize that the commitment to maintain the policy rate at the zero lower bound was essential for these positive correlations. Otherwise QE2 would only have resulted in a half to a third of the increase stated above. However, Engen et al. (2015) stress that macroeconomic effects happen with a substantial time lag. They claim the Fed's LSAPPs to take full effect only within the first two years after introducing them. Their model estimates the unemployment rate to decline from 2011 onwards having its peak in early 2015 while the inflation effect was anticipated to climax in early 2016.

Weale and Wieladek (2016) confirm that LSAPPs in general induce increases in GDP and CPI. They use a Bayesian VAR model to analyze data from March 2009 to May 2014. According to their work an asset purchase announcement worth 100bps of national GDP increases real GDP by 58bps and CPI by 62bps. According to Khemraj and Yu (2016) US-American quantitative easing programs were also effective in increasing short-term aggregate private investment through inducing a compression in the corporate bond yield spread. In spite of this, Khemraj and Yu use a GARCH model to show that LSAPPs reduce volatility among investors. Thus, quantitative easing is a legitimate tool to pursue the target of price stability and full employment when conventional policy interventions are blocked by a zero lower bound environment.

Quantitative easing has led the US-dollar to depreciate in the international market. When the introduction of QE1 was announced on 18 March 2009, the effective dollar exchange rate fell by 2.3% (Deutsche Bundesbank, 2017). Neely (2010) shows that the dollar significantly depreciated compared to various foreign currencies. Cumulative declines ranged from -3.5% (GBP/USD) to -7.8% (EUR/USD) between July 2007 and January 2010. Neely also points out some global consequences of US-American quantitative easing programs. He shows that the Federal Reserve's large-scale asset purchases induced a decrease in international own-currency nominal 10-year bond yields. This drop ranged from -63bps in Australia to -18bps in Japan during July 2007 and January 2010. By using a global VEC model Chen et al. (2015) confirm that the impact on emerging markets is even greater than on the US economy itself. Thus, when implementing these programs central banks have to be aware of the fact that cross-border spillover effects may cause economic overheating and financial instability in emerging markets. They raise awareness for the need for international policy coordination.

Summarizing current literature, quantitative easing programs can be regarded as effective in reducing long-term interest rates. Secondly, US-American LSAPPs increased real GDP and CPI. Therefore, hypothesis 1 and 2 seem to hold although opinions about the magnitude of these effects severely differ. The impact is most apparent for QE1 while the effects of the other programs seem to be limited. QE1 was implemented during the peak of the financial crises. Thus, the large effects may be explained by the favorable date of implementation.

Gern et al. (2015) hit the nail on the head when saying that QE1 worked "*via providing liquidity, restoring confidence and alleviating financial market distress by signaling [sic!] that the Fed would decidedly combat possible tail risks based on lessons learned from the Great Depression. When QE2 was undertaken, financial market stress had already fallen substantially, so that a significant liquidity provisioning effect was unlikely and transmission via increasing market confidence played a smaller role*."

In general it can be claimed that the announcement effect is stronger in its impact than changes induced by the actual asset purchases. Event studies seem to be dominant in analyzing changes in interest rates. A main drawback of these studies is that findings are highly dependent on the way event dates are defined. They incorporate the risk of either omitting important events or not being able to distinguish between changes caused by the programs themselves and effects due to non-policy shocks. If unconventional monetary operations are surprisingly implemented, analyzing changes after the announcement of the program serves as an accurate measure. However, if actions are already anticipated, determining the point in time at which expectations change and thus capturing the announcement effect is difficult. The implementation of subsequent quantitative easing programs may not have been surprising. Thus, event studies are likely to underestimate the effects of these operations (Gern, et al., 2015). Furthermore, the decomposition of the overall impact of quantitative easing into its transmission channels proves to be difficult. The existence of the signaling channel and thus hypothesis 3 is largely confirmed but there exists a large divergence in the importance of different channels. Conclusions drawn with regards to the effect of individual transmission channels should thus be regarded with caution. Hypothesis 4 seems to hold as the USD depreciated against a wide range of foreign currencies.

# 4 Quantitative easing in Europe

## 4.1 The European Central Bank

This chapter deals with the European Central Bank (ECB) and its quantitative easing programs. The ECB was established in 1998 and was entrusted with planning and executing the monetary policy of the newly created euro area. The ECB's authority is legally based on the "Treaty on the Functioning of the European Union" and the "Statute of the European System of Central Banks and of the European Central Bank". Responsibility for monetary policy was transferred from the national central banks to the newly created ECB. It can adopt binding regulations. However, national central banks are still involved in implementing these regulations and monetary policy in general. The Eurozone currently consists of the 19 EU member states that have adopted the euro. The ECB together with the national central banks of all EU member states form the European System of Central Banks (ESCB) while the Eurosystem comprises the central banks of the member states whose national currency is the euro and the ECB only (European Central Bank, 2018b). The ECB's primary target is to maintain price stability. Besides this objective it also strives for financial stability and European financial integration. Connected to this the ECB is responsible for banking supervision also. The ECB together with the national central banks of the euro area form the Single Supervisory Mechanism (SSM) (European Central Bank, 2018c).

The ECB consist of four key entities. First of all, main decisions are taken by the Governing Council which consists of the six member of the Executive Board and the governors of the national central banks which are members of the Eurosystem. It formulates monetary policy for the euro area and ensures accordance of the ECB's and the Eurosystem's actions with the objectives they committed to. Thirdly, it provides entrusted entities with a framework for supervisory decisions. The Governing Council holds meetings twice a month in Frankfurt but monetary policy decisions are only taken every six weeks. Separate meetings are organized to discuss supervisory issues to ensure a clear separation of these two tasks. After monetary policy decisions have been taken a press conference is given to inform the public (European Central Bank, 2018d). The six members of the Executive Board are responsible for preparing Governing Council meetings and for implementing decisions taken during these meetings (European Central Bank, 2018e). To determine decision rights, members of the Eurosystem were ranked based on the size of their economies and financial sectors. The first five have four voting rights while all others together share eleven voting rights. These voting rights rotate on a monthly basis. Members of the Executive board have permanent decision rights (European Central Bank, 2014).

There also exists a transitional council, the General Council. It comprises the governors of the national central banks of the whole ESCB, the president and the vice president of the ECB. The Council will be dissolved as soon as all members of the EU have joined the Eurosystem (European Central Bank, 2018f). The Supervisory Board is responsible for planning and conducting the supervisory tasks of the ECB. It meets twice a month to prepare draft decisions for the Governing Council meetings (European Central Bank, 2018g).

Political independence is important to ensure objective implementation of monetary policy to the best of all member states. Thus, according to Article 130 of the Treaty, no member of the ECB and the national central banks is allowed to take orders from EU institutions or any national government. Additionally, they should not seek instructions themselves and avoid any influence from these institutions. The ECB has its own budget independent of any other EU institutions. This budget is paid in fully by national central banks of the euro area. It may not be used to grant loans to any EU bodies or national public sector entities (European Central Bank, 2018h). The national central banks' shares in this capital are calculated by considering the country's share in the total population and the EU's gross domestic product. Both components are weighted equally. Numbers are updated every five years. When the ECB makes profits, at least 20% are paid into the general reserve fund which serves to cover possible losses incurred. Remaining profits are allocated to countries in proportion to their shares. Losses exceeding the general reserve fund balance are offset against the ECB capital income of the respective year in proportion to the amounts paid-up by national central banks. Non-euro area national banks are required to contribute to the ECB's budget to cover operational costs. However, they do not receive proportional shares of the profits incurred nor are they required to bear losses (European Central Bank, 2018i).

The ECB is accountable to the European Parliament and the Council of the EU. The ECB President holds quarterly meetings with the Parliament's Committee on Economic and Monetary Affairs. He can opt for support by other members of the ECB Executive Board. Furthermore, the ECB has to publish annual reports and present them to the European Parliament. Apart from that, the Parliament can approach the ECB with written questions (European Central Bank, 2018j). As part of their emphasis on transparency, the ECB publishes its Board members' monthly meeting calendars with a time lag of three months (European Central Bank, 2018k). Additionally, two weeks after every meeting in which monetary policy has been discussed, an economic bulletin is published. It summarizes main economic and monetary information based on which decisions were taken. Another two weeks later monetary policy accounts are published. Operations and activities are presented in form of publicly accessible weekly financial statements (European Central Bank, 2018j).

### 4.2 Monetary policy in the euro area

The ECB's primary objective is to maintain price stability.

"*The ECB's Governing Council has defined price stability as a year-on-year increase in the Harmonised Index of Consumer Prices for the euro area of below 2% [over the medium term]*" (European Central Bank, 2018l).

The Treaty of the European Union stresses the importance of this target, but it also emphasizes the role of the Eurosystem in achieving full employment and balanced economic growth, which are the main objectives of the European Union (European Central Bank, 2018m). In order to achieve this target, the ECB uses the "two pillars" approach of monetary policy strategy which includes economic and monetary analysis (European Central Bank, 2018l). Economic analysis focuses on the short- and medium-term price developments. It reviews overall output, labor market condition, various price and cost indicators, fiscal policy and the balance of payments in the Eurozone as well as shocks to these determinants. It is used to assess real activity and financial conditions in the economy. In spite of this, it helps to monitor financial markets expectations (European Central Bank, 2018n). The monetary analysis, on the other hand assesses long-term developments and their implications for inflation and economic growth. It is mainly done by analyzing monetary aggregates and credit developments (European Central Bank, 2018o).

The ECB clearly separates operations concerning liquidity management from monetary policy decisions specifically targeting maintenance of price stability. To implement single monetary policy, the ECB uses a set of tools, which is referred to as the operational framework. It consists of three operations: Open market operations, altering reserve requirements and standing facilities. In general the Eurosystem only operates with counterparties that are financially sound. To be eligible, credit institutions also need to be subject to the Eurosystem's minimum reserve system. The ECB's open market operations are usually implemented through reverse transactions, meaning that the central bank buys assets under a repurchase agreement. It can also grant a loan against assets pledged as collateral. Open market operations can further be divided into four main groups. Main refinancing operations (MROs) are the ECB's key monetary policy tool. They involve short-term lending to counterparties against adequate collateral for maturities up to one week. MROs are conducted on a weekly basis in form of fixed or variable rate tenders. In the fixed rate tender the ECB sets an interest rate in foresight and participating institutions bid the amount of funds they wish to transact. In a variable rate tender, on the other hand, counterparties bid amounts and interest rates. The ECB then decides over the magnitude of liquidity provision she wants to conduct. In a fixed rate tender liquidity is distributed on a pro rata allotment. In variable rate tender bids are ranked contingent on their interest rates. Liquidity is provided starting with the highest interest rate bid and continuing until the pre-specified amount of liquidity provision is exhausted. Longer-term refinancing operations (LTROs) aim providing longer-term liquidity for up to three months. LTROs are usually conducted as monthly variable rate tenders. Fine-tuning operations (FTOs) not only comprise reverse transactions but also foreign exchange swaps. These operations are a non-standardized instrument to control liquidity fluctuations either through absorbing or through providing it. FTOs are irregularly conducted on a case-by-case basis. Last but not least, structural operations include outright purchases and sales of assets or the issuance of ECB debt certificates, meaning that the central bank directly interferes in the market. These operations are used to adjust the structural liquidity situation over a longer time horizon (European Central Bank, 2011).

Despite open market operations, the ECB sets the reserve ratio. Credit institutions are obliged to hold minimum reserve requirements, not with the ECB itself but with the national central banks. This minimum reserve is determined by the reserve base multiplied by a reserve ratio. The reserve base is calculated by setting the elements of the balance sheet into relation. The reserve ratio itself is determined by the ECB (European Central Bank, 2011).

Thirdly, the ECB also controls short-term interest rates through standing facilities. Marginal lending facilities include overnight lending while deposit facilities are implemented by paying interest on overnight deposits. Overnight deposits are just the excess reserves that an institution holds with its national central bank. However, as interest rates on marginal lending facilities are substantially above money market rates and interest rates on deposit facilities are below them, these facilities are only used in cases of acute lack of alternatives. The facilities can be used without limits. Thus, the rates on them usually provide a ceiling and a floor to overnight money market rates measured by the euro overnight index average (EONIA) (European Central Bank, 2011). In June 2014 the ECB even introduced negative deposit facility rates which still persist (European Central Bank, 2018p).

### 4.3 Quantitative easing programs in the euro area

The European Central Bank unlike the Federal Reserve System concentrated on credit easing programs until June 2014 to fight against the repercussions of the banking, financial and sovereign debt crises. These measures included the covered bond purchase programs one (CBPP1) and two (CBPP2) as well as the securities markets program (SMP). In June 2014 the main refinancing rate hit the zero lower bound incentivizing the ECB to implement further non-standard measures. In June 2014 targeted longer-term refinancing operations (TLTROs) were introduced, aiming to facilitate borrowing from the Eurosystem. Despite the measures taken so far, inflation prospects and market participants' long-term inflation expectations remained worryingly low which led the ECB to announce its first quantitative easing program. The expanded asset purchase program (APP) was introduced in January 2015. Initially the ECB announced to spend €60 billion per month on asset purchases in total until September 2016 with the possibility to extend the program until an inflation rate close to the 2% threshold has been achieved. In April 2016 the volume of the monthly spending was increase by €20 billion and exiting the program was postponed to March 2017 (Deutsche Bundesbank, 2016). In April purchases were reduced to €60 billion per month again and the program was prolonged until

December 2017. From January 2018 onwards the magnitude of the APP was reduced to €30 billion per month until the end of September 2018 (European Central Bank, 2018q).

The APP consists of four different programs. The third covered bond purchase program (CBPP3) started on 20 October 2014. It is part of the APP although its implementation started before introducing APP. Under this program the Eurosystem started to buy covered bonds. This program targets enhancing transmission channels and easing financing conditions in the Eurozone. Secondly, on 21 November 2014 the asset-backed securities purchase program (ABSPP) was introduced. It was implemented to provide a stimulus to the issuance of new securities and to support banks in expanding provision of credit. The implementation of the public sector purchase program (PSPP) started on 9 March 2015. It involves purchasing public sector securities including "*nominal and inflation-linked central government bonds, bonds issued by recognized agencies, regional and local governments, international organizations and multilateral development banks located in the euro area*". Principal redemptions on these securities are reinvested by the ECB within the month they fall due. Reinvestment must be made in the same jurisdiction in which the maturing bond was issued. The corporate purchase program (CSPP), the last program implemented under APP, started on 8 June 2016. It involves the buying of corporate sector bonds. It provides further accommodation to the real economy (European Central Bank, 2018q).

In October 2017 the ECB announced to gradually scale back APP and that it prepares to exit it in September 2018. However, Draghi emphasized that the target has not yet been reached and he wants to leave the door open for a fourth extension of the program if necessary (Skolimowski, 2017).

### 4.4 Evaluation of European quantitative easing

When analyzing the effects of asset purchases in the Eurozone, credit easing needs to be differentiated from quantitative easing. As a lot of programs were implemented within a relatively small time frame, isolating the effects of different unconventional monetary policy instruments is demanding. Credit easing programs were implemented in the immediate aftermath of the financial crises and were already terminated. They are the linchpin of many studies most of them claim them to have reduced sovereign bond spreads (Gibson, et al., 2016). However, effects on crises countries are clearly negative while effects on non-crises countries can be ambiguous (Falagiarda & Reitz, 2015; Jäger & Grigoriadis, 2017).

The APP, which can be defined as quantitative easing in the narrow sense, is still ongoing and effectiveness can only be preliminarily analyzed. While the literature on European credit easing programs is abounding, analysis concerning the APP is more reluctant. The Federal Reserve System has implemented its quantitative easing programs in the peak of financial turmoil. On the other hand, financial distress has already eased when the APP's implementation started. By using a term structure model that controls for macroeconomic releases, Altavilla et al. (2015) point out that a low degree of financial stress indeed weakens some transmission channels but has reinforced spill-over effects to non-targeted asset classes. In times of high financial distress arbitrageurs are highly risk-averse limiting their power to integrate markets. Thus, market segmentation is extremely high during these periods. Effects of quantitative easing measures are then concentrated on the assets targeted during asset purchases. In contrast to this, European LSAPPs take place within a timeframe of weaker market segmentation. Thus effects on the targeted asset segments are contained while the compression of risk premia spreads across a wider range of maturities and asset classes. Altavilla et al. predict 10-year sovereign bond yields to decline between -30bps to -50bps. These effects seem to rise with maturity and riskiness of the asset doubling effects in high-yield countries as Italy and Spain. They claim the spill-over effect of a -100bps shock on sovereign bonds spreads on BBB-rated corporate spreads to amount to -63bps for financial and -50bps for non-financial corporations. Urbschat and Watzka (2017) also conclude that quantitative easing in the euro area was effective in reducing government bond yields. Bonds with longer maturities were more affected than shorter maturities. However, the size of the effect differs among member states ranging from -85.5bps for Portuguese bonds to -5.91bps for German bonds. Thus, countries with higher yields benefitted more from the programs. Countries with yields close to the zero lower bound were less affected. Urbschat and Watzka explain this finding by using the preferred-habitat theory. For quantitative easing programs to work, market frictions must be present, making assets imperfect substitutes. With yields close to zero, bonds of core countries may be regarded as close substitutes to the risk free rate. Hence, the portfolio rebalancing channel does not work on these countries whereas term premia could be reduced for periphery countries. Furthermore, they find evidence that the effects on yield reductions were most appealing right after the announcement of the public sector purchase program but decreased with additional announcements.

Andrade et al. (2016) confirm that the impact of quantitative easing increases with the maturity of the assets bought as well as with a lower rating of these assets. They also show that expected discounted future profits are highest for banks that have a large asset share in sovereign bonds. Thus, these banks benefited most from the programs and are claimed to expand provision of credit. Overall APP could raise actual inflation by 40bps and actual output by 110bps over the 2-year horizon. These impacts are comparable to a standard interest rate shock of -110bps. Furthermore Andrade et al. show that effects on asset prices occurred on announcements rather than when purchases are actually carried out. What strengthens evidence for the signaling channel is that the APP decreased expected future policy rates for all forecast horizons. At the same time expectations of future inflation increased by 45bps and growth rate by 55bps over the 1-year horizon. Long-term inflation forecasts could be raised by 9bps.

In accordance to this Sahuc (2016) emphasizes the importance of forward guidance in combination with asset purchases. He uses a dynamic stochastic general equilibrium model to forecast the impact of an asset purchase programs which purely consists of public bonds. He simulates an asset purchase program which is implemented in 2015 and is worth 9% of 2014 euro area GDP in total. Using asset purchases only would limit the effect to +10bps on inflation and +20bps on output growth in 2016. Thus investors' expectations of increasing short-term interest rates would offset the effect of pushing up prices. Supplementing APP with forward guidance could improve the impact to +60bps on inflation and +30bps on GDP growth in 2016. Sahuc also points out that effects on real GDP growth happen quicker but pose the risk of inducing a negative growth in the long-term. Inflation, however, reacts with a time lag but the impact is longer lasting. Even though the study is subject to several limitations, it points out the importance of the signaling channel and the commitment of the central bank to keep interest rates low.

Priftis and Vogel (2016) contribute to these findings by making predictions in a dynamic general equilibrium model, introducing the international market and hence adding the exchange rate channel. A major drawback, however, is that the signaling channel is absent in their study. With a -6bps reduction in term-premium their model predicts a -90bps effective euro depreciation leading to a real GDP increase of 30bps and an increase in prices of 50bps by 2016. Frontloading QE and thus increasing the size of the program at the beginning while reducing the magnitude of later extensions would not have any effect on the impact of APP as long as the duration of the program remains the same. An early exit would have even weakened the positive impact. Building on this model, Priftis and

Vogel (2017) later revise their findings and claim the APP in its initially announced form leading to an effective euro deprecation of -40bps, an increase in real GDP of 20bps and an increase in prices by 30bps by 2017. They claim the impact to be doubled by the subsequent extension and increases of the LSAPP. Building on the event study approach used by Altavilla et al (2015), Deutsche Bundesbank (2017) in its monthly report in January adds to this discussion that monetary policy measures usually unfold most of their impact on exchange rates within 24 hours after announcing changes. The announcement of the APP on 22 January for example incurred a loss of -2.6% in the nominal effective exchange rate against the currencies of 19 major trading partners. The bilateral loss against the US dollar even amounted to -3.6%. In the time period between 2 January 2014 and 15 December 2016 the overall depreciation added up to -4.7% in the nominal effective euro exchange rate and -6.5% bilaterally against the US dollar. Most of the effect is attributed to the first phase till the announcement of the asset purchase program. Subsequent expansions had less of an impact. However, it is quite difficult to extract changes induced by the quantitative easing instruments directly from changes caused by other non-policy shocks. Deutsche Bundesbank points out that euro depreciation rates are especially sensitive to US monetary policy announcements. Neglecting these events falsifies the results. Secondly, findings are highly contingent on the event dates chosen as well as the event window during which changes are investigated. Besides the effects of monetary policy announcements they cannot find any evidence that actual asset purchases have a significant influence on exchange rates. Thus, changes in exchange rates are caused by the announcement effect rather than the asset purchases themselves.

Lewis and Roth (2017) show that asset purchases reduce financial stress in the 5-month time window but impose a risk on financial stability in the longer-term. They use a VAR model to investigate the effects of an expansion of the ECB's balance sheet on the macroeconomy and financial markets. Their time series ranges from July 2009 until March 2016. They distinguish direct asset purchases from effects of the full rate allotment policy. Financial stress significantly decreased during the first five months but increased again afterwards. The same happened to output. GDP growth even fell below pre-shock level after approximately 18 months.

European member states are not homogenous. They are dispersed in their state of development and in the soundness of their banking system. Burriel and Galesi (2018) account for these heterogeneities and interdependencies across euro area member states.

They use a global VAR model to analyze unconventional monetary policy shocks. Unfortunately their dataset ranges from January 2007 to September 2015, making it impossible to draw conclusions for APP only. However, they show that benefits in real output were the least for Eurozone countries with a more fragile banking system. Furthermore, less developed countries with higher unemployment rates have the largest gains in prices. Heterogeneity thus has substantial effects on transmission of quantitative easing in the euro area. It weakens the macroeconomic impact on the whole currency union. A major part of this heterogeneity can be explained by spill-over effects resulting from cross-country interdependencies. Kucharčuková et al. (2016) show that conventional and unconventional monetary policies have different spill-over effects on European countries that are not members of the Eurozone. They use a block-restricted structural VAR model to investigate international impacts. Standard monetary policy measures have largely the same effects on non-euro area countries as on Eurozone members. Effects of non-standard instruments, however, are low and limited, leaving inflation largely untouched. In contrast to this, Horvath and Voslarova (2017) find sizeable spill-over effects on Central-European countries especially in output growth. The ECB's unconventional monetary policy measures accounted for approximately 11% to 14% of output fluctuations in these countries. Effects on the price level, on the other side, were two times weaker.

Overall literature shows that the announcement effect in Europe is as substantial as in the US. Furthermore, APP was effective in reducing government bond spreads. However, effects differ across euro area member states. The impact increases with maturity which confirms hypothesis 2. Secondly, it rises with riskiness of the asset. Thus, high-yield countries benefit most from LSAPPs while transmission through the portfolio rebalancing channel is largely blocked for low-yield core countries. The signaling and the exchange rate channel, on the other hand, seem to be working for the whole currency union. Thus, hypothesis 4 seems to hold as well. Clear conclusions about which of these channels are dominant cannot be drawn. However, European quantitative easing measures increased expectations about future inflation, confirming hypothesis 3. Actual macroeconomic effects, on the other hand, could not yet be fully determined given that APP was introduced in 2015 and the impact occurs with a time lag. Thus, in order to verify hypothesis 1 current euro area figures must be considered. Therefore, in the following chapter the latest European data will be examined in order to be able to compare European to US-American quantitative easing programs.

## 5 Empirical analysis

Previous chapters have shown that if successfully implemented quantitative easing programs can stimulate output, prices and inflation through a variety of complementary transmission channels. As well they can boost economic confidence through improving the economic outlook, lowering uncertainty and reducing volatility. Anticipating the effects of quantitative easing in general is hardly possible. Repercussions can only be analyzed after actually implementing the programs. However, disentangling them from other factors in hindsight also proves to be challenging.

Literature dealing with quantitative easing programs can be broadly grouped into three main categories. Theoretical models like DGSE models are often used to evaluate asset purchase programs while building them into the standard New Keynesian model (Urbschat & Watzka, 2017). However, these models usually rely on perfect markets. In order to be able to investigate the effect of quantitative easing models through the portfolio-rebalancing channel, market frictions must be introduced. Secondly, effects on financial variables can be analyzed by using term-structure models or event studies. Event studies investigate the impact that announcements of quantitative easing programs have on interest rates within a certain time window. A big weakness of these studies is that they assume that effects occur as soon as market participants update their expectations and thus are independent of actual asset purchases. Hence, they concentrate on how reliable and surprising announcements by the central banks are. If new measures were anticipated by market participant even before the announcement takes place, analyzing effects dependent on the announcement date will falsify findings (Gern, et al., 2015). When investigating long-term macroeconomic effects, time series models p.ex. vector auto-regression (VAR) models are prevalent. These models regress long-term yields and macroeconomic variables on the net supply of assets included in the asset purchase program and vice versa. This approach includes actual asset purchases only and leaves the effects of investor's expectations undiscovered. Event studies as well as time series models suffer from identification problems and should be interpreted with caution (Gern, et al., 2015).

The main target of this master thesis is to shed light on the effectiveness of quantitative easing programs in the euro area and in the US. Effectiveness can be defined in several ways. Within this thesis effectiveness is defined as achieving the goal of an inflation rate slightly below 2%. Thus, long-term macroeconomic variables are investigated. In order to do so, I chose to use a VAR model. As US-American LSAPPs have already been extensively analyzed, this thesis focuses on investigating the effects of European quantitative easing programs and later on comparing them to empirical results concerning the US. First of all, the theoretical model is described. Afterwards the reader is introduced to the empirical approach and the identification scheme. Secondly, the dataset used is outlined and descriptive analysis is conducted. Next, empirical results are presented and are tested for their robustness.

### 5.1 Model and identification scheme

One way of defining inflation is that it occurs when aggregate demand exceeds aggregate output. This is referred to as the demand-pull theory of inflation. A potential source of this kind of inflation is a monetary shock coming from expansionary monetary policy.  In other words, inflation is induced when nominal income rises faster than real income. An increase in nominal income while unemployment rates are low results in an increase in consumption. Higher aggregate demand then drives up prices, leading to inflation. The cost-push theory of inflation, on the other hand, states that inflation occurs when firms face increasing production costs and pass these costs on to their customers by raising prices. The inflation rate is measured as the percentage change in the general price level. For this purpose indices were developed that represent the price level. The dominant one is referred to as the consumer price index (CPI) (Moosa, 2014, p. 58 ff.). Based on the idea of the aggregate-demand-aggregate-supply model, Romer (1996) constructed a basic model to explain inflation. He defines the supply of money $S(.)$ by dividing the money stock $M$ by the price level $P$. Demand for real money $D(.)$ is contingent on the nominal interest rate $R$ and the real income $Y^r$. When time is introduced all of the variables are subject to shocks and thus stochastic. Therefore, equilibrium position must be characterized by a time index. I extend this model by introducing the possibility to hold money. Thus, demand for money is contingent on the difference between the interest rate on government bonds $R_b$ and the interest rate on money stock $R_m$. In the long-run steady-state equilibrium aggregate supply is equal to aggregate demand $S(ln(M),P)_t = D(Y^r, R_b - R_m)_t$. However, shocks can occur which imply a deviation from steady-state. When the system moves back to the previous equilibrium a transitory shock happens. However, if the system moves to a new equilibrium the shock is said to be permanent. These shocks are measured by $v_t$, which is stationary and independent and identically normally distributed with mean $\mu$ and variance $\sigma^2$. It measures the deviation from steady-state at time *t*. The final theoretical model can be written as follows:

$$S(ln(M),P)_t - D(Y^r, R_b - R_m)_t = v_t \quad (1)$$

Money stock $M$ is measured by the natural logarithm of end of the month cumulated securities held for monetary purposes in Euro million. Securities purchased for credit easing purposes are included in the sample. However, these purchases were sterilized and thus have no vital impact on the monetary base. The harmonized consumer price index (HCPI) was chosen to measure the price level $P$. Thirdly, as real GDP data for the euro area is not available on a monthly basis, I included the industrial production index and the service turnover index. Thus, the secondary and tertiary sectors are integrated in the model while the primary sector can be neglected due to its subordinate importance in the Eurozone. In 2016 the tertiary sector only accounted for 1.6% of total value added by economic activity (European Central Bank, 2018r). These indexes are rather weak proxies for the real income $Y^r$ as they do not measure net value creation. However, the indexes still give indications on the direction of the real GDP. Thus, they will be used but not interpreted as real income. Next, for the interest rate on government bonds $R_b$ the euro area monthly average of the 10-year government bond yields of all government bond issuers is used. Issuers of all ratings are included. The interest rate on money stock $R_m$ is measured by the deposit rate set by the ECB. The difference between these two interest rates is used and is entitled term premium. A more detailed description of the variables used can be found in Appendix A. This model is a stark simplification and mainly focuses on inflation caused by the demand-pull effect. There are many other variables that are related to inflation. However, adding more variables does not necessarily lead to a better model. When working with autoregressive analysis parsimony is important and thus I expect this basic model to be sufficient to investigate whether quantitative easing was effective in raising the inflation rate.

All of the above variables are treated as being endogenous and are subject to a monetary policy shock. Thus, a VAR model is chosen to analyze the effects of monetary policy. First of all the augmented Dickey-Fuller test was used to show that all variables contain one unit root. They are all non-stationary at levels but their first differences are stationary. Thus, all of the variables are integrated of order one. (1) Writing it in vector-error correction (VEC) model form allows us to use co-integrated variables. This means that there exists at least one combination of the variables in levels that is stationary. While ordinary VAR models only measure short-run dynamics, the VEC model allows to investigate long-run

(1) Existence of a unit root could be confirmed for all variables when using the generalized least-squares augmented Dickey–Fuller test as well.

dynamics. The empirical VEC model consisting of cointegrating variables of order 1 can be written as:

$$\Delta y_t = v + \prod y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-1} + \varepsilon_t \qquad (2)$$

where $\Delta y_t$ is a *K x 1* vector of the first differences of *K* endogenous variables. It comprises the variables described above. $v$ is a *K x 1* vector of parameters capturing deterministic trends. The lagged levels matrix $\prod$ is the linchpin of the VEC model as its rank is equal to the number of linearly independent cointegrating vectors. It is defined as $\prod = \sum_{j=1}^{j=p} A_j - I_k$ where $A_j$ is a matrix of coefficients that determines the dependence of $y_t$ from its lagged values and $I_k$ is the unit matrix. $\prod$ has rank $0 \leq r < K$. $\Gamma_i = -\sum_{j=i+1}^{j=p} A_j$ is a matrix containing the short-run dynamic effects. $\varepsilon_t$ is independent and identically normally distributed with mean zero and a covariance matrix $\sum$. It is assumed to be white noise.

If $\prod$ has reduced form $0 < r < K$ such that $\prod = \alpha\beta'$ and the deterministic component is split into a constant and a linear time trend, (2) can be rewritten as

$$\Delta y_t = \alpha\beta' y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-1} + v + \delta t + \varepsilon_t \qquad (3)$$

where $v = \alpha\mu + \gamma$ is a constant in first differences and thus implies a linear time trend in levels and $\delta t = \alpha\rho t + \tau t$ implies a linear trend in first differences and a quadratic time trend in levels. $\beta'$ is a *r x K* matrix of rank *r* containing coefficients for the long-run equilibrium relations measured by the long-run stationary cointegrating relations. $\alpha$ is a *r x K* matrix which includes long-run error correction terms. These terms measure the speed of adjustment at which deviations from the long-run equilibrium of the previous period are reversed in this period.

Two restrictions are posed on the time trends: $\rho$ = 0 and $\tau$ = 0. Thus, I do only allow for linear time trends in levels but not for quadratic trends. Secondly, the cointegrating relations must be stationary around constant means. Furthermore, in spite of the fact that Akaike's information criterion (AIC) and the final prediction error (FPE) would suggest to take two as the appropriate lag length, I chose four as the post-estimation eigenvalue stability condition postulates stable eigenvalues at a lag length of four. The maximum eigenvalue statistic confirms the existence of one cointegrating equation at the 5% significance level while the trace statistic suggest 2 cointegrating relations. I decided to choose rank one as the maximum eigenvalue test has more power than the trace test. The results from the lag-order and rank selection criteria are shown in Appendix B1 and B2. The

Johansen normalization scheme is used to restrict the long-term dynamics. The $\beta$-coefficient of HCPI is normalized to one. Hence, in this case $\beta$ is exactly identified.

### 5.2 Dataset and descriptive analysis

Monthly data from January 2010 to February 2018 for the euro area in changing composition is used. The US-American quantitative easing program had spillover effects on Europe as well. To largely avoid biases caused by QE1, January 2010 was used as a starting point. At this point of time the announcement effect of QE1 is likely to have already faded. Secondly, from mid-2009 onwards the ECB started buying securities for monetary reasons. A main drawback of this sample is that it excludes the beginning of the financial crises. To test whether narrowing down my data sample has major effects on the findings, I will use the same model applied to monthly data from January 2006 to February 2018 in the robustness check section. All data is taken from Eurostat, the statistical office of the European Union.

Analyzing the data in levels shows that HCPI is following a linear upwards trend with two little interruptions as displayed in Figure 2. One could be tempted to attribute these changes to announcement event dates. The first drop occurred end of November 2014 when the announcement of the European quantitative easing program was already anticipated. The second one happened in December 2015 when a further extension of APP was introduced. However, macroeconomic variables are said to react with a time lag and thus these little interruptions probably had other reasons. From 2016 onwards the HCPI continued rising at a constant rate.

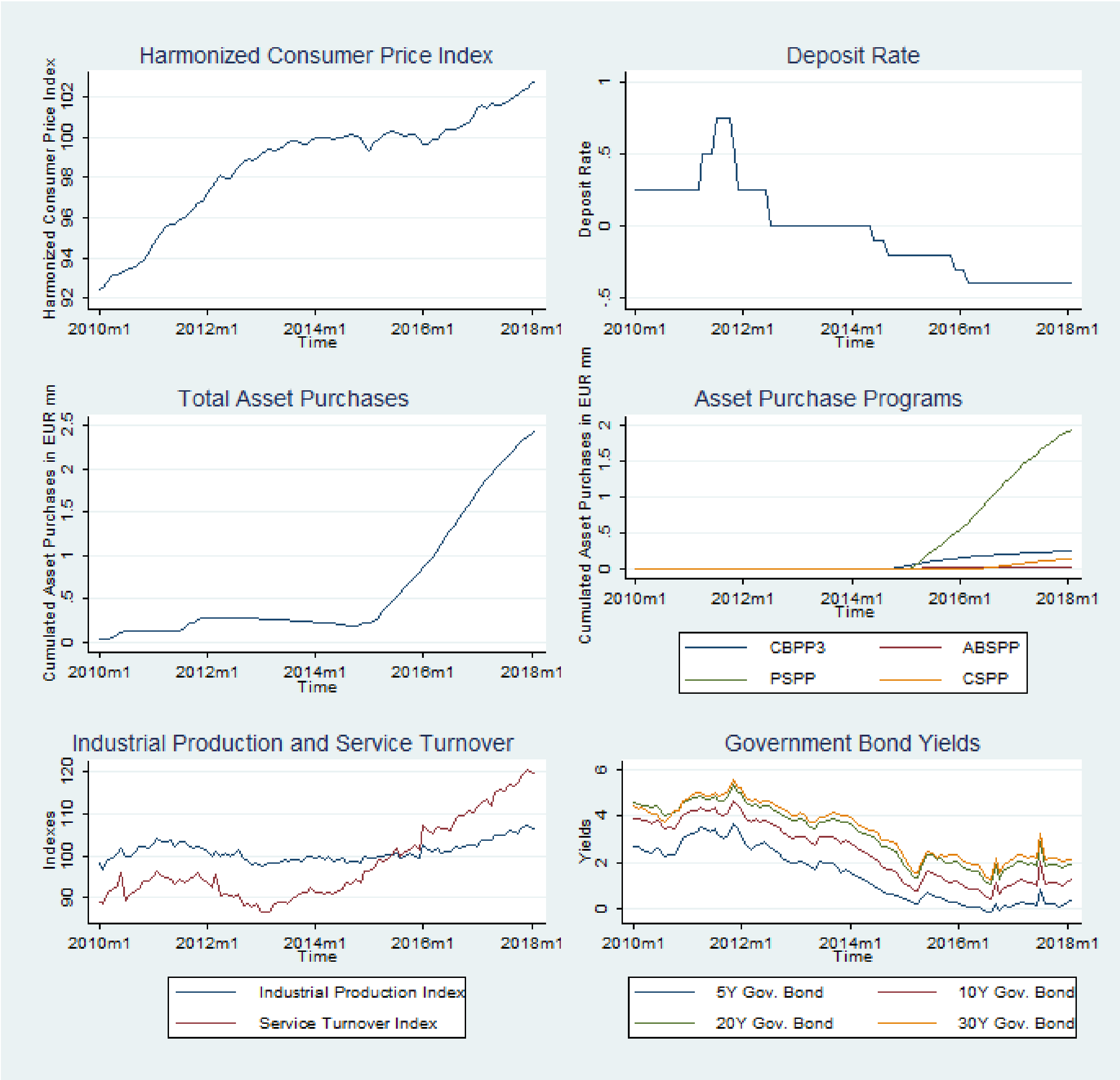


**Figure 2: Timelines of endogenous variables**

The ECB tried to increase the deposit rate before end of 2011 but then decided to let it converge towards zero. Negative interest rates were introduced on 11 June 2014. Figure 2 also shows that industrial production and service turnover indexes both experience a downsizing trend beginning in the second half of 2011. This may be a consequence of the European debt crises. Both indexes recover afterwards although at a different pace. Remarkable is that both, industrial production and the service turnover indexes show a spike in their first differences in January 2016 as displayed in Figure 2. This spike coincides with the HCPI picking up its continuous growth again. What is interesting as well is that a rise in government bond yields 3 to 6 months after introducing SMP on 10 May 2010 started and continued almost until its termination in 6 September 2012. Afterwards

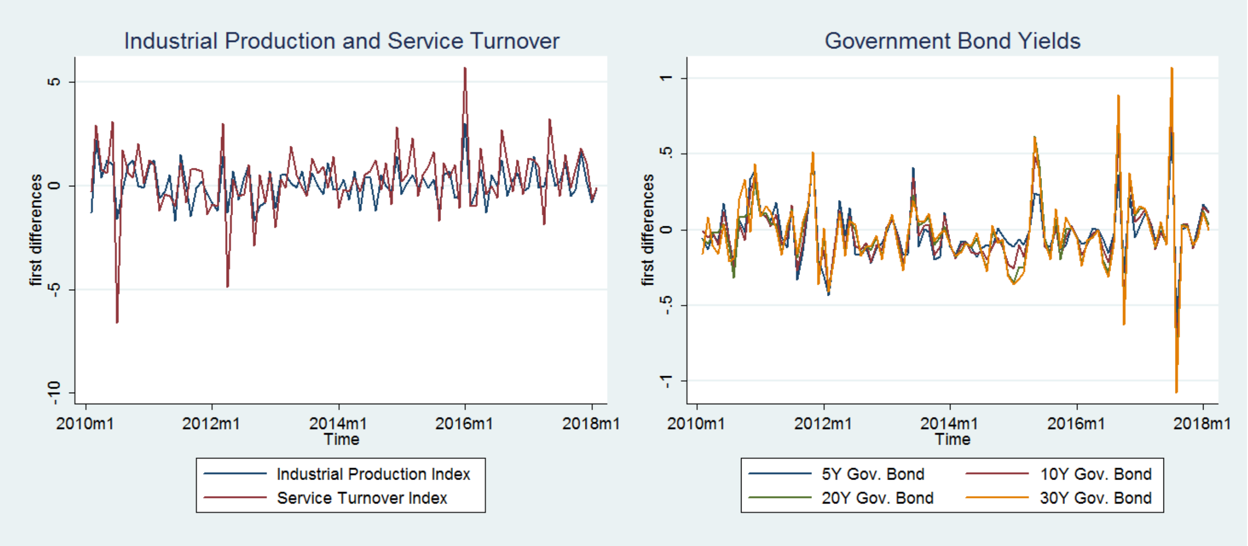


**Figure 3: Industrial Production, Service Turnover Index and Government Bond Yields in first-differences**

a downward trend persisted disturbed by two indentations that were immediately followed by reversing shocks. The first one occurred in Q1 2015 when APP was introduced and the second in Q3 2016 after the announcement of an extension of APP. Another spike occurred in July 2017. After this shock has been reversed, yields stagnate. The graph points to a quick reaction of government bond yields to announcements. Spikes are generally increasing with maturity as displayed in Figure 3. Nevertheless, APP seems to lose its influence on government bond yields after Q3 2016. To sum up, descriptive analysis suggests that financial as well as macroeconomic variables react to changes in the deposit rate as well as to shocks induced by LSAPP announcement. Simply by analyzing timelines no clear conclusions on the effects of APP can be drawn but in general the impact is expected to be humble.

### 5.3 Empirical results

This section describes the main results. For my VEC model one cointegrating relation could be found:

$$HCPI = +64.40847 lnTotal + 35.49941 ind\_production - 17.18998 service$$
$$- 48.28925 term\_premium - 2742.076$$

where all of the coefficients are significant at the 1% level. The error correction terms were predicted as follows:

$$\hat{\alpha}' = \begin{bmatrix} 0.00045559 & -0.0009594 & -0.0147549 & -0.0013727 & 0.0031476 \\ (0.501) & (0.001) & (0.000) & (0.831) & (0.001) \end{bmatrix}$$

with the t-statistics in parentheses beneath. In the long-run equilibrium a 1% increase in the natural logarithm of securities purchased for monetary purposes is associated with a

64.41% increase in HCPI ceteris paribus. Converted into actual asset purchases in Euro million, an 1% increase in these purchases would induce an increase in HCPI by approximately 0.08%. Thus, ceteris paribus to achieve the target of an annual inflation rate of 2%, annual asset purchases need to increase by 25%. Cumulated asset purchases increased by 370% in 2015, by 200% in 2016 and by 145% in 2017. Even though indirect effects through other variables are not considered in these calculations, the $\beta$-coefficients of the cointegrating relation still seem unrealistic. Secondly, it seems controversial that a 1% increase in the industrial production index is connected to a 35.5% increase in HCPI while a 1% increase in the service turnover index induces a decrease in HCPI by 17.19%. A possible explanation is that the error correction term for HCPI not significant and positive. For the industrial production index $\hat{\alpha}$ is negative and significant. Thus, the previous month's deviations from the long-run equilibrium are corrected for within the current month at a convergence speed of 1.48%. Cumulated asset purchases have a significant convergence rate of 0.1%.  While asset purchases and the industrial production index decrease, the term premium increases to adjust back to equilibrium. All other variables do not have a significant dynamic adjustment to the equilibirium. The predicted constants, incorporating the linear time trend in levels, are displayed beneath (with the t-statistics in parentheses beneath):

$$\hat{\nu} = \begin{bmatrix} 0.0658409 & -0.0172931 & -0.0845974 & 0.7146387 & -0.0997059 \\ (0.030) & (0.172) & (0.569) & (0.013) & (0.024) \end{bmatrix}$$

The p-values for joint short-run effects of all lags of a specific variable are displayed in Table 1. At a significance level of 5% in the short-run HCPI is caused by its own lagged values as well as the constant. The natural logarithm of cumulated asset purchases is significantly caused by its own lagged values and by the lagged values of HCPI. The industrial production index is influenced by the lagged values of itself and the cumulated asset purchases. In the short-run the service turnover index and the term premium  are both significantly caused by the lagged values of asset purchases, the service turnover index and the constant. The term-premium is influenced by the lagged values of HCPI as well. The individual short-run coefficients of each lagg seperately are displayed in Appendix B3.

| | *D.HCPI* | *D.lnTotal* | *D.ind_production* | *D.service* | *D.term_premium* |
|---|---|---|---|---|---|
| *lagged HCPI* | 0.0003 | 0.0302 | 0.3306 | 0.1571 | 0.0024 |
| *lagged lnTotal* | 0.9853 | 0.0000 | 0.0343 | 0.0172 | 0.0339 |
| *lagged ind_production* | 0.1959 | 0.2260 | 0.0124 | 0.1617 | 0.3451 |
| *lagged service* | 0.2386 | 0.9727 | 0.0515 | 0.0316 | 0.0010 |
| *lagged term_premium* | 0.7989 | 0.2703 | 0.3965 | 0.8878 | 0.0548 |

**Table 1: P-values for joint short-run effects of lagged variables. The first row gives the dependent variables while the first column names the lagged independent variables. Each p-value represents a separate test. Tests were performed after running the VEC model. The significance of joint short-run effects of all lags of one independent variable together on the first difference of the dependent variable were tested.**

To sum up, in the short-run APP seems to have an effect on all variables except from the consumer price index. In the long-run an increase in asset purchases induces a small increase in HCPI. However, an insignificant and positive error correction term for HCPI indicates that deviations in HCPI from the long-run equilibrium are not corrected for. Thus, the long-run impact of asset purchases on HCPI may be mitigated.

Figure 4 displays the orthogonalized impulse-response functions with the natural logarithm of asset purchases as the impulse variable and all others as the response variables. Ordinary impulse-response functions investigate the effect on a variable solely arising from the impulse on another variable while holding other impulses constant. However, if the variables are correlated, the assumption that an impulse only affects one variable while the other impulses are constant does not hold. The orthogonalized impulse-response function uses the Cholesky decomposition of the variance-covariance matrix to isolate the contemporaneous impact that the impulses on all variables have on one specific variable. While responses in VAR models usually die out, shocks in VEC models can have permanent character. Confirming the discussion made above, the short and long-term effects of the natural logarithm of cumulated asset purchases on HCPI are negligible. The peak is reached after 4 periods and causes an increase in HCPI by 1.78bps only. However, asset purchases drive up the service turnover index in the short run. A one-standard-deviation impulse to asset purchases induces an increase by approximately 50bps in the service turnover index within the first two months. This effect fades out after approximately 6 months and thus the shock is transitory. The long-term impact on the industrial production index and the term-premium, however, are more sustainable. Surprisingly, 1% increase in the natural logarithm of asset purchases decreases the industrial production index in the long-run by approximately 10bps and

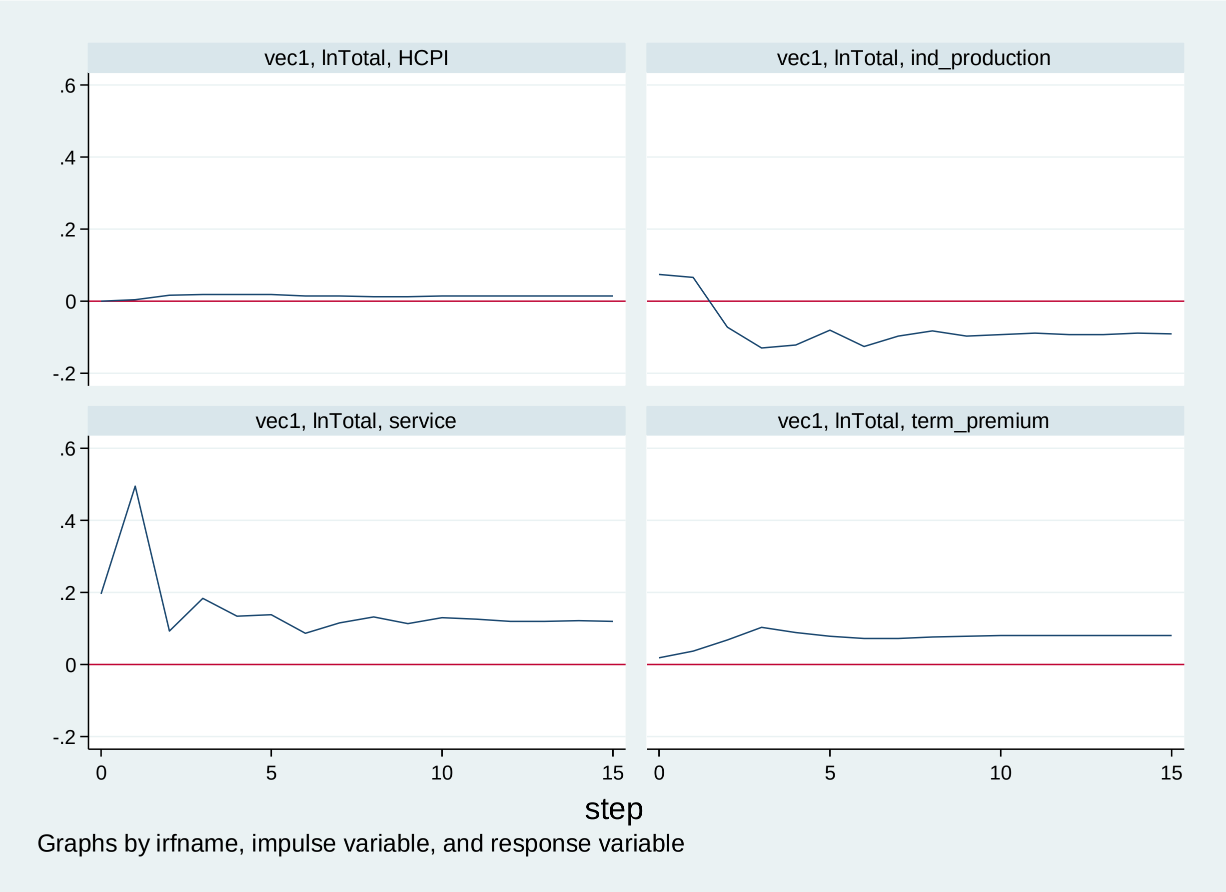


**Figure 4: Orthogonalized impulse response functions with lnTotal as the impulse variable and HCPI, ind_production, service and term_premium as the response variables**

increases the term premium by slightly more than 8bps. The exact numbers for each step can be found in the Appendix B4.

Figure 5 shows the orthogonalized impulse response functions with HCPI as the sole response variable to impulses by all variables (2). It confirms that a shock to the natural logarithm of cumulated securities purchased for monetary reasons does only have a negligible influence on HCPI. Even though the effects almost double, reaching its peak after 6 months at an increase by 3bps. HCPI largely reacts to impulses to its own variable and to some extend to changes in the industrial production index. The reaction to stimuli to other variables are not sizeable. The exact numbers for each step can be found in the Appendix B5 in the Eurozone.

Thus, taken the findings together I can confirm my initial expectations that the impact that asset purchases have on HCPI are limited. Their contribution to achieving an inflation rate of slightly below 2% may be humble. A one-standard-deviation impulse to the natural logarithm of asset purchases induces an increase in HCPI by approximately 1.78bps. Thus, converting it into asset purchases in EUR million the effects are even less.

(2) Impulse response functions do not severly differ when the 10-year government bond yield is substituted by the 5, 20 or 30-year government bond yields.

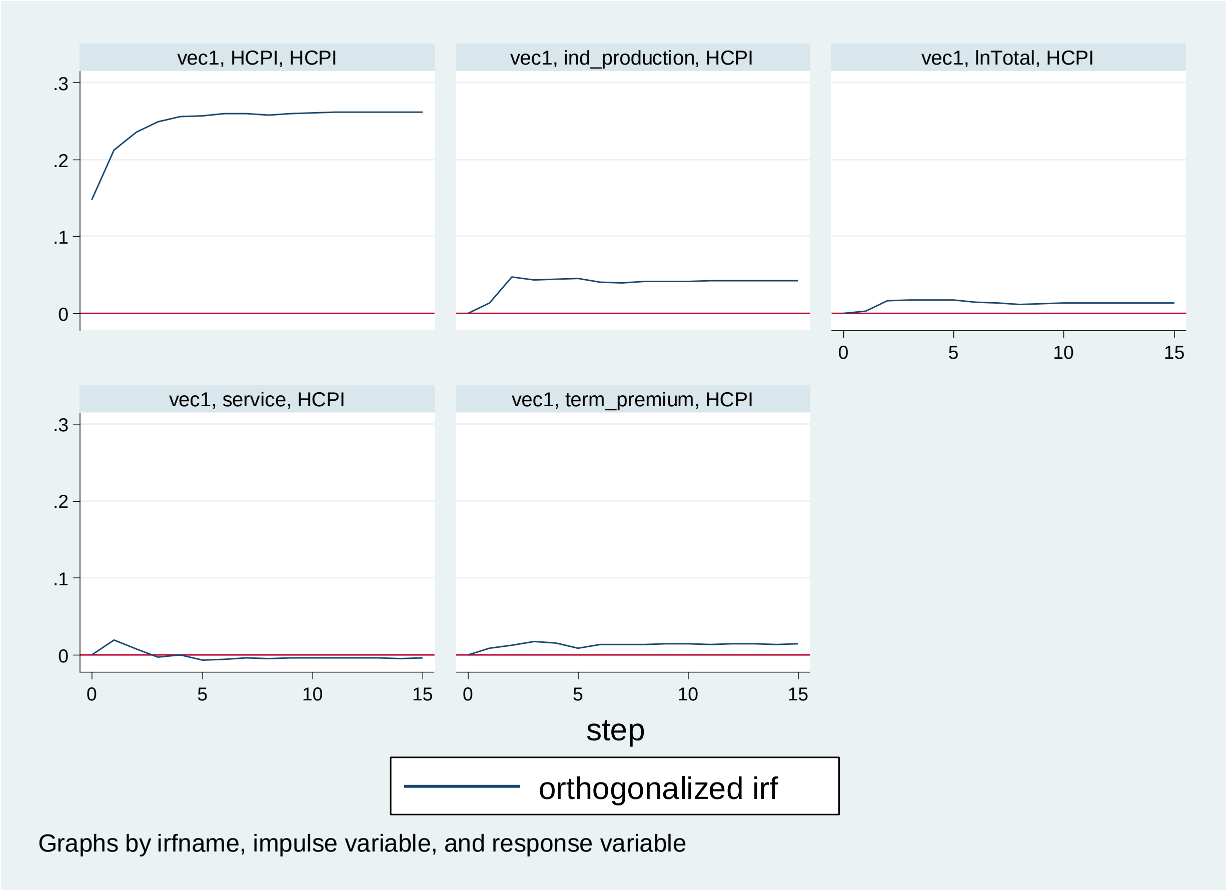


**Figure 5: Orthogonalized impulse response functions with HCPI, ind_production, lnTotal, service and term_premium as the impulse variables and HCPI as the response variable**

Thus, taken the findings together I can confirm my initial expectations that the impact that asset purchases have on HCPI are limited. Their contribution to achieving an inflation rate of slightly below 2% may be humble. A one-standard-deviation impulse to the natural logarithm of asset purchases induces an increase in HCPI by approximately 1.78bps. Thus, converting it into asset purchases in EUR million the effects are even less.

## 5.4 Robustness check

First of all, the lagrange-multiplier test does not reject the null-hypothesis that there is no autocorrealtion at lag length four. No autocorrelation in the residuals is prevalent in our model. Thus, a lag length of four is appropriate. The Jarque-Bera test confirms that for the HCPI model the residuals are normally distributed. The same applies to the industrial production index. For all other variables as well as for the model as a whole the null-hypothesis of normally distributed residuals can be rejected. Hence, while conclusions can be drawn with regards to HCPI, other variables should be interpreted as control variables only. The output of these two postestimation tests as well as the confirmation of stable eigenvalues can be found in Appendix B6.

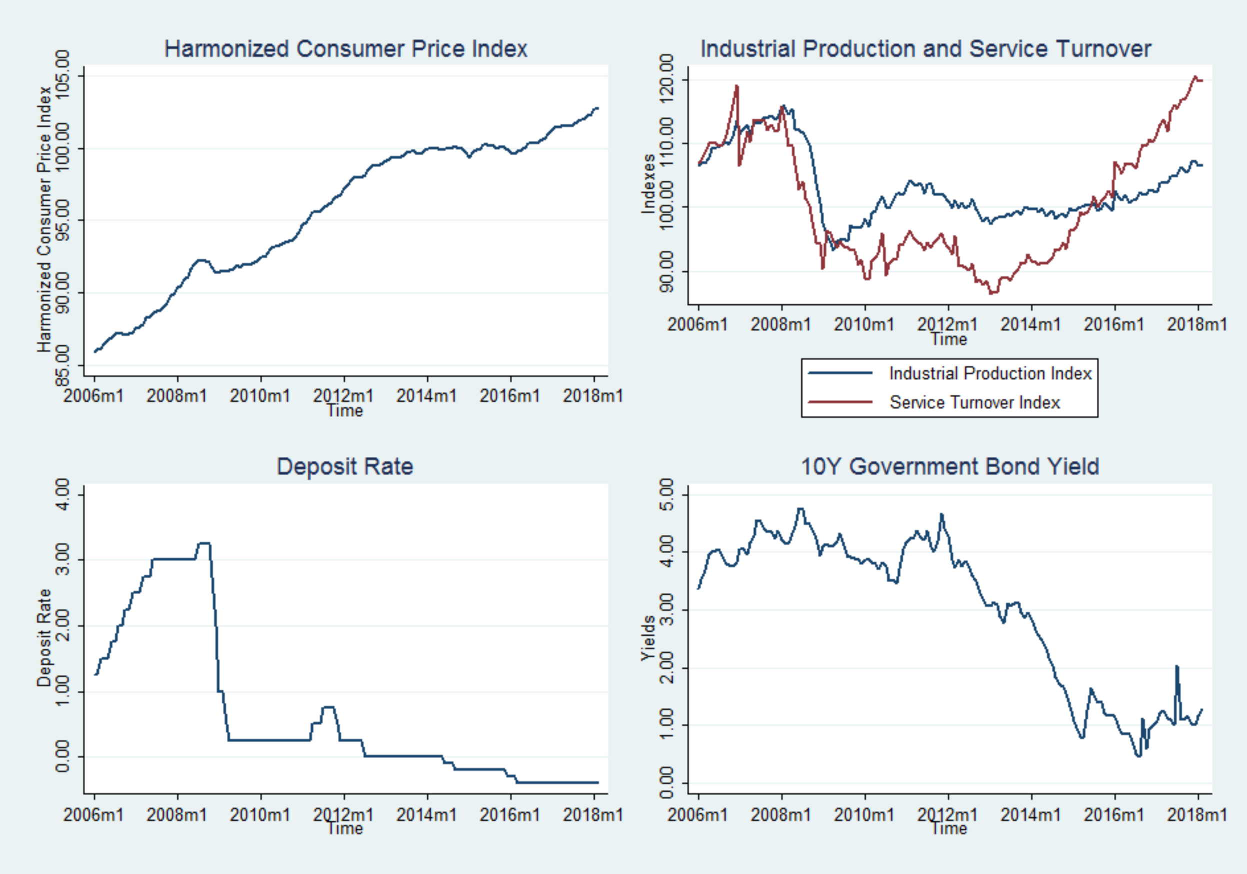


**Figure 6: Timelines of endogenous variables for the extended data sample**

As previously noted, findings are sensitive to the selection of the data sample. I will run the same model for a prolonged time window from January 2006 to February 2018 to confirm my findings. A negative aspect of this data sample is that it incorporates reactions to the US-American quantitative easing program. On the other hand, it includes the financial crises, the major driving factor for implementing quantitative easing. Results will only be briefly summarized. For detailed pre- and post-estimation results consider Appendix C which is organized in the same order as for the previous sample. In Figure 6 the consequences of the financial crises are visible. While the industrial production and service turnover index nosedived sharply, the effects on the HCPI seem to be limited.

The AIC and FPE criteria confirm that a lag length of four is appropriate for this data sample as well. Secondly, trace statistics and max eigenvalue statistics confirm the existence of one cointegrating relation. Thus, the same model as before can be applied to the extended data sample. When prolonging the timeframe of the data sample, joint lags of the natural logarithm of cumulated security purchases lose their short-run effects on all variables. Secondly, the magnitude of the log-run impact of asset purchases on HCPI diminishes as well. Comparing the orthogonalized impulse response functions of this data sample displayed in Figure 7 to the previous one, major differences can only be detected for the service turnover index. Instead of having a positive effect in the short-run, the impact of asset purchases on this index now resembles the effect of asset purchases on the industrial production index. The short-run as well as the long-run dynamics are negative and settle down at a level of approximately -3% after 6 periods. Figure 8 also shows that no severe differences appear when comparing the orthogonalized impulse response functions with HCPI as the response variable to impulses of all variables. The long-run effect of the industrial production index on HCPI increases, but the impact of asset purchases remains low.

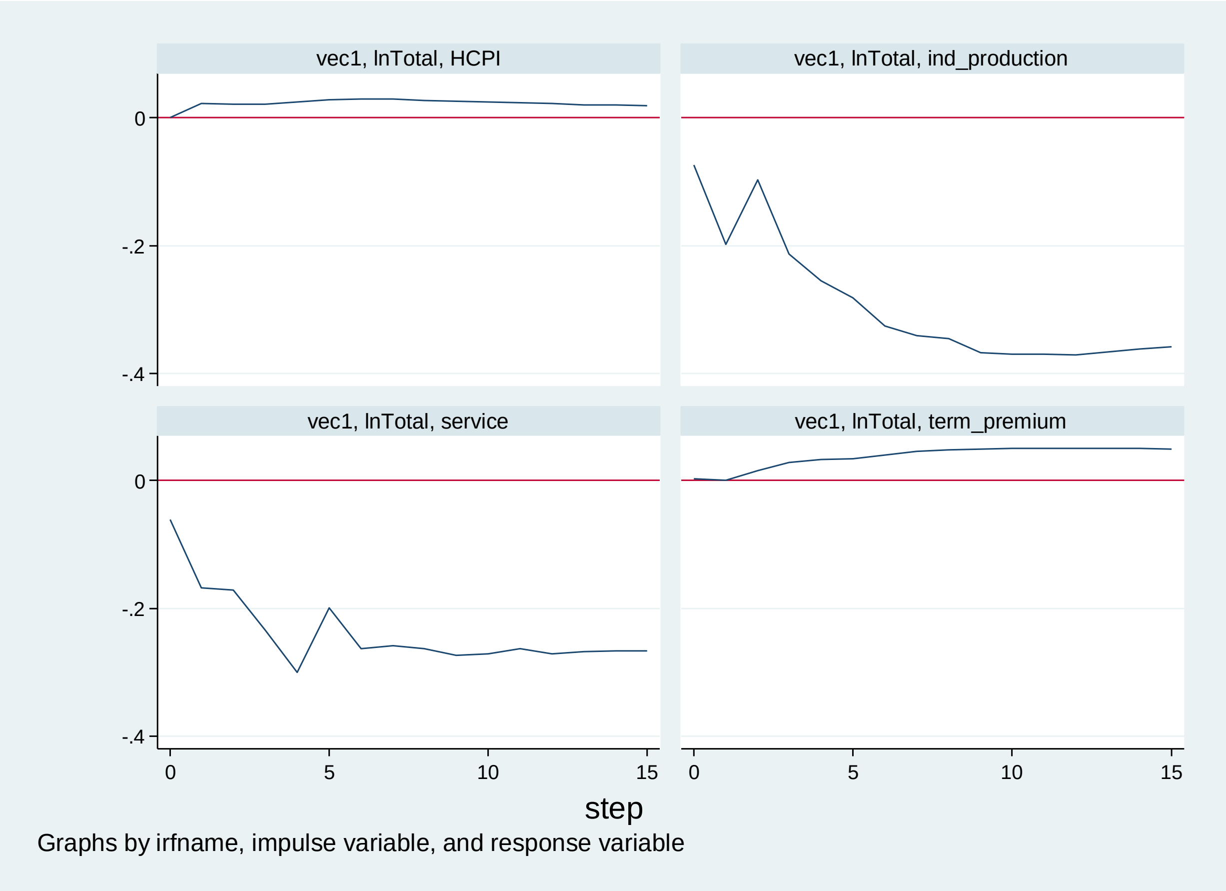


**Figure 7: Orthogonalized impulse response functions with lnTotal as the impulse variable and HCPI, ind_production, service and term_premium as the response variables for the extended data sample**

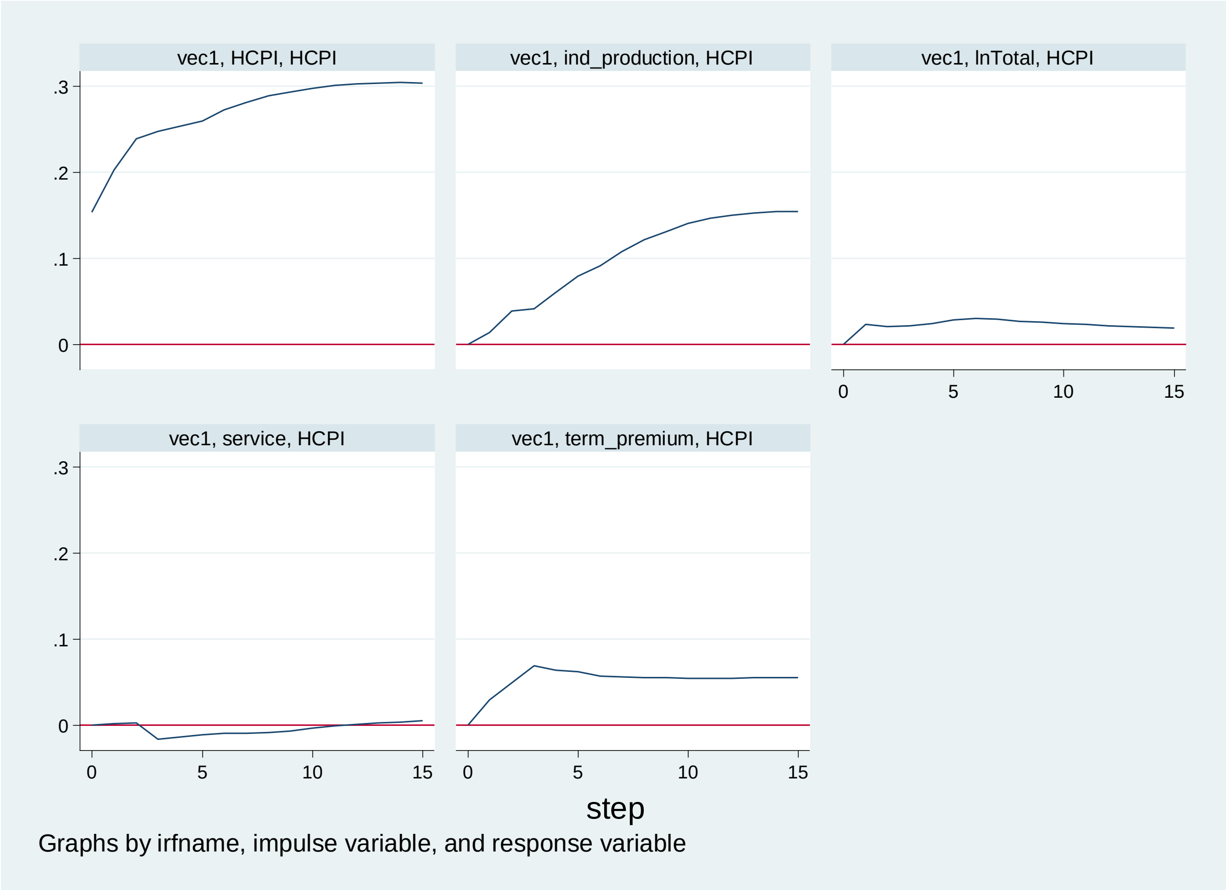


**Figure 8: Orthogonalized impulse response functions with HCPI, ind_production, lnTotal, service and term_premium as the impulse variable and HCPI as the response variables for the extended data sample**

Initially, the AIC and FPE criteria suggested taking a lag length of two. Running the model with lag two instead of four induces some differences in the responses of HCPI to impulses in the industrial production and service turnover index as well as in the long-run effects of asset purchases on the service turnover index. However, our main findings on reponses of HCPI on impulses steming from asset purchases are not affected. The model in general mainly focuses on the demand-pull effect. A main component that drives this effect, the unemployment rate, is missing from the model and should be controlled for. In a demand-pull model inflation is incurred only when unemployment rates are low. But even when the unemployment rate is added as a control variable, the impact of asset purchases on HCPI does not increase. The orthogonalized impulse response functions for these two models can be found in Appendix D and E.

Different robustness checks have confirmed the finding, that APP up to February 2018 only had negligible effects on the harmonized consumer price index. Thus, if effectiveness of quantitative easing is measured by its contribution to achieve an inflation rate of slightly less than 2%, APP seems to have limited effectiveness.

# 6 Comparison of European and US-American quantitative easing programs

The Fed as well as the ECB lowered their targets for the interbank money market in response to the financial crises. Both of them increased their balance sheets to provide the markets with liquidity and thus ease financial stress. Both LSAPPs had substantial effects on the local economy. However, measures taken by these banks severely differ. The Fed, on the one hand, launched outright asset purchase programs right after the financial crises hit our economies. The EU, on the other hand, initially stuck to conventional monetary tools namely direct lending to banks. As the sovereign debt crises hit Europe, the ECB changed their strategy. It determined certain market segments that seemed to seize and concentrated on revitalizing them, which can be categorized as credit easing. These differences in monetary policy can be explained by financing patterns in these particular economies. While in the US the main source of financing are capital markets, European companies heavily rely on bank lending. In January 2015 the ECB decided to implement quantitative easing, compared to the Fed that introduced QE1 in December 2008 already. Quantitative easing programs are said to be most effective when the economy is still suffering from financial distress. As financial stress has partly been alleviated at times of implementation of APP, the European LSAPP is limited in its effectiveness (Gern, et al., 2015). Cenesizoglu et al. (2017) show that the Fed chose the right point in time to switch from conventional to unconventional monetary policy measures. They use a SVAR model and estimate it over two samples. The first one excludes the financial crises while the second one includes the first year of financial turmoil in which conventional were still dominant over unconventional tools. They construct dynamic responses of selected variables for both samples and compare them. Implementation of expansionary monetary policy was effective in decreasing the federal funds rate and yields over all maturities as well as increasing output. However, their work suggests that conventional monetary policy lost its capability of influencing macroeconomic aggregates at the beginning of 2008. A major drawback of their model is that the effects of factors underlying the term structure of interest rates on macroeconomic variables are investigated isolated from one another. This implies that these factors are not related to one another which contradicts reality. Nevertheless, Cenesizoglu et al. show that the Fed's decision to complement conventional by unconventional measures in 2008 was appropriate in influencing the term structure of interest rates. Of course this does not mean that the right point of implementing quantitative easing in Europe must be the same. As previously noticed, there are vital differences in the banking system of the US and the euro area. However, comparing inflation rates in the USA and in the Eurozone shows that rates experienced a sharp decline from 2008 onwards. Figures 9 and 10 show that the euro area inflation rate seems to recover faster than the US, but the increases were sustainable in the US while the trend was reversing in the Eurozone. The second downfall from 2012 onwards may be explained by the European debt crises. The European inflation rate starts to recover in late 2016. The question remains whether the negative effects of the Eurozone crises could have been mitigated by implementing quantitative easing earlier. A positive aspect of implementing quantitative easing in times of low financial stress is that it is connected to weaker market segmentation. Additionally, the ECB implemented their programs simultaneously while the Fed's programs were conducted sequentially. The ECB thus focuses on a broader range of assets at the same time. Taking these two facts together, the ECB was less affected by the consequences of preferred habitat theory and managed to induce reductions in a broader spectrum of asset class yields and maturities. However, the magnitude of these effects were weaker than in the US. While the cumulated 10Y government bond reduction of QE1, 2, 3 and the Operational Twist together fluctuates around 100bps to 200bps (Gagnon, et al., 2010; D'Amico, et al., 2012), the impact of the European programs seems not to exceed 90bps even for high-risk countries (Urbschat & Watzka, 2017). In general the impact rises with riskiness and maturity of the asset, making long-term bonds in riskier euro area member states most susceptible to LSAPPs. Effects on macroeconomic indicators were more sizeable in the US as well. The US-American GDP increased by 58bps and CPI by 62bps due to quantitative easing (Weale & Wieladek, 2016). In the Eurozone on the other hand HCPI increased by 1.78bps to 40bps only (Andrade, et al., 2016). Comparing it to the US-American QE1, which was introduced to directly respond to the emerging financial crises, would lead to a bias towards the American program. It is rather comparable to the second-round QE program. (Gern, et al., 2015). But still effects of the US-American program are substantially larger. The same applies to the exchange rate channel. While the USD depreciated against the EUR by -7.8% (Neely, 2010), cumulated depreciation for the EUR against the USD only mounted up to -6.5%. Changes in the nominal effective euro exchange rate were even less (Deutsche Bundesbank, 2017).

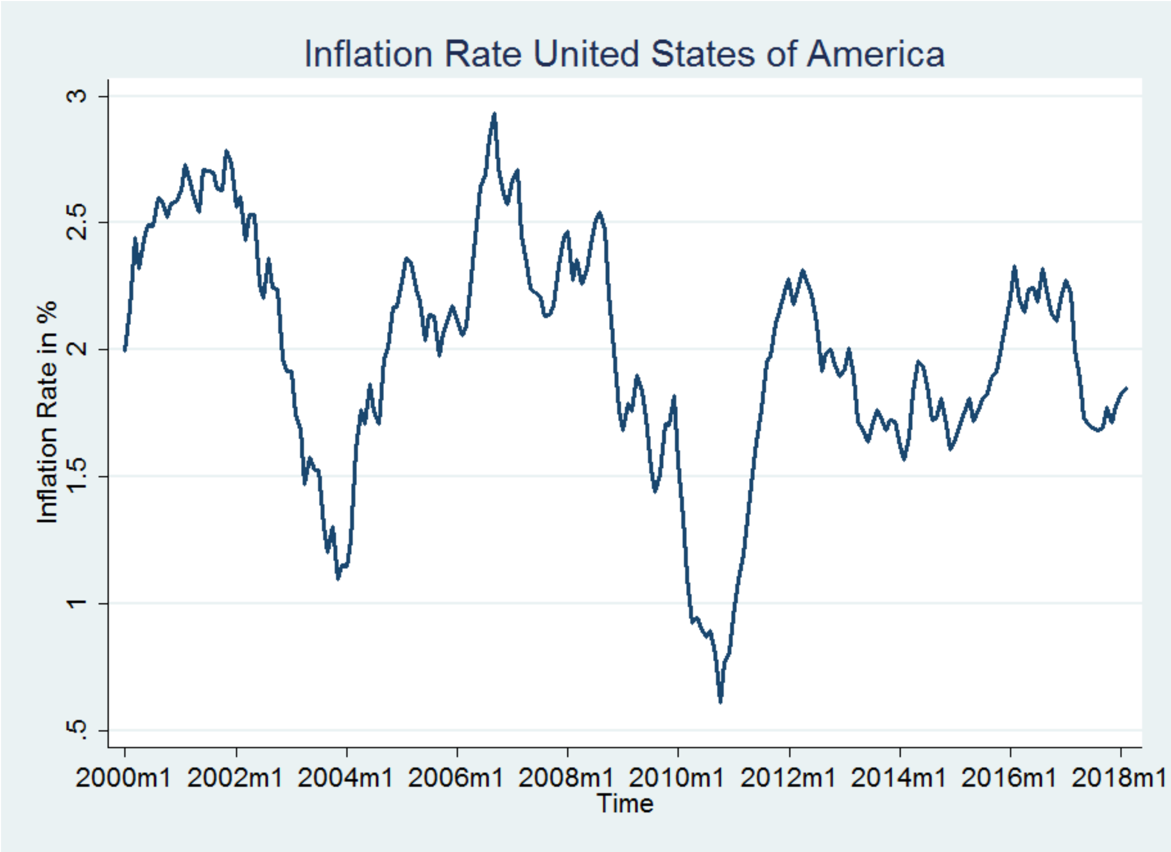


**Figure 9: US-American inflation rate. Source of the data: FRED Economic Data Federal Reserve Bank of St. Louis**

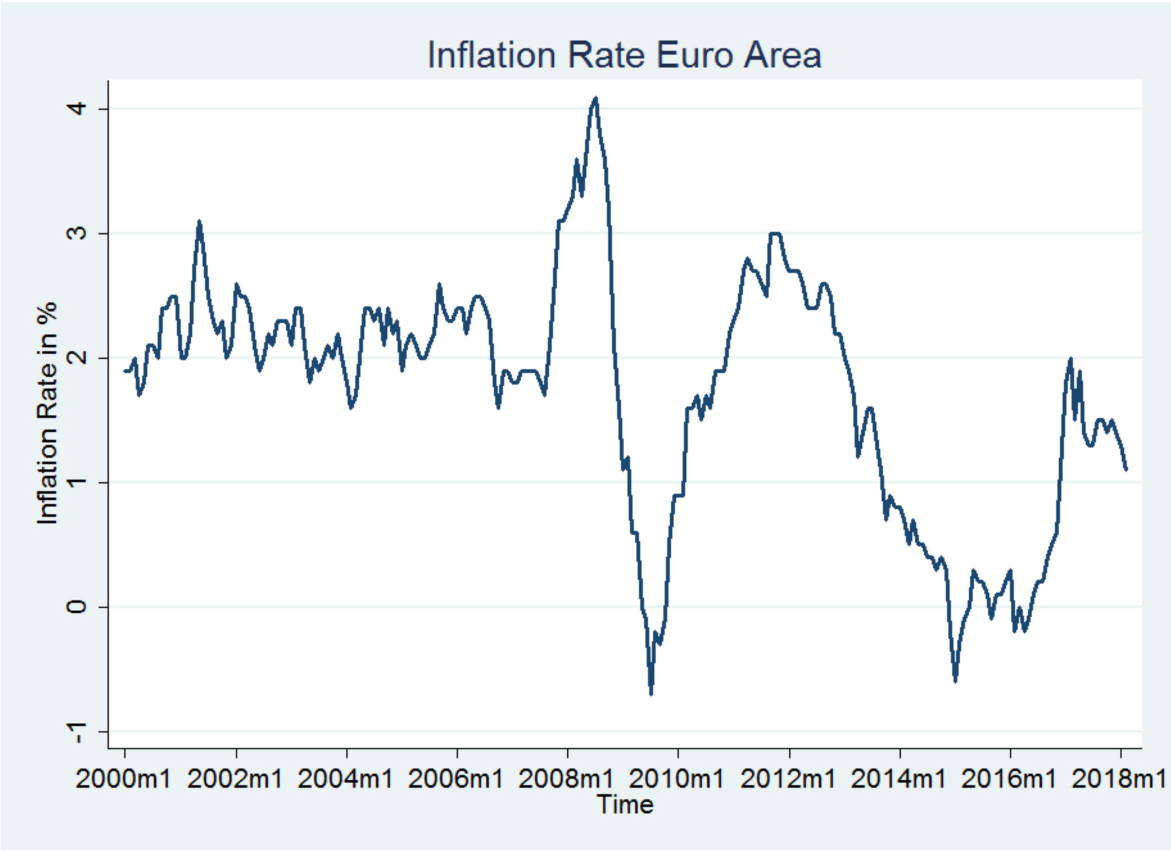


**Figure 10: Eurozone inflation rate. Source of the data: Eurostat**

A second main difference between the US and the euro area is that monetary policy is elaborated by the supranational institution ECB but is partly implemented by the national central banks. The Eurozone as a currency union consists of states with independent governments. They conduct fiscal policy individually. Buying government bonds not only jeopardizes the central bank's independence as it blurs the line between monetary and fiscal policy, it also evokes concerns over the independence of the national governments (Gern, et al., 2015). Additionally, the ECB compared to the Fed is a rather young institution that still has to defend its position and build authority. Thus, monetary policy in the euro area is affected by trust issues to a larger extend than monetary policy in US-America. As previously discussed, quantitative easing is highly dependent on investor's expectations. Especially the signaling channel relies on signals being trustworthy and credible. If investors do not believe in the actions taken by the ECB, transmission channels of quantitative easing programs are partly blocked. While expected inflation in the US could be raised by 96bps to 146bps over the 10-year horizon (Krishnamurthy & Vissing-Jorgensen, 2011), in the euro area long-term inflation forecasts increased by 9bps only (Andrade, et al., 2016). This confirms that the ECB needs to rebuild trust while investors still believe in decisions made by the Fed.

Thirdly, the USA presents itself as one union while the Eurozone is more fragmented and less cooperative. The economic position and health of member countries of the euro currency union severely differs. The ECB as such cannot implement a monetary policy strategy that is tailor-made to all 19 member states. Monetary policy in more solid economies was already elaborate before establishing a currency union. These economies are more susceptible to monetary actions taken by central banks (Gern, et al., 2015). The ECB has to find its balance between favoring and pushing these economies or trying to close the gap between developed and less developed economies. Either way, some of the countries will always be disadvantaged or left behind. Furthermore, implementing supranational monetary policy keeps economically weak countries from implementing necessary structural changes which even worsens the divergence within the union. In spite of this, united US-America has bigger effects on economic developments in Europe than the other way round. The US-American inflation rate hardly reacts to the emergence of the European debt crises. Thus, the ECB needs to consider US-American monetary policy actions when making their decision, while European programs are less important to the US. This may be another reason why the ECB decided to wait with the implementation of quantitative easing. They wanted to await reactions to the US-American LSAPP. Whether this happened out of cowardice or strategic thinking hardly makes any difference. Fact is that the US-American inflation rate has stabilized and has been fluctuating around 2% for almost 4 years now. Thus, the Fed is able to successfully unwind from quantitative easing and normalize monetary policy. The European inflation rate, on the other hand is still fragile. The ECB needs to be really cautious in terminating the quantitative easing program to avoid destabilizing the Eurozone economy again. On the other hand, risks of quantitative easing increase with the duration of the program. Thus, the ECB needs to trade-off the chances that quantitative easing has not yet unfold his full impact and will further improve economic conditions against possible risks involved in further pursuing the programs.

# 7 Conclusion

This master thesis analyzed the effectiveness of quantitative easing programs implemented by the Fed and the ECB. Effectiveness is defined as reaching a persistent inflation rate of slightly below 2%. While this target was met in the USA, the inflation rate in the euro area still needs to increase and stabilize at a level of 2%. Based on the transmission channels of quantitative easing, effects of the programs were investigated. The impact of the different channels are hard to determine and to isolate from one another. Thus, no clear conclusions can be drawn regarding the importance of different channels. Depending on the market structure, trust in the financial system and policy communication, contributions of each channel differ. While the analysis of US-American quantitative easing programs is broad in its magnitude and rather conclusive, effects of the European APP could not yet be fully revealed. However, literature agrees on that the announcement effect is substantial in reducing yields for both programs. Hence, actual asset purchases only have limited impact on financial variables. This emphasizes that forward guidance and communication is essential for a quantitative easing programs to be effective.

In general the impact of the US-American program seems to be larger not only for financial variables but also for macroeconomic ones. Thus, the US-American programs can be regarded as effective in contributing to the objective of increasing inflation to a level of slightly below 2%. The contribution of LSAPPs to increase inflation in the Eurozone, on the other hand, is questionable. This can be partly explained by the fact that the US-American programs were implemented at times of high financial distress. When European programs were implemented financial stress has significantly eased, limiting their effects on the targeted securities but enriching spill-over effects on other asset classes. Secondly, the ECB struggles with gaining back the trust of investors. Expectations about future interest rates and inflation are a major determinant of economic health and growth. Measures taken by the ECB were not as effective in improving investors' expectation as programs implemented by the Fed. Thirdly, effects in Europe severely differ across member states. Dispersion in the financial system of the euro area may have contributed to the limited effects of local large-scale asset purchase programs. The question still remains whether the delayed introduction of quantitative easing measures in the euro area set a limit to their effectiveness compared to US-American LSAPPs. In spite of this, a decision on whether to exit or further pursue quantitative easing in the euro area needs to be made. Based on the findings of this master thesis, effectiveness of LSAPPs is humble and is not expected to increase. Thus, risks and costs of quantitative easing may outweigh its benefits. The ECB needs to decide over whether terminating quantitative easing programs destabilizes the economy more than exiting them before the trust into the financial system has been rebuild.

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# Appendix

## Appendix A

| *Label* | *Variable* | *Description* |
|---|---|---|
| *HCPI* | harmonized consumer price index | overall index, monthly average, euro area changing composition, working day and seasonally adjusted, 2015=100% |
| *ind_production* | industrial production index | total industry, monthly average, euro area 19, working day and seasonally adjusted, 2010=100% |
| *service* | service turnover index | wholesale and retail trade and repair of motor vehicles and motorcycles, monthly average, euro area 19, working day and seasonally adjusted, 2010=100% |
| *lnTotal* | natural logarithm of cumulated securities held for monetary policy purposes | end of the month total in EUR million |
| *deposit_rate* | ECB deposit rate | end of the month in %, euro area changing composition |
| *gov_bond* | 5Y, 10Y, 20Y and 30Y government bond yields | nominal, monthly average, all issuers and all ratings included, euro area changing composition |
| *term_premium* | difference between gov_bond and deposit_rate | |
| *unemploy* | unemployment rate | monthly average, euro area changing composition, seasonally adjusted, not working day adjusted |

**Table 2: Description of the variables used. Source: Eurostat**

## Appendix B

### Appendix B1

Selection-order criteria
Sample: 2010m5 - 2018m2 Number of obs = 94

| lag | LL | LR | df | p | FPE | AIC | HQIC | SBIC |
|---|---|---|---|---|---|---|---|---|
| 0 | -724.897 | | | | 3.82031 | 15.5297 | 15.5844 | 15.665 |
| 1 | -52.8032 | 1344.2 | 25 | 0.000 | 4.0e-06 | 1.76177 | 2.08963* | 2.57346* |
| 2 | -16.3775 | 72.851 | 25 | 0.000 | 3.2e-06* | 1.51867* | 2.11975 | 3.00677 |
| 3 | 8.30326 | 49.361 | 25 | 0.003 | 3.2e-06 | 1.52546 | 2.39976 | 3.68997 |
| 4 | 30.8355 | 45.064* | 25 | 0.008 | 3.5e-06 | 1.57797 | 2.72549 | 4.41888 |

Endogenous: HCPI logTotal ind_production service term_premium
Exogenous: _cons

**Table 3: Likelihood-ratio test, final prediction error (FPE), Akaike's information criterion (AIC), Schwarz's, Hannan and Quinn information criterion (HQIC) and Bayesian information criterion (SBIC) lag-order selection statistics. The * indicates which lag length should be selected when choosing this criterion.**

### Appendix B2

Johansen tests for cointegration
Trend: constant Number of obs = 94
Sample: 2010m5 - 2018m2 Lags = 4

| maximum rank | parms | LL | eigenvalue | trace statistic | 5% critical value |
|---|---|---|---|---|---|
| 0 | 80 | -24.734582 | . | 111.1402 | 68.52 |
| 1 | 89 | 6.1687298 | 0.48186 | 49.3335 | 47.21 |
| 2 | 96 | 18.253495 | 0.22673 | 25.1640* | 29.68 |
| 3 | 101 | 26.08322 | 0.15345 | 9.5046 | 15.41 |
| 4 | 104 | 29.690507 | 0.07388 | 2.2900 | 3.76 |
| 5 | 105 | 30.835502 | 0.02407 | | |

| maximum rank | parms | LL | eigenvalue | max statistic | 5% critical value |
|---|---|---|---|---|---|
| 0 | 80 | -24.734582 | . | 61.8066 | 33.46 |
| 1 | 89 | 6.1687298 | 0.48186 | 24.1695 | 27.07 |
| 2 | 96 | 18.253495 | 0.22673 | 15.6594 | 20.97 |
| 3 | 101 | 26.08322 | 0.15345 | 7.2146 | 14.07 |
| 4 | 104 | 29.690507 | 0.07388 | 2.2900 | 3.76 |
| 5 | 105 | 30.835502 | 0.02407 | | |

**Table 4: Johansen's trace statistic test and maximum-eigenvalue statistics to determine the number of cointegrating relations. The * indicates that the trace statistics would select rank two at a significance level of 5%. The maximum eigenvalue statistics would suggest choosing a rank of one instead, as the statistics for rank one are less than the 5% critical value.**

## Appendix B3

| | *D.HCPI* | *D.lnTotal* | *D.ind_production* | *D.service* | *D.term_premium* |
|---|---|---|---|---|---|
| *LD.HCPI* | 0.4702574 | 0.0968413 | -0.6158013 | -1.283786 | 0.227605 |
| | (0.000) | (0.046) | (0.279) | (0.246) | (0.180) |
| *L2D.HCPI* | -0.0566624 | 0.0009936 | -0.1485523 | -0.2638598 | 0.0643597 |
| | (0.662) | (0.985) | (0.814) | (0.830) | (0.733) |
| *L3D.HCPI* | 0.031677 | -0.0992181 | -0.5813873 | -1.666444 | 0.4988257 |
| | (0.787) | (0.043) | (0.312) | (0.136) | (0.004) |
| *LD.lnTotal* | -0.0374905 | 0.5300649 | 0.969311 | 6.148187 | -0.0024994 |
| | (0.881) | (0.000) | (0.427) | (0.010) | (0.995) |
| *L2D.lnTotal* | 0.021202 | -0.1018393 | -2.269698 | -7.481052 | 0.0500574 |
| | (0.941) | (0.393) | (0.105) | (0.006) | (0.904) |
| *L3D.lnTotal* | 0.0742066 | 0.0826208 | -1.429001 | 1.483583 | 0.8722637 |
| | (0.779) | (0.452) | (0.267) | (0.554) | (0.023) |
| *LD.ind_production* | -0.0267494 | 0.0154916 | -0.1064672 | 0.0488907 | -0.0566061 |
| | (0.355) | (0.198) | (0.451) | (0.859) | (0.179) |
| *L2D.ind_production* | 0.041211 | 0.0035682 | -0.2224144 | -0.2268881 | -0.0093054 |
| | (0.143) | (0.761) | (0.106) | (0.396) | (0.820) |
| *L3D.ind_production* | 0.0007644 | -0.0136893 | 0.2668256 | 0.4199413 | 0.0326255 |
| | (0.978) | (0.225) | (0.044) | (0.103) | (0.408) |
| *LD.service* | 0.0272218 | -0.0020368 | -0.1637228 | -0.4097099 | 0.0975463 |
| | (0.118) | (0.779) | (0.054) | (0.013) | (0.000) |
| *L2D.service* | -0.0058949 | 0.0014065 | 0.004254 | 0.0193908 | 0.0654313 |
| | (0.736) | (0.847) | (0.960) | (0.907) | (0.010) |
| *L3D.service* | -0.0117617 | 0.0014641 | -0.1198228 | -0.1119017 | 0.0111425 |
| | (0.463) | (0.826) | (0.126) | (0.462) | (0.633) |
| *LD.term_premium* | 0.0627579 | -0.0477943 | 0.2955485 | 0.1920736 | -0.2517552 |
| | (0.381) | (0.109) | (0.398) | (0.778) | (0.016) |
| *L2D.term_premium* | 0.0445062 | -0.0369047 | 0.0873574 | 0.230335 | -0.1397728 |
| | (0.538) | (0.220) | (0.805) | (0.737) | (0.184) |
| *L3D.term_premium* | -0.0068673 | -0.0330421 | -0.4559813 | -0.3838122 | -0.1527268 |
| | (0.921) | (0.249) | (0.175) | (0.558) | (0.128) |

**Table 5: Short-run coefficients of each lag of the independent variable individually (with the p-values in parentheses beneath). The first row gives the dependent variables while the first column names the lags of independent variables. LD is the first lag of the variable in first differences but the second lag in levels.**

## Appendix B4

Results from vec1

| step | (1) oirf | (1) fevd | (2) oirf | (2) fevd | (3) oirf | (3) fevd | (4) oirf | (4) fevd |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | .074026 | 0 | .194964 | 0 | .018899 | 0 |
| 1 | .003272 | 0 | .065108 | .01058 | .494003 | .019406 | .036026 | .007766 |
| 2 | .016237 | .000158 | -.07276 | .012939 | .092455 | .091829 | .068051 | .021227 |
| 3 | .017533 | .002179 | -.130352 | .014722 | .183193 | .067651 | .102477 | .055387 |
| 4 | .017729 | .003052 | -.122412 | .023084 | .133701 | .055644 | .087827 | .10631 |
| 5 | .017699 | .003465 | -.081237 | .027583 | .137259 | .047031 | .078088 | .122475 |
| 6 | .014311 | .003699 | -.125391 | .026402 | .085353 | .041149 | .07166 | .128642 |
| 7 | .013557 | .003567 | -.096862 | .028635 | .115018 | .035521 | .072522 | .133067 |
| 8 | .011683 | .003431 | -.082032 | .02826 | .130362 | .031912 | .075891 | .136601 |
| 9 | .012758 | .003245 | -.097358 | .027274 | .112083 | .029487 | .077188 | .140526 |
| 10 | .013665 | .003141 | -.092455 | .027037 | .129593 | .027195 | .079223 | .143628 |
| 11 | .013676 | .003091 | -.089777 | .026699 | .124429 | .025638 | .078876 | .146913 |
| 12 | .013833 | .003049 | -.094179 | .026319 | .119634 | .024276 | .080264 | .149557 |
| 13 | .013807 | .003019 | -.092642 | .026127 | .11948 | .023065 | .079993 | .152232 |
| 14 | .013626 | .002993 | -.088931 | .025921 | .120841 | .022037 | .079692 | .154554 |
| 15 | .013559 | .002966 | -.091422 | .025621 | .118227 | .021159 | .07988 | .156505 |

(1) irfname = vec1, impulse = lnTotal, and response = HCPI
(2) irfname = vec1, impulse = lnTotal, and response = ind_production
(3) irfname = vec1, impulse = lnTotal, and response = service
(4) irfname = vec1, impulse = lnTotal, and response = term_premium

**Table 6: Results of orthogonalized impulse–response functions and Cholesky forecast-error variance decompositions per step for each combination with lnTotal as impulse variable. The first column indicates the time since impulse. Combinations of impulse and response variables are numbered. They are then defined at the bottom of the table.**

## Appendix B5

Results from vec1

| step | (1) oirf | (1) fevd | (2) oirf | (2) fevd | (3) oirf | (3) fevd | (4) oirf | (4) fevd | (5) oirf | (5) fevd |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .147408 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | .212833 | 1 | .003272 | 0 | .013267 | 0 | .018813 | 0 | .008386 | 0 |
| 2 | .235602 | .990967 | .016237 | .000158 | .047387 | .002602 | .007828 | .005233 | .012418 | .00104 |
| 3 | .249376 | .9735 | .017533 | .002179 | .043857 | .019238 | -.003169 | .003299 | .017412 | .001784 |
| 4 | .256001 | .969152 | .017729 | .003052 | .044138 | .022796 | -.000646 | .002231 | .014732 | .002769 |
| 5 | .25662 | .967676 | .017699 | .003465 | .045284 | .024333 | -.00731 | .001646 | .008597 | .00288 |
| 6 | .259588 | .966813 | .014311 | .003699 | .040365 | .025519 | -.005772 | .001465 | .013421 | .002504 |
| 7 | .259663 | .967461 | .013557 | .003567 | .039719 | .025159 | -.004394 | .001293 | .013469 | .00252 |
| 8 | .258189 | .968096 | .011683 | .003431 | .041448 | .024798 | -.004829 | .001142 | .01302 | .002534 |
| 9 | .259734 | .968367 | .012758 | .003245 | .041548 | .024825 | -.0047 | .001038 | .013995 | .002525 |
| 10 | .260846 | .968522 | .013665 | .003141 | .041474 | .024823 | -.004322 | .000955 | .013974 | .002559 |
| 11 | .261652 | .968652 | .013676 | .003091 | .042854 | .024791 | -.004525 | .000884 | .013609 | .002582 |
| 12 | .261925 | .968634 | .013833 | .003049 | .042432 | .024904 | -.004614 | .000827 | .013814 | .002586 |
| 13 | .261835 | .968655 | .013807 | .003019 | .042144 | .02495 | -.004441 | .000782 | .013849 | .002595 |
| 14 | .261654 | .968699 | .013626 | .002993 | .042423 | .024962 | -.004742 | .000742 | .013573 | .002604 |
| 15 | .261574 | .96872 | .013559 | .002966 | .042173 | .025 | -.004637 | .00071 | .013804 | .002605 |

(1) irfname = vec1, impulse = HCPI, and response = HCPI
(2) irfname = vec1, impulse = lnTotal, and response = HCPI
(3) irfname = vec1, impulse = ind_production, and response = HCPI
(4) irfname = vec1, impulse = service, and response = HCPI
(5) irfname = vec1, impulse = term_premium, and response = HCPI

**Table 7: Results of orthogonalized impulse–response functions and Cholesky forecast-error variance decompositions per step for each combination with HCPI as response variable. The first column indicates the time since impulse. Combinations of impulse and response variables are numbered. They are then defined at the bottom of the table.**

## Appendix B6

Lagrange-multiplier test

| lag | chi2 | df | Prob > chi2 |
|---|---|---|---|
| 1 | 48.4563 | 25 | 0.00329 |
| 2 | 23.7644 | 25 | 0.53302 |
| 3 | 43.4253 | 25 | 0.01257 |
| 4 | 23.0704 | 25 | 0.57345 |
| 5 | 19.9884 | 25 | 0.74743 |
| 6 | 27.6078 | 25 | 0.32622 |

H0: no autocorrelation at lag order

**Table 8: Lagrange-multiplier test for autocorrelation. The null hypothesis is that there is no autocorrelation at this lag order. Thus, for lag order four no autocorrelation problem exists.**

Jarque-Bera test

| Equation | chi2 | df | Prob > chi2 |
|---|---|---|---|
| D_HCPI | 1.297 | 2 | 0.52296 |
| D_lnTotal | 496.576 | 2 | 0.00000 |
| D_ind_production | 2.113 | 2 | 0.34774 |
| D_service | 0.416 | 2 | 0.81212 |
| D_term_premium | 32.908 | 2 | 0.00000 |
| ALL | 533.308 | 10 | 0.00000 |

**Table 9: Jarque–Bera statistic to test for normality. The null hypothesis is that the disturbances for that particular equation are normally distributed. Each row represents a different equation. The variable given is the dependent variable. The last row tests for all equations jointly, whether the K disturbances come from a K-dimensional normal distribution. The single-equation explaining HCPI does not reject the null of a univariate normal distribution.**

Eigenvalue stability condition

| Eigenvalue | Modulus |
|---|---|
| 1 | 1 |
| 1 | 1 |
| 1 | 1 |
| 1 | 1 |
| .7982813 | .798281 |
| -.3669855 + .6596153i | .754832 |
| -.3669855 - .6596153i | .754832 |
| -.6332177 + .2704387i | .68855 |
| -.6332177 - .2704387i | .68855 |
| .4984401 + .4654976i | .682005 |
| .4984401 - .4654976i | .682005 |
| .05760531 + .6275091i | .630148 |
| .05760531 - .6275091i | .630148 |
| .6219217 | .621922 |
| .2495915 + .5578558i | .611146 |
| .2495915 - .5578558i | .611146 |
| -.2604712 + .5283711i | .589085 |
| -.2604712 - .5283711i | .589085 |
| .5371687 | .537169 |
| -.5284337 | .528434 |

The VECM specification imposes 4 unit moduli.

**Table 10: Test for eigenvalue stability. The model consists of five variables. The test proposes the existence of four unit moduli confirming that a rank of one (5-4=1) is appropriate for this model and that the cointegrating equation is stationary.**

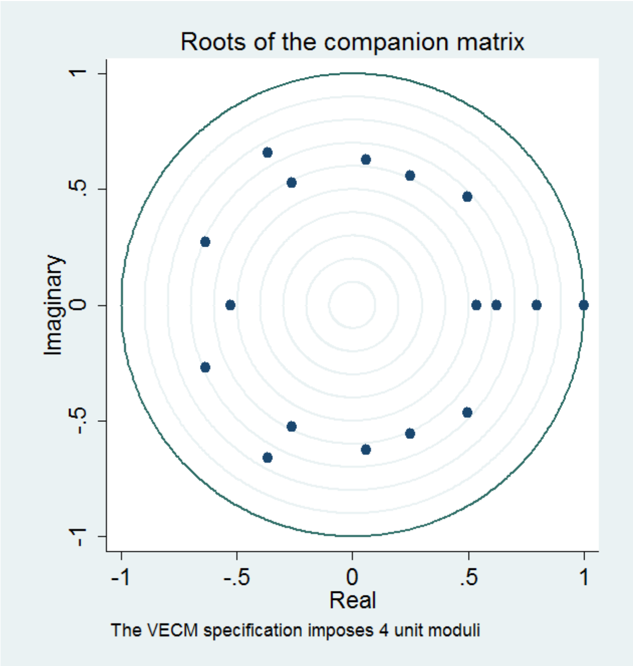


**Figure 11: Eigenvalues of the companion matrix with the real component on the x axis and the imaginary component on the y axis. Four eigenvalues lie on the unit circle while the others are not close to it. This confirms the existence of one cointegrating relation.**

# Appendix C

## Appendix C1

Selection-order criteria
Sample: 2006m5 - 2018m2 Number of obs = 142

| lag | LL | LR | df | p | FPE | AIC | HQIC | SBIC |
|---|---|---|---|---|---|---|---|---|
| 0 | -1752 | | | | 38448.9 | 24.7465 | 24.7888 | 24.8505 |
| 1 | -534.32 | 2435.4 | 25 | 0.000 | .001948 | 7.94817 | 8.20193* | 8.57264* |
| 2 | -507.331 | 53.978 | 25 | 0.001 | .001897 | 7.92016 | 8.38538 | 9.06502 |
| 3 | -476.816 | 61.03 | 25 | 0.000 | .001761 | 7.84248 | 8.51917 | 9.50774 |
| 4 | -447.174 | 59.285* | 25 | 0.000 | .001659* | 7.77709* | 8.66525 | 9.96274 |

Endogenous: HCPI lnTotal ind_production service term_premium
Exogenous: _cons

**Table 11: Likelihood-ratio test, final prediction error (FPE), Akaike's information criterion (AIC), Schwarz's, Hannan and Quinn information criterion (HQIC) and Bayesian information criterion (SBIC) lag-order selection statistics for the extended data sample. The * indicates which lag length should be selected when choosing this criterion.**

## Appendix C2

Johansen tests for cointegration

Trend: constant Number of obs = 142

Sample: 2006m5 - 2018m2 Lags = 4

| maximum rank | parms | LL | eigenvalue | trace statistic | 5% critical value |
|---|---|---|---|---|---|
| 0 | 80 | -499.40688 | . | 104.4663 | 68.52 |
| 1 | 89 | -468.67227 | 0.35136 | 42.9971* | 47.21 |
| 2 | 96 | -456.17977 | 0.16134 | 18.0121 | 29.68 |
| 3 | 101 | -449.20724 | 0.09354 | 4.0670 | 15.41 |
| 4 | 104 | -447.41408 | 0.02494 | 0.4807 | 3.76 |
| 5 | 105 | -447.17374 | 0.00338 | | |

| maximum rank | parms | LL | eigenvalue | max statistic | 5% critical value |
|---|---|---|---|---|---|
| 0 | 80 | -499.40688 | . | 61.4692 | 33.46 |
| 1 | 89 | -468.67227 | 0.35136 | 24.9850 | 27.07 |
| 2 | 96 | -456.17977 | 0.16134 | 13.9451 | 20.97 |
| 3 | 101 | -449.20724 | 0.09354 | 3.5863 | 14.07 |
| 4 | 104 | -447.41408 | 0.02494 | 0.4807 | 3.76 |
| 5 | 105 | -447.17374 | 0.00338 | | |

**Table 12: Johansen's trace statistic test and maximum-eigenvalue statistics to determine the number of cointegrating relations for the extended data sample. The * indicates that the trace statistics would select rank one at a significance level of 5%. The maximum eigenvalue statistics would suggest choosing a rank of one as well, as the statistics for rank one are less than the 5% critical value.**

## Appendix C3

One cointegrating relation could be found:

$$HCPI = +1.767788lnTotal + 1.74503ind\_production - 0.5099094service - 2.211674term\_premium - 43.33532$$

where all of the coefficients are significant at the 5% level. The error correction terms were predicted as follows:

$$\hat{\alpha}' = \begin{bmatrix} -0.0064411 & 0.0833308 & 0.054835 & 0.0219264 & -0.0018314 \\ (0.034) & (0.000) & (0.005) & (0.591) & (0.695) \end{bmatrix}$$

with the t-statistics in parentheses beneath. In the long-run equilibrium a 1% increase in the natural logarithm of securities purchased for monetary purposes is associated with a 1.77% increase in HCPI ceteris paribus. Converted into actual asset purchases in Euro million, an increase in these purchases would induce an increase in HCPI by approximately 0.02%. Ceteris paribus a 2% annual inflation rate solely driven by asset purchases would require to increase purchases by 100%. This number seems to be more reasonable but still needs to be regarded with caution as indirect influences through the other variables are not considered. The error correction term for HCPI is negative and significant. Thus, the previous month's deviations from the long-run equilibrium are corrected for within the current month at a convergence speed of 0.64%. Cumulated asset purchases and the industrial production index have a significantly positive error correction term of 8.3% and 5.5% respectively. All other variables do not have a significant dynamic adjustment to the equilibirium. The predicted constants, incorporating the linear time trend in levels, are displayed beneath (with the t-statistics in parentheses beneath):

$$\hat{v} = \begin{bmatrix} 0.078051 & 0.0674198 & -0.2324246 & 0.3464092 & -0.0186022 \\ (0.000) & (0.376) & (0.065) & (0.184) & (0.533) \end{bmatrix}$$

The p-values for joint short-run effects of all lags of a specific variable are displayed in Table 13. At a significance level of 5% in the short-run HCPI is caused by its own lagged values as well as the constant. The natural logarithm of cumulated asset purchases is significantly caused by the lagged values of the industrial production and the service turnover index. The industrial production index is influenced by the lagged values of itself. In the short-run the term premium is significantly caused by the lagged values of the industrial production index and the service turnover index. The individual short-run coefficients of each lagg seperately are displayed in Table 14 beneath.

| | *D.HCPI* | *D.lnTotal* | *D.ind_production* | *D.service* | *D.term_premium* |
|---|---|---|---|---|---|
| *lagged HCPI* | 0.0009 | 0.2351 | 0.1004 | 0.5320 | 0.6752 |
| *lagged lnTotal* | 0.4951 | 0.6299 | 0.4124 | 0.8806 | 0.7609 |
| *lagged ind_production* | 0.4814 | 0.0000 | 0.0398 | 0.1211 | 0.0034 |
| *lagged service* | 0.3673 | 0.0020 | 0.3400 | 0.2586 | 0.0466 |
| *lagged term_premium* | 0.0582 | 0.4420 | 0.2479 | 0.9547 | 0.5880 |

**Table 13: P-values for joint short-run effects of lagged variables for the extended data sample. The first row gives the dependent variables while the first column names the lagged independent variables. Each p-value represents a separate test. Tests were performed after running the VEC model. The significance of joint short-run effects of all lags of one independent variable together on the first difference of the dependent variable were tested.**

| | D.HCPI | D.lnTotal | D.ind_production | D.service | D.term_premium |
|---|---|---|---|---|---|
| LD.HCPI | 0.3242625 | 0.6185426 | 0.9816762 | -0.2667505 | -0.0112621 |
| | (0.000) | (0.080) | (0.093) | (0.825) | (0.935) |
| L2D.HCPI | 0.0621099 | 0.0293357 | 0.3325497 | -0.0324771 | -0.1025027 |
| | (0.525) | (0.939) | (0.599) | (0.980) | (0.494) |
| L3D.HCPI | -0.0888579 | 0.162385 | 0.5157916 | -1.598807 | 0.1626993 |
| | (0.323) | (0.645) | (0.375) | (0.185) | (0.239) |
| LD.lnTotal | 0.0295499 | -0.0373719 | -0.1238342 | -0.1737715 | -0.0129609 |
| | (0.148) | (0.640) | (0.349) | (0.525) | (0.679) |
| L2D.lnTotal | -0.011408 | -0.0755395 | 0.1880136 | -0.0680687 | 0.0070581 |
| | (0.560) | (0.325) | (0.138) | (0.795) | (0.814) |
| L3D.lnTotal | -0.003477 | -0.0458497 | -0.0408128 | -0.1079396 | 0.0284051 |
| | (0.861) | (0.556) | (0.751) | (0.686) | (0.353) |
| LD.ind_production | 0.0067949 | 0.1049122 | -0.0510103 | -0.0282676 | -0.0733378 |
| | (0.683) | (0.107) | (0.635) | (0.899) | (0.004) |
| L2D.ind_production | 0.0246682 | 0.3106223 | 0.1434158 | -0.1807974 | -0.0619342 |
| | (0.131) | (0.000) | (0.175) | (0.409) | (0.014) |
| L3D.ind_production | 0.0088439 | 0.1374259 | 0.3194619 | 0.5149937 | -0.0133227 |
| | (0.628) | (0.054) | (0.007) | (0.035) | (0.634) |
| LD.service | 0.0053869 | -0.0081106 | 0.0467374 | -0.212563 | 0.0278713 |
| | (0.530) | (0.809) | (0.400) | (0.065) | (0.034) |
| L2D.service | -0.0023475 | -0.1135907 | 0.0723503 | 0.0262297 | 0.0285153 |
| | (0.785) | (0.001) | (0.193) | (0.820) | (0.030) |
| L3D.service | -0.014176 | -0.0834673 | 0.0789266 | -0.024947 | -0.0044203 |
| | (0.100) | (0.013) | (0.157) | (0.829) | (0.738) |
| LD.term_premium | 0.1449019 | 0.1073881 | -0.098294 | 0.4444261 | -0.0711403 |
| | (0.015) | (0.646) | (0.799) | (0.578) | (0.437) |
| L2D.term_premium | 0.0563591 | -0.2847987 | -0.4412557 | -0.0496315 | 0.0756619 |
| | (0.351) | (0.229) | (0.259) | (0.951) | (0.415) |
| L3D.term_premium | 0.0667091 | -0.2507157 | -0.695553 | -0.0449691 | -0.0519077 |
| | (0.265) | (0.285) | (0.073) | (0.955) | (0.572) |

**Table 14: Short-run coefficients of each lag of the independent variable individually for the extended data sample (with the p-values in parentheses beneath). The first row gives the dependent variables while the first column names the lags of independent variables. LD is the first lag of the variable in first differences but the second lag in levels.**

## Appendix C4

Results from vec1

| step | (1) oirf | (1) fevd | (2) oirf | (2) fevd | (3) oirf | (3) fevd | (4) oirf | (4) fevd |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | -.074006 | 0 | -.060583 | 0 | .002564 | 0 |
| 1 | .023079 | 0 | -.198157 | .005543 | -.167868 | .000866 | .000181 | .000118 |
| 2 | .021014 | .008016 | -.096926 | .022581 | -.171202 | .004698 | .015869 | .000061 |
| 3 | .021716 | .007623 | -.21375 | .015925 | -.233835 | .006466 | .028818 | .001472 |
| 4 | .024611 | .007361 | -.254977 | .016793 | -.300605 | .008792 | .033351 | .004417 |
| 5 | .028501 | .007613 | -.2817 | .019839 | -.199761 | .012499 | .03467 | .006678 |
| 6 | .029917 | .008228 | -.326052 | .022306 | -.263523 | .012332 | .039495 | .008264 |
| 7 | .02969 | .00864 | -.340944 | .02537 | -.258609 | .013171 | .0462 | .009957 |
| 8 | .026928 | .008758 | -.345395 | .028376 | -.262586 | .013923 | .047571 | .012202 |
| 9 | .025904 | .008489 | -.367282 | .030824 | -.274021 | .014516 | .049298 | .014131 |
| 10 | .024717 | .008166 | -.370048 | .033575 | -.271697 | .015115 | .049948 | .015899 |
| 11 | .023342 | .00781 | -.370212 | .036235 | -.263025 | .015619 | .050453 | .017477 |
| 12 | .02204 | .007441 | -.371633 | .038648 | -.271565 | .015911 | .050977 | .018908 |
| 13 | .020786 | .00708 | -.366704 | .040963 | -.267864 | .016257 | .050946 | .020234 |
| 14 | .01968 | .006737 | -.362406 | .043088 | -.266457 | .016539 | .050323 | .021431 |
| 15 | .018991 | .00642 | -.359005 | .045021 | -.266741 | .016762 | .04984 | .022465 |

(1) irfname = vec1, impulse = lnTotal, and response = HCPI
(2) irfname = vec1, impulse = lnTotal, and response = ind_production
(3) irfname = vec1, impulse = lnTotal, and response = service
(4) irfname = vec1, impulse = lnTotal, and response = term_premium

**Table 15: Results of orthogonalized impulse–response functions and Cholesky forecast-error variance decompositions per step for each combination with lnTotal as impulse variable for the extended data sample. The first column indicates the time since impulse. Combinations of impulse and response variables are numbered. They are then defined at the bottom of the table.**

## Appendix C5

Results from vec1

| step | (1) oirf | (1) fevd | (2) oirf | (2) fevd | (3) oirf | (3) fevd | (4) oirf | (4) fevd | (5) oirf | (5) fevd |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .153608 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | .203053 | 1 | .023079 | 0 | .014092 | 0 | .002182 | 0 | .029715 | 0 |
| 2 | .238643 | .975634 | .021014 | .008016 | .038615 | .002989 | .002856 | .000072 | .049549 | .013289 |
| 3 | .247717 | .952932 | .021716 | .007623 | .041903 | .013222 | -.015962 | .000101 | .069139 | .026121 |
| 4 | .253977 | .932402 | .024611 | .007361 | .060407 | .017542 | -.01354 | .001363 | .064218 | .041332 |
| 5 | .259801 | .918959 | .028501 | .007613 | .079517 | .026326 | -.011106 | .001674 | .061881 | .045429 |
| 6 | .272761 | .9054 | .029917 | .008228 | .091688 | .038549 | -.009206 | .00165 | .056675 | .046174 |
| 7 | .281129 | .895359 | .02969 | .00864 | .107803 | .050163 | -.00949 | .001515 | .056125 | .044324 |
| 8 | .289113 | .884364 | .026928 | .008758 | .121618 | .063124 | -.00843 | .001414 | .054873 | .04234 |
| 9 | .2937 | .873634 | .025904 | .008489 | .130815 | .07632 | -.006963 | .001298 | .055318 | .040259 |
| 10 | .297844 | .863688 | .024717 | .008166 | .140264 | .088408 | -.003374 | .001175 | .054063 | .038563 |
| 11 | .300861 | .854333 | .023342 | .00781 | .146473 | .099897 | -.000952 | .001034 | .054251 | .036926 |
| 12 | .303131 | .845928 | .02204 | .007441 | .150243 | .11016 | .000839 | .000911 | .054291 | .03556 |
| 13 | .303931 | .838696 | .020786 | .00708 | .153165 | .118999 | .002423 | .000813 | .054799 | .034412 |
| 14 | .304214 | .832332 | .01968 | .006737 | .154299 | .126697 | .003795 | .000737 | .05517 | .033497 |
| 15 | .303875 | .826916 | .018991 | .00642 | .154237 | .133217 | .004906 | .000681 | .055628 | .032764 |

(1) irfname = vec1, impulse = HCPI, and response = HCPI
(2) irfname = vec1, impulse = lnTotal, and response = HCPI
(3) irfname = vec1, impulse = ind_production, and response = HCPI
(4) irfname = vec1, impulse = service, and response = HCPI
(5) irfname = vec1, impulse = term_premium, and response = HCPI

**Table 16: Results of orthogonalized impulse–response functions and Cholesky forecast-error variance decompositions per step for each combination with HCPI as response variable for the extended data sample. The first column indicates the time since impulse. Combinations of impulse and response variables are numbered. They are then defined at the bottom of the table.**

## Appendix C6

Lagrange-multiplier test

| lag | chi2 | df | Prob > chi2 |
|---|---|---|---|
| 1 | 27.5231 | 25 | 0.33027 |
| 2 | 34.0058 | 25 | 0.10778 |
| 3 | 29.6914 | 25 | 0.23605 |
| 4 | 25.7441 | 25 | 0.42135 |
| 5 | 23.9075 | 25 | 0.52473 |
| 6 | 45.2319 | 25 | 0.00787 |

H0: no autocorrelation at lag order

**Table 17: Lagrange-multiplier test for autocorrelation in the residuals for the extended data sample. The null hypothesis is that there is no autocorrelation at this lag order. Thus, for lag order four no autocorrelation problem exists.**

Jarque-Bera test

| Equation | chi2 | df | Prob > chi2 |
|---|---|---|---|
| D_HCPI | 0.073 | 2 | 0.96411 |
| D_lnTotal | 1.7e+04 | 2 | 0.00000 |
| D_ind_production | 6.360 | 2 | 0.04158 |
| D_service | 299.211 | 2 | 0.00000 |
| D_term_premium | 80.277 | 2 | 0.00000 |
| ALL | 1.7e+04 | 10 | 0.00000 |

**Table 18: Jarque–Bera statistic to test for normality for the extended data sample. The null hypothesis is that the disturbances for that particular equation are normally distributed. Each row represents a different equation. The variable given is the dependent variable. The last row tests for all equations jointly, whether the K disturbances come from a K-dimensional normal distribution. The single-equation explaining HCPI does not reject the null of a univariate normal distribution.**

Eigenvalue stability condition

| Eigenvalue | Modulus |
|---|---|
| 1 | 1 |
| 1 | 1 |
| 1 | 1 |
| 1 | 1 |
| .8337899 + .179655*i* | .852925 |
| .8337899 - .179655*i* | .852925 |
| -.4199469 + .5928708*i* | .726534 |
| -.4199469 - .5928708*i* | .726534 |
| .2284854 + .6383777*i* | .678035 |
| .2284854 - .6383777*i* | .678035 |
| -.6431667 | .643167 |
| .5916392 | .591639 |
| -.5386235 + .01817602*i* | .53893 |
| -.5386235 - .01817602*i* | .53893 |
| .4233397 + .3030613*i* | .520637 |
| .4233397 - .3030613*i* | .520637 |
| .0159563 + .4775403*i* | .477807 |
| .0159563 - .4775403*i* | .477807 |
| -.1622857 + .2198704*i* | .273276 |
| -.1622857 - .2198704*i* | .273276 |

The VECM specification imposes 4 unit moduli.

**Table 19: Test for eigenvalue stability for the extended data sample. The model consists of five variables. The test proposes the existence of four unit moduli confirming that a rank of one (5-4=1) is appropriate for this model and that the cointegrating equation is stationary.**

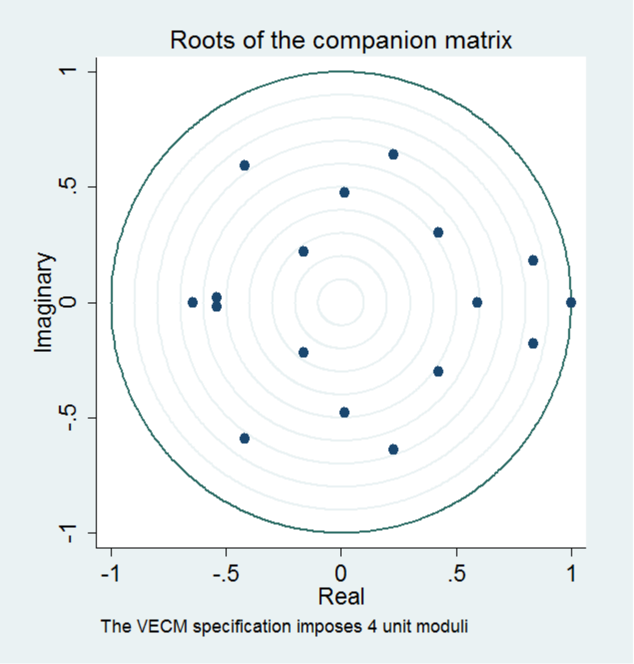


**Figure 12: Eigenvalues of the companion matrix for the extended data sample with the real component on the x axis and the imaginary component on the y axis. Four eigenvalues lie on the unit circle while the others are not close to it. This confirms the existence of one cointegrating relation.**

# Appendix D

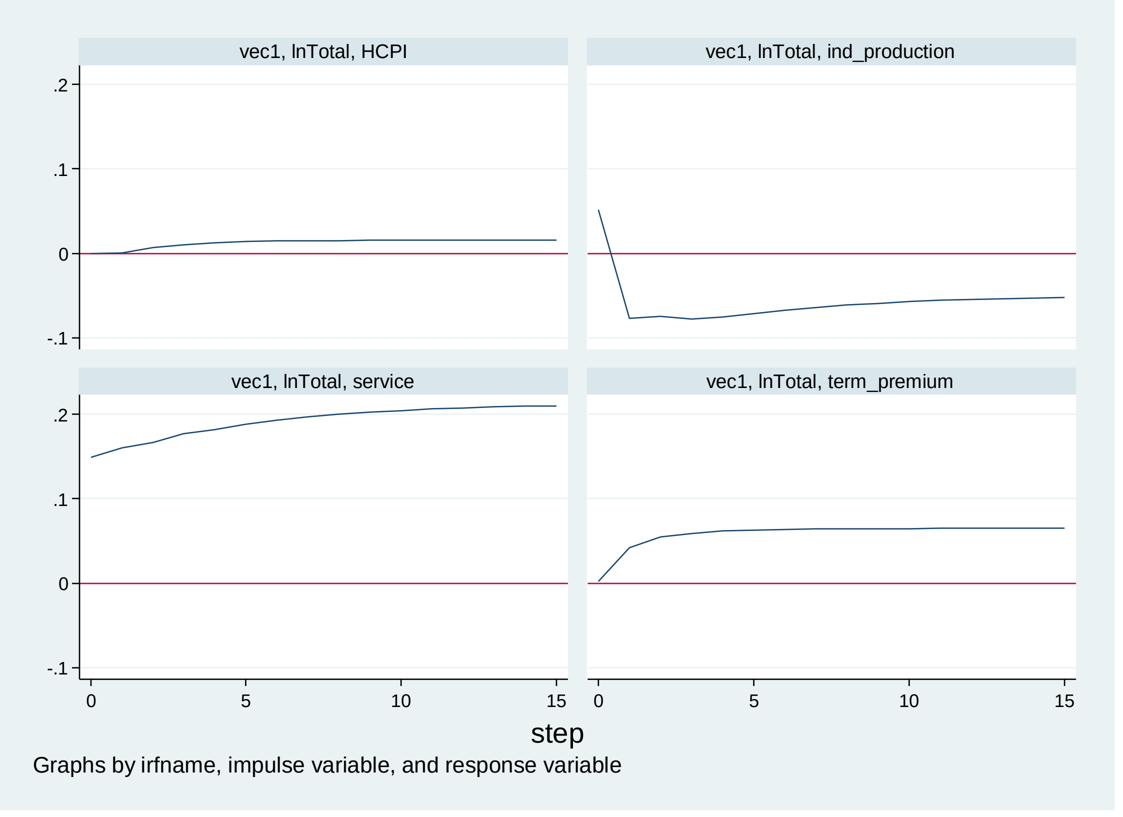


**Figure 13: Orthogonalized impulse response functions with lnTotal as the impulse variable and HCPI, ind_production, service and term_premium as the response variables for the VEC model with lag length two**

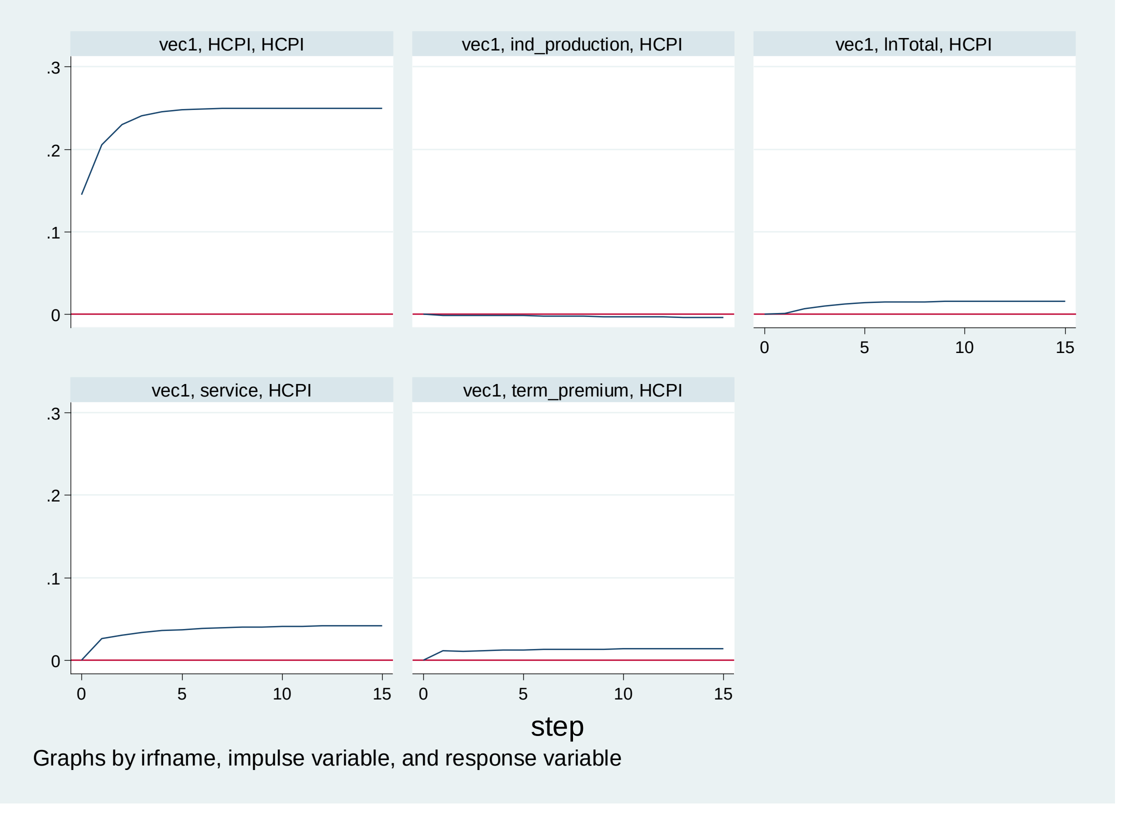


**Figure 14: Orthogonalized impulse response functions with HCPI, ind_production, lnTotal, service and term_premium as the impulse variables and HCPI as the response variable for the VEC model with lag length two**

## Appendix E

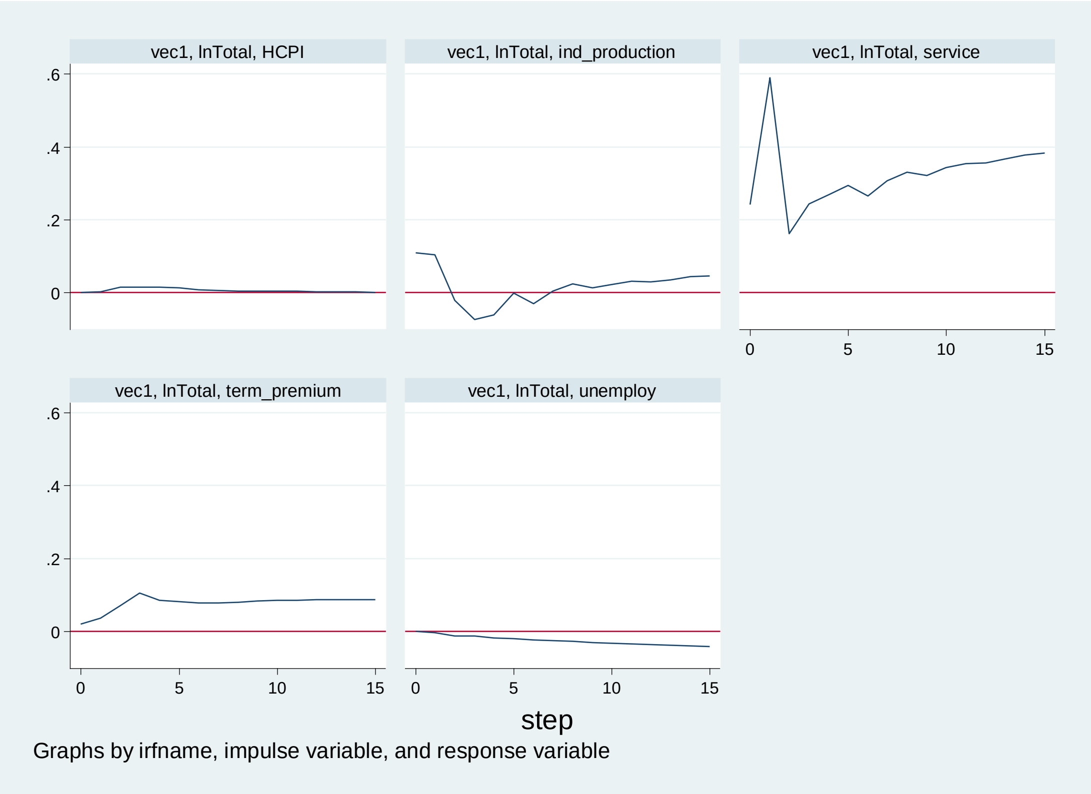


**Figure 15: Orthogonalized impulse response functions with lnTotal as the impulse variable and HCPI, ind_production, service, term_premium and unemploy as the response variables for the VEC model containing the unemployment rate**

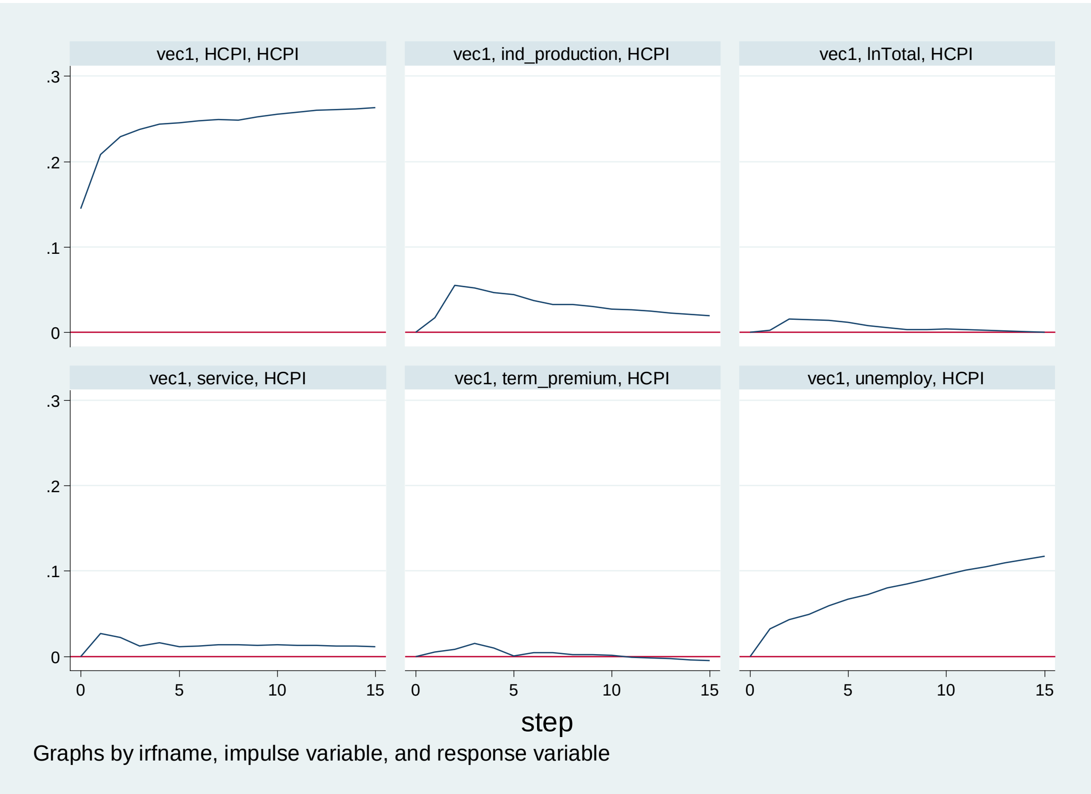


**Figure 16: Orthogonalized impulse response functions with HCPI, ind_production, lnTotal, term_premium and unemploy as the impulse variables and HCPI as the response variable variables for the VEC model containing the unemployment rate**

## Abstract

Quantitative easing has been the subject of heated discussions for some years now. The objective of this master thesis is to investigate the effectiveness of European and US-American quantitative easing programs and to compare them. Effectiveness is defined as reaching a persistent inflation rate of slightly below 2%. Thus, this thesis aims at answering the question whether quantitative easing programs in the euro area and in the US have contributed to reaching this target. Empirical literature was analyzed to determine the effects of the programs implemented by the Federal Reserve System. These programs were terminated already and the full impact should be visible in most current studies. The consequences of the still active European Central Bank's programs is determined by applying a vector error correction model on most current figures. Furthermore, the effects of different transmission channels are examined by analyzing and comparing empirical literature. In general, US-American programs seem to have a more sizeable impact on financial and macroeconomic variables. This may be explained by the fact that the US-American programs were implemented at times of high financial stress, when quantitative easing is said to unfold its full impact. Secondly, trust issues and dispersion in the banking system of the euro area may have contributed to the limited effects of local large-scale asset purchase programs.

## Zusammenfassung

Quantitative Easing hat in den letzten Jahren für hitzige Diskussionen gesorgt. Das Ziel dieser Masterarbeit ist es die Effektivität von US-amerikanischen und europäischen quantitative Easing Programmen zu beurteilen und diese zu vergleichen. Wirksamkeit wird in dieser Arbeit als das Erreichen einer Inflationsrate von knapp unter 2% definiert. Folglich soll in dieser Masterarbeit beantwortet werden, ob Quantitative Easing Programme in den USA und in der Eurozone zum Erreichen dieses Richtwertes beigetragen haben. Empirische Literatur wird analysiert um die Effekte der Programme zu bestimmen, welche vom Federal Reserve System implementiert wurden. Diese Programme wurden bereits beendet und die vollständige Wirkung sollte in den aktuellsten Studien sichtbar sein. Auswirkungen der Programme der Europäischen Zentralbank werden mit Hilfe eines Vector Error Correction Modelles untersucht. Zusätzlich werden die Effekte der verschiedenen Wirkungskanäle des Quantitative Easings durch eine Literaturanalyse bestimmt. Generell lässt sich sagen, dass die Wirkung der US-amerikanischen Programme bedeutender ist. Das lässt sich zum Teil dadurch erklären, dass diese Programme implementiert wurden, als die finanzielle Anspannung sich noch nicht gelockert hatte. Quantitative Easing soll jedoch die größten Auswirkungen in Zeiten von finanzieller Notlage haben. Fehlendes Vertrauen in das Finanzsystem der Eurozone und Ungleichheiten in ihren Mitgliederstaaten könnten weitere Gründe sein, die zur bescheideneren Wirkung in Europa beigetragen haben.

## Ehrenwörtliche Erklärung

Hiermit versichere ich an Eides Statt, dass ich die vorliegende Arbeit selbstständig und ohne die Benutzung anderer als der angegebenen Hilfsmittel angefertigt habe. Alle Stellen, die wörtlich oder sinngemäß aus veröffentlichten und nicht veröffentlichten Schriften entnommen wurden, sind als solche kenntlich gemacht. Die Arbeit ist in gleicher oder ähnlicher Form oder auszugsweise im Rahmen einer anderen Prüfung noch nicht vorgelegt worden.

Unterschrift

Telfs, 31.07.2018
Eva Kranebitter