Fiscal Consolidation and Unconventional Monetary Policy, an Awkward Combination

An empirical analysis of the impact of the fiscal policies in the eurozone on the effectiveness of the unconventional monetary policy pursued by the ECB between 2009 and 2018.

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Abstract

I investigate the impact of fiscal policy on the effectiveness of unconventional monetary policy conducted between 2009 and 2018. I do this firstly by estimating the effectiveness of unconventional monetary policy using a Structural Vector Autoregressive (SVAR) model and secondly by making this model of monetary policy conditional on fiscal policy in a Vector Autoregression with exogenous variables (VARX). Using both a recursive and sign restrictions identification strategy to identify unconventional monetary policy shocks, I find that unconventional monetary policy has been successful in raising output and inflation. When including fiscal policy as an exogenous variable, I find that fiscal policy, which was mostly consolidative during this time period, has halved the peak inflation response of unconventional monetary policy but has not affected the peak output response in an economically relevant way.

Keywords: Monetary policy, fiscal policy, VAR model, SVAR model, VARX model, effectiveness

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1. Introduction

Since the outbreak of the financial crisis in 2008, the ECB has implemented extremely loose monetary policy. It has gradually lowered its policy rates to zero and below and has been conducting asset purchasing programmes buying up to 80 billion of assets each month between 2015 and 2018. With a short hiatus in between, the ECB is currently buying 20 billion of assets each month.

Despite the monetary stimulus, the economic performance in the eurozone has been mediocre. Economic growth has been slow with only 0,88% average year-on-year growth (own calculations) and unemployment is much higher than in the US and Japan (Eurostat, 2020). On top of that, inflation has consistently missed the ECB's inflation target since the outbreak of the global financial crisis. Only since 2018, inflation is close but below 2%, as the ECB is aiming for. This was short lived, however, as inflation dropped as soon as the ECB temporarily stopped its asset purchasing programme.

The fact that the loose monetary policy was not able to increase inflation to the desired level and lift the eurozone out of its mediocre growth path might be explained by the austerity measures that were implemented by eurozone governments at the same time. Following the global financial crisis, many eurozone governments were stuck with excessive debt levels which needed to be addressed. Encouraged by the European institutions and the common budget rules, countries either voluntarily or forcedly, cut their spending. These fiscal policies had a serious impact on economic growth in the eurozone and left the ECB with a counterproductive fiscal environment to conduct its monetary policy operations in.

Despite the prevailing view that monetary and fiscal policy should each focus on achieving distinct goals, fiscal and monetary policies do not work completely independently from each other. Rather, they can reinforce or obstruct each other. In the case of fiscal policy, it has been found that fiscal policies are more effective under the effective lower bound (ELB) than under normal circumstances (Eggertson, 2011; Christiano, Eichenbaum & Rebelo, 2011; Bonam, de Haan & Soederhuizen, 2017). Vice versa, fiscal policy affects monetary policy outcomes through the effect that fiscal policy has on aggregate demand, the interest rate and inflation (Tran, 2019; Fontana, Pacella & Realfonzo, 2017).

In this thesis, I want to empirically test the impact of the fiscal policies on the effectiveness of monetary policy between 2009 and 2018. My research question is as follows: What has been the impact of the consolidative fiscal policies in the eurozone on the effectiveness of unconventional monetary policy (UMP) implemented by the ECB?

To find an answer to my research question, I will firstly estimate a structural vector autoregressive (SVAR) model of UMP transmission to estimate the impact of UMP on inflation and output. In the second step, I will make the monetary policy system I estimated in step one conditional on fiscal policy. This will be done by including the primary balance as an exogenous variable in a vector autoregressive model with unmodelled variables (VARX). The contribution of this thesis to the literature is threefold. Firstly, I estimate the impact of an UMP shock in the eurozone using two identification schemes over a longer time period than any other paper has done so far. Secondly, it is a first step in trying to quantify the impact of austerity on the effectiveness of unconventional monetary policy. Thirdly, by quantifying the impact of fiscal policy on monetary policy effectiveness, I also try to contribute to the understanding of the limited effect of unconventional monetary policy.

My results show that an UMP shock, on average between the two identification schemes, increases output by about 0,12% and inflation by 0,04%. These findings are in line with what has been reported in earlier studies. When I include fiscal policy as an exogenous variable to the model, I find that the peak inflation response is halved whilst the output peak response is affected marginally. This shows that the fiscal policy between 2009 and 2018 has made UMP less effective at increasing inflation. However, it does not provide much evidence to explain the muted overall impact of UMP on output during this same period. This could be due to the fact that I use a general measure of fiscal policy rather than multiple disaggregated measures of fiscal policy that might be better at capturing fiscal policies that directly impact aggregate demand and consumption.

The remainder of this thesis is structured as follows. After the introduction, chapter 2 contains a literature overview, followed by the empirical approach in chapter 3 that contains a general discussion on VAR models and identification schemes. After the general description, I explain how I utilize VAR models and identify shocks. The chapter concludes with a discussion on data related matters. After the empirical approach, the results of the analysis will be presented in chapter 4. Subsequently the results and their implications will be discussed in chapter 5. The thesis is concluded in the sixth and final chapter where a summary of the findings is presented, suggestions for further research are made and weaknesses in the research design are discussed. The chapter ends with a policy suggestion.

2. Literature overview

Because my research question concerns monetary as well as fiscal policy, both will be discussed in the literature overview. Firstly, I will discuss the literature on estimating the impact of monetary policy extensively because answering my research questions stands or falls with a good estimation of the impact of unconventional monetary policy. Because of this reason, the bulk of attention will be devoted to this part of the literature. Secondly, the interactions between monetary policy and fiscal policy will be discussed from both a fiscal policy perspective and a monetary policy perspective. I will devote attention to the literature discussing the impact of monetary policy on the fiscal multiplier because these papers operate in a similar fashion as how I intent to answer my research question with the difference being that I approach the question from the opposite direction.

2.1 History of monetary policy research

The research into the effects of monetary policy on the economy has a long history. During the 1970s and 1980s it was common to measure monetary policy shocks as shocks to the monetary base (Ramey, 2016). Using the monetary base, monetary policy shocks were found to be responsible for substantial output gains. Following the shift in conducting monetary policy, problems arose when the policy rate was added in the analysis. Including interest rates in a then new vector autoregressive (VAR) model, Sims (1980a) found no significant effects of monetary policy on output. The VAR model that Sims (1980b) proposed was a further development of the then prevailing restricted macroeconomic models. Restricted models are linear equation systems where the number of lags in each equation is restricted based on theoretical justifications. However, according to Sims, these restrictions had no real theoretical bearing. The model he proposed, a VAR model, is unrestricted in the sense that the number of lags in each equation that together make up the linear system of equations is equal.

Sims finding, however, led to a temporary dip in the interest in monetary policy as a factor for understanding economic fluctuations (Ramey, 2016). The interest rose again after Romer and Romer (1989), by rigorous labour and by linking monetary policy decisions to industrial production, proved that monetary policy does affect real economic outcomes (Ramey, 2016).

Romer and Romer's (1989) paper became a new starting point for the monetary policy effectiveness literature. However, seeing that the original problem of insignificance of the monetary base in explaining economic fluctuations remained, the focus shifted to correctly specifying the monetary policy function. The monetary policy function is the equation in the

VAR system that models how monetary policy is decided. A new problem that arose at this time was the so-called price puzzle. The price puzzle refers to the contradictory finding in many models that a monetary contraction leads to a short run price increase. Sims (1992), however, argued that this remarkable finding is because the central bank has more information available in determining its policy than the academic models that try to mimic this function. He showed that, by including commodity prices as a proxy for future inflation, the prize puzzle largely disappears (Ramey, 2016).

Christiano, Eichenbaum and Evans (1999) built on all the progress made in identifying monetary policy shocks by using a new recursive identification scheme for the VAR model introduced by Sims (1980b). To measure the effect of a shock in the system to the other variables in the system, an identification scheme must be applied. An identification scheme is a set of restrictions that is imposed on the contemporaneous impact of the variables following a shock in the variable of interest. Identification is necessary, because due to the unrestrictive nature of VAR models, the equations in the system all largely depend on the same variables, making the error terms correlated between equations. By applying an identification strategy to a VAR system, it is common to speak of a Structural VAR (SVAR). Christiano et al. (1999) used an identification strategy that limits the effect on impact of inflation, output and commodity prices following a monetary policy shock. By using this identification scheme, they majorly contributed to the literature because they found both significant output and inflation effects following a contractionary monetary policy shock, regardless of using the policy rate or the monetary base (Ramey, 2016).

Christiano et al. (1999) provided, what turned out to become, a benchmark for further research into the identification of monetary policy shocks in VAR models. Since then, new identification schemes have been introduced. In addition to the recursive identification strategy, sign restrictions have become prominent. Rather than restricting the movement upon impact to zero as in the recursive identification strategy, sign restrictions only impose a positive or negative restriction on the effect at impact. This makes the identification less restrictive and enables the data to speak more. A combination of the two, where some variables are restricted to zero upon impact whilst others are only restricted to be either positive or negative, has also become popular. Identification schemes will be discussed more in depth in the empirical approach chapter.

2.2 UMP transmission channels

Following the profound impact of the global financial crisis, the conduct of monetary policy has shifted. Before the crisis, monetary policy was conducted by altering the policy rate, while nowadays monetary policy is conducted mainly through asset purchasing programmes and other UMP measures. This created a new challenge for identifying the effects of monetary policy shocks and correctly specifying the monetary policy function.

To correctly specify the monetary policy function, the transmission channels of UMP must be identified. Gambetti and Musso (2017) have investigated which transmission channels are activated by UMP. They find evidence for the activation of the portfolio rebalancing channel, the exchange rate channel, the expectations channel, and the credit channel. Unconventional monetary policy transmits to the financial markets through the portfolio rebalancing channel (Altavilla, Carboni & Motto, 2015). Rebalancing happens because quantitative easing (QE) programmes buy up low-risk assets which forces investors to take on more risky equity. Within the larger category of portfolio rebalancing, another smaller channel that is activated is the exchange rate channel (Rogers, Scotti & Wright, 2014). Another channel of UMP is the signalling channel (Altavilla et al., 2015). By committing longer term to a lower inflation term, the central bank signals to the economy that it is determined to increase inflation. To this category of transmission channels belong the inflation expectations and inflation re-anchoring channels. Both these channels function in a similar fashion. By committing to inflationary policies, the central bank can affect inflation expectations of market participants. Finally, the credit channel, which is one of the main channels for conventional policy, functions for UMP as well. The central bank frees up space on the balance sheet of banks by buying up debt assets thereby creating room for supplying loans to the economy.

2.3 Measurement of UMP shocks

Much of the literature's attention has been devoted to correctly identify and estimate the effects of an UMP shock in a VAR setting. Even though UMP has started quite some time ago already, its effect on real economic outcomes is unclear. This is because the effects that are found tend to be small or even negligible, as can be seen in table 1. Moreover, as will be further discussed later, Elbourne (2019) shows that estimations using the central bank balance sheet suffer from the foresight problem rendering the estimations of these studies uncertain. Most studies find a short-term output effect following an UMP shock whilst the effect on inflation manifests on the long-term. Given these results in the literature, Papadamou, Kyriazis and Tzeremes (2018) have conducted a meta study of the empirical results of unconventional monetary policy studies and find that many of the differences in the findings can be attributed to methodological variation.

Table 1 Overview of results of other studies into the effect of UMP in the eurozone

Study	Policy variable	Shock size	Inflation	Output	Data range
Gambacorta et al. (2014)	Balance sheet	3% increase	0,06%-0,11%	0,06%-0,15%	2008-2011
Wieladek & Pascual (2016)	Balance sheet	1% increase	0,075%	0,11%	2012-2016
Boeckx et al. (2017)	Balance sheet	1,5% increase	0,1%	0,1%	2007-2014
Gambetti & Musso (2017)	Balance sheet	-	0,36%	0,18%	2009-2016
Burriel & Galesi (2018)	Balance sheet	1% increase	0,05%	0,1%	2007-2015
Burriel & Galesi (2018)	Shadow rate	25 basis points	0,1%	2,5%	2007-2015
Anttila (2018)	Shadow rate	25 basis points	0,4%	0,2%	2011-2016
Elbourne et al. (2018)	Shadow rate	20 basis points	Negligible	0,05%	2009-2016
Zabala & Prats (2019)	Balance sheet	-	0,02%	-	2007-2018

Gambacorta, Hofmann and Peersman (2014) employ a panel VAR between 2008 and 2011 in the eurozone. In a panel VAR setting, it is possible to estimate the effect on country level rather than on aggregate eurozone level. They use the size of the ECB's balance sheet as a proxy for unconventional monetary policy. They find that a 3% increase in the size of the ECB's balance sheet results in an output increase between 0,06 and 0,15% and an inflation increase between 0,06% and 0,11%.

Wieladek & Pascual (2016) employ a Bayesian VAR model between 2012 and 2016 and use four different identification schemes. In a Bayesian VAR, the estimated coefficients of the variables in the system are treated as random variables and probabilities are assigned to these random variables using a prior. This prior is a probability distribution that expresses the expectations one has about the random variable. Bayesian VARs have become popular because they are better at handling many parameters in relatively short time frames, which is common in macroeconomics. Wieladek & Pascual (2016) find an average (over their four identification schemes) output peak response to a 1% balance sheet shock of 0,11% and for inflation 0,075%.

Boeckx, Dossche & Peersman (2017) use a combination of zero and sign restrictions to identify exogenous unconventional monetary policy shocks between 2007 and 2014 and find a similar result for output and inflation. Both increase with approximately 0,1% following an increase of 1,5% in the size of the balance sheet of the ECB. Gambetti and Musso (2017) use a combination of sign, timing, and magnitude restrictions to identify the UMP shock in 2015. This is a very strictly defined identification strategy that is much more restrictive than what other papers use.

They do this because they do not want to identify UMP shocks in general but are only interested in the impact of the UMP shock of 2015. They find that the UMP shock of 2015 increased output at the peak with 0,18 percentage points and inflation with 0,36 percentage points. The output effect is strongest in the short run and slowly diminishes, whilst the inflation effect becomes stronger as time passes.

Burriel and Galesi (2018) employ a Global VAR model using the same identification scheme as Boeckx et al. (2017). A Global VAR system is a two-step model. Firstly, Burriel & Galesi estimate a VAR model conditional on the global economy in a VARX model. In the second step, all national VARX models are combined in one large regular VAR. They find that output increases with 0,1% and inflation with 0,05% following a 1% increase in the size of the balance sheet.

One problem in identifying exogenous shocks in monetary policy VARs, is the element of foresight. If private agents know that a monetary policy change is coming, they adjust their behaviour following the announcement rendering estimating the shock nearly impossible. Since QE announcements are announced before they start, using the balance sheet as an indicator of UMP suffers from this problem. The shadow rate offers a potential solution to this problem. It is a good proxy of UMP, but it does not suffer from the foresight problem (Elbourne, 2019). It is because of this that Burriel & Galesi (2017) have also done their analysis using the shadow rate as the policy variable rather than the size of the balance sheet. Using the shadow rate, they find that a 25-basis point expansionary shock in the shadow rate increases GDP growth with 2,5% and inflation by 0,1%. Following Burriel & Galesi, other papers have also employed the shadow rate as the policy variable for unconventional monetary policy

Anttila (2018) used the shadow rate in a factor augmented VAR (FAVAR) model between 2009 and 2016. A FAVAR model is yet another version of the regular VAR and emerged as response to the problem of overparameterization in VARs. Also, they emerged as a response to solve the prize puzzle, which Sims(1980b) showed mainly existed because of the inclusion of too little information. FAVARs offer a way around this by including factors to the VAR that contain a lot of information about the wider economy. Anttila (2018) finds that an expansionary shadow rate shock of 25 basis points increases output by 0,2% and inflation by 0,4%.

Elbourne, Ji and Duijndam (2018) use the shadow rate in an SVAR model with zero and sign restrictions. Between 2009 and 2016, they find a peak effect of a 20-basis point shadow rate shock of 0,05% and no significant effect on inflation. They expand their baseline model to the country level by estimating a VARX model with the identified shocks as the exogenous variable. They find a considerable economically significant difference in the effects of UMP in eurozone countries.

Zabala and Prats (2019) estimate an SVAR model between 2007 and 2018 and use short term and long-term restrictions to identify the shocks. Instead of using only conventional or unconventional monetary policy proxy, they include both. They find no significant effect on inflation and only a very temporary small effect on GDP. They perform a robustness analysis by redoing the analysis with the shadow rate as the proxy for unconventional monetary policy but find no difference. This might be explained by the fact that they have included all their variables at first difference which removed important information on the dynamics between the variables (for a further discussion see section 3.5.1).

2.4 Monetary and fiscal interaction literature

Since I am interested in the effect of fiscal policy on the effectiveness of UMP, next to understanding UMP transmission and estimating its impact, a proper understanding of the interactions between monetary and fiscal policy is required. There is a myriad of interactions between monetary and fiscal policies. Consequently, a large body of literature exists that can be largely divided into three categories. This thesis fits within the empirical and data driven studies that employ VAR models to understand the workings of policy interactions. The other two strands are studies that purely conduct a theoretical exercise and studies that seek to find an optimal combination of monetary and fiscal policy. These last two strands will not be further discussed, as they are not relevant for the purpose of this thesis.

2.4.1 Monetary policy affecting fiscal policy effectiveness

The following papers have researched whether the effectiveness of fiscal policy is amplified in an environment where monetary policy is at the ELB. The reason why I discuss these papers is because they function in a similar vein as my thesis. I want to estimate the monetary policy function and measure the impact of a fiscal environment wherein the government cuts spending on monetary policy effectiveness. The following papers estimate the fiscal policy function and want to measure the impact of a monetary policy environment in which the ELB is reached on fiscal policy effectiveness.

The fiscal multiplier is affected by the ELB environment, as several papers using different methodologies have found. When the ELB is reached, the fiscal multiplier can rise above unity (Eggertson, 2011; Christiano et al., 2011; Bonam et al., 2017). There are two mechanisms under the ELB that increase the effectiveness of fiscal policy. Firstly, under normal circumstances, the central bank counters the fiscal expansion by raising interest rates, crowding out domestic private demand and net exports and thereby reducing the output effects of fiscal expansion. The ELB, however, constrains the central bank to increase the interest rate allowing the fiscal expansion to be more effective (Woodford, 2011). Secondly, the fiscal expansion can fill the output gap that might exist because the central bank cannot lower the interest rate below zero (Coenen et al., 2012)

Eggertson (2011) and Christiano et al. (2011) both employ DSGE models to model the effect of the fiscal multiplier under the ELB. DSGE models and VAR models are both macroeconomic models and share similarities. One advantage of DSGE models over VAR models is that DSGE models can incorporate structural change in one part of the economy without making the rest of the model about the remaining part of the economy invalid. Bonam et al. (2017) use a VAR to model the effect of the fiscal multiplier under the ELB. They use a dummy to deal with the structural change. The dummy makes that for periods under the ELB spell a separate VAR is estimated, effectively dealing with inability of VAR models to incorporate structural change.

Furthermore, Eggertson (2011) and Albertini, Poirier and Roulleau-Pasdeloup (2014) find that the type of fiscal policy matters for the interaction with monetary policy. Eggertsson (2011) notes that government spending under the ELB is only more effective when it is used for goods that are imperfect substitutes for private consumption. That is the case because private consumption exactly offsets any effect from government spending in goods that are perfect substitutes. Albertini et al. (2014) show that productive government spending can even decrease the effectiveness of fiscal policy under the ELB. Productive spending decreases real marginal costs and therefore prices. This deflationary effect leads to a higher real interest rate which reduce private consumption, which eventually lowers the fiscal multiplier.

2.3.1 Fiscal policy affecting monetary policy effectiveness

From a monetary policy perspective, fiscal policy can affect the transmission channels of UMP. By affecting aggregate demand, fiscal policy affects the credit channel and high debt levels have the potential to interfere in the expectation channel. Besides impact on transmission channels, fiscal policy is also able to affect monetary policy effectiveness through its impact on the interest rate and inflation.

Fiscal policy impacts the credit channel because fiscal expansions or contractions alter the demand for credit. A fiscal contraction leads to lower current income and higher tax liabilities of households and businesses and limits consumption. Lower consumption translates to lower credit demand which can undermine monetary policy that is dependent on increased credit demand. The effect of fiscal policy on aggregate demand and credit is sometimes downplayed but Blinder (2016) finds that the effect of fiscal policy on consumption is greater than what is often assumed by neoclassical theory. Because fiscal policy affects the demand and supply of credit, it also partly determines the interest rate level in the economy. Another way fiscal policy affects the interest rate is when debt levels rise to such a high level that the creditworthiness of a nation becomes questionable. In that scenario the sovereign risk premium would rise quickly leading to an overall interest rate hike in the economy (Tran, 2019)

The expectations channel is impacted by high debt levels and the potential presence of fiscal dominance. High debt levels can increase the doubts about a nation's creditworthiness and can bring the central bank in the position where its room for manoeuvre is highly limited. In that case, the fiscal authority is dominant over the monetary authority. Fiscal dominance limits the ability of the central bank to control the level of inflation in the economy. That is the case because a monetary expansion would lead to lower interest rates causing even higher debt levels and higher inflation and a monetary contraction would increase the debt refinancing costs, leading to higher debt levels and again higher inflation. When the fiscal authority is dominant over the monetary authority because of too high debt levels, the central bank is not able to credibly commit to any policy. Ahmed, Aizenman & Jinjarak (2019) indeed find that in advanced economies with high debt-to-GDP ratios, the policy rate tends to be lower, indicating the presence of fiscal dominance to some extent.

On a more general level, Fontana et al. (2017) argue that fiscal policy is a necessary condition for monetary policy to have an effect. They argue that a policy change by the central bank will only have real effects if fiscal policy at the same time impacts the demand and supply for credit. If it does not do so, a decrease in the policy rate will have no expansionary effects. Fiscal policy also partly determines the price level in the economy because it affects the employment level and consequently wage and price setting. A fiscal contraction is likely to decrease employment which decreases wages and prices and therefore inflation.

A different theory on prices argues that fiscal policy determines the development of inflation and not monetary policy, the so-called fiscal theory of the price level (Leeper& Leith, 2016). The theory assumes that the intertemporal budget constraint of the government needs to be in equilibrium. This implies that the government is constrained in setting its budget by current and future constraints. The theory further assumes that future budget surpluses are exogenously given. If this is the case, then only the price level can make the future surpluses consistent with inherited debt from the past. This theory thus states that not monetary policy is predominantly responsible for inflation but the interaction between fiscal and monetary policy is.

3. Empirical approach

3.1 Structural Vector Autoregressive Model (SVAR)

To answer my research question, I utilize a structural VAR model. Ever since the introduction of vector autoregressive (VAR) models by Sims in the 1980s, VARs have become extremely popular in analysing the effects of public policy. Before step-by-step explaining how I will use an SVAR model to answer my research question, I will discuss VAR models in general first.

A VAR model is a system of linear equation with *n-variables* and *n-equations.* Each variable is explained using its own lagged values and the lagged values of the other variables in the system. It is for this reason that VAR models can capture dynamic relationships between macroeconomic variables that are indistinguishable for simpler univariate models. The main asset of VAR models is at the same time its main weakness. By aiming to capture the dynamic relationship between variables, a VAR model can quickly become overparameterized. This means that more parameters must be estimated than what the data reasonably can provide. This also means that in the case of monetary policy transmission, a VAR cannot be specified in such a way that it incorporates all the transmission channels. This is the case because the necessary number of variables and lags that would have to be included makes the model overparameterized.

A standard VAR specification is not suitable for policy analysis because of correlated error terms and the absence of contemporaneous relationships. In a standard VAR specification, the error terms are correlated across the equations. This is problematic because it means that it is not possible to shock one variable without incorporating effects of other shocks of other variables too. Secondly, contemporaneous dynamics between variables are not included in the standard VAR specification. Only the lagged values of the $n-1$ variables appear in the $n-$variable equation of a standard VAR. The inclusion of contemporaneous relations is important for policy analysis. For monetary policy for example, the central bank can react immediately to changes in inflation and GDP. Therefore, the contemporaneous values of GDP and inflation must appear, or else the VAR model is not correctly specified.

A VAR model that allows for contemporaneous relationships and has uncorrelated error terms is a structural VAR (SVAR) model. Creating uncorrelated error terms and allowing for contemporaneous relations between variables creates a whole new problem that is not present in regular VAR models. In an SVAR model, restrictions must be imposed on the contemporaneous relationships between the variables and the error terms. This necessity lies in the fact that the covariance matrix of the system (due to it being symmetric) only has $n(n+1)/2$ pieces of information (for a 4x4 matrix, 10 unique pieces of information) whilst the matrix governing the contemporaneous relations and the matrix governing the error terms both have n^2 free parameters.

This process of imposing restrictions on the VAR model is called identification. It is called this way because by imposing restrictions, the shocks in the model can be identified. Identification can be done in multiple ways. One way is to give a recursive structure to the variables in the VAR model. In this recursive ordering strategy, the contemporaneous effects of the variables are restricted. The first ordered variable is contemporaneously only affected by itself and further only by the lagged values of the remaining variables. All the other variables ordered after the first variable only respond contemporaneously to the variables ordered before them and with a lag to the variables ordered after it. The last variable in the system is the only variable that responds to *all* the other variables contemporaneously. Since the effect of a shock is completely different for every ordering, the structure given to the model must be motivated by theory.

Zero restrictions are similar to the recursive ordering in that they limit the contemporaneous responses in the system. The difference is that zero restrictions can be imposed regardless of the structure. Zero restrictions do, however, still need to adhere to the required minimum number of restrictions. In the extreme case where zero restrictions are imposed on all the variables, the SVAR effectively becomes a standard VAR without contemporaneous responses. Sign restrictions are less invasive because they do not impose a strict zero limitation on the contemporaneous effects. Rather, sign restrictions only impose a positive or negative condition on the contemporaneous effect. In the monetary policy effectiveness literature, zero and sign restrictions are often combined (see Gambacorta et al. 2014; Boeckx et al., 2017; Burriel & Galesi, 2018). By imposing a zero restriction on the contemporaneous impact but only a sign restriction on the further response of the variables, the model is less restricted but still in line with theory. The reason for this is that it is commonly accepted that monetary policy only affects GDP and inflation with a lag. This is a reasonable assumption as it is unlikely that prices and output react within the month to changes in monetary policy.

3.2 Baseline model

The structural VAR model that I use in my analysis as the baseline model looks as follows

$$AY_t = c_0 + Z_1 Y_{t-1} + \cdots + Z_p Y_{t-p} + Bu_t \tag{1}$$

Where y_t is an $n \times 1$ vector containing the endogenous variables that are included in the baseline model at month t. The variables that are included are real GDP, inflation, a measure of sovereign stress, the shadow rate, and the money market spread defined as the spread between the Euro OverNight Index Average (EONIA) rate and the main refinancing operations (MRO) rate. c_0 is a vector that contains the constant term. A is a $n \times n$ matrix governing the contemporaneous relationships between the variables and B a $n \times n$ matrix that governs the shocks. u_t are the structural form error terms with mean zero and covariance matrix $\sum$. Finally, Z_p is a $n \times n$ matrix that contains the estimated coefficients. The number of lags to include in the model is determined by the Akaike information criterion (AIC) and is set at one. Although one is also the minimum number of lags to include in order to specify a VAR model, it is sufficient to apply the identification strategy and therefore accepted.

To estimate the model, the model described above must first be transformed to the reduced form. This means shifting all the contemporaneous effects to the left so that each equation is expressed as a function of the contemporaneous and lagged values of the other endogenous variables. The reduced from looks as follows

$$Y_t = A^{-1}c_0 + A^{-1}Z_1 y_{t-1} + \cdots + A^{-1}Z_p Y_{t-p} + A^{-1}Bu_t \tag{2}$$

Where a simplification leads to the equation

$$Y_t = k_0 + A^* Y_{t-1} + \cdots + A^* Y_{t-p} + \varepsilon_t \tag{3}$$

$$k_0 = A^{-1}c_0 \tag{4}$$

$$A^* = A^{-1}Z_t \tag{5}$$

$$R^* = A^{-1}R_t \tag{6}$$

$$\varepsilon_t = A^{-1}Bu_t \tag{7}$$

3.3 Identification strategy

3.3.1 Recursive identification

In the reduced form, the error terms are a linear function of the structural error terms. This means that a shock to the reduced form error cannot be taken as a structural shock. The reduced form errors are related to the structural errors as can be seen in (7). By bringing the inverse of the A matrix to the other side I end up with equation (8).

$$A\varepsilon_t = Bu_t \tag{8}$$

To identify the shocks in the reduced form model, restrictions must be imposed on the A and B matrix. Since identification is done by imposing restrictions on A and B, this type of model is called the AB model. The recursive ordering strategy is a special case of the AB model where the A matrix is a lower triangular matrix and B an identity matrix. To recover the structural shocks from the system, a Cholesky decomposition will be applied. The identification strategy then looks as follows

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 \end{pmatrix} \begin{pmatrix} \varepsilon_{\inf t} \\ \varepsilon_{gdp\ t} \\ \varepsilon_{sovciss\ t} \\ \varepsilon_{shadow\ t} \\ \varepsilon_{spread\ t} \end{pmatrix} = \begin{pmatrix} b_{11} & 0 & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 & 0 \\ 0 & 0 & b_{33} & 0 & 0 \\ 0 & 0 & 0 & b_{44} & 0 \\ 0 & 0 & 0 & 0 & b_{55} \end{pmatrix} \begin{pmatrix} u_{\inf t} \\ u_{gdp\ t} \\ u_{ciss\ t} \\ u_{shadow\ t} \\ u_{spread\ t} \end{pmatrix} \tag{9}$$

Because y_t is a vector of endogenous variables, the model in (3) is a simple notation of a system that consists out of five linear equations. The first equation in the system is the inflation equation. Inflation is modelled to only respond contemporaneously to its own shocks. Changes in output, monetary policy, stress in the sovereign debt market, and the EONIA-MRO spread impact inflation only with a lag. This is in line with the common assumption in macroeconomics of sticky prices which means that prices only change slowly. In the second output-equation, GDP responds immediately to changes in inflation, reflecting the downward pressure on demand following price increases. In the third equation, sovereign debt stress is modelled here to be contemporaneously affected by changes in output and inflation. Although it is economically reasonable to assume that unexpected changes in output and inflation can increase or decrease sovereign debt stress, the variable is mainly included in the model to include the sovereign spreads into the monetary policy function. The fourth equation is the monetary policy function. This equation reflects that the ECB incorporates inflation, output, and sovereign debt stress in setting monetary policy. Although this monetary policy function is likely too parsimonious to resemble the actual monetary policy function on which the ECB bases its decisions, by including the sovereign debt stress next to GDP and inflation, the main targets of the ECB are incorporated. It is therefore likely that this monetary policy function is close enough to the true function to be useful in this analysis and increases the likelihood of identifying truly exogenous shocks. The fifth equation reflects the effect of unconventional monetary policy on bringing down money market rates. The effects of UMP on financial market variables are well reported (Beirne et al. 2011; Baumeister & Benati, 2013). By explicitly modelling this effect of unconventional monetary policy on financial variables, the chance of identifying exogenous shocks is increased.

3.3.2 Sign restrictions

Besides the recursive identification strategy, I will also use sign restrictions to identify the UMP shock to increase the robustness of the findings from the recursive identification strategy. I use sign restrictions because this strategy does not suffer from the major criticism on the recursive identification strategy that often theory follows from identification rather than what should be the case, that the identification strategy follows from theory. Only if a recursive ordering in the contemporaneous relations in the system (the first variable is only affected contemporaneously by itself and the second variable contemporaneously by the first variable and itself, and so on) can be justified by theory is the recursive ordering applicable. This is often not exactly the case. If a recursive ordering is used in that case, it will lead to wrong shocks because the data is forced to behave in the way that the structure imposes. This in contrast to sign restrictions, that use prior beliefs about the structural shock to identify shocks in the model.

Sign restrictions (or any other identification strategy that includes sign restrictions) cannot be estimated in a similar fashion as the recursive ordering strategy. Instead, a Bayesian VAR (BVAR) is used where (depending on rejection criteria and the number of draws) multiple draws from the data are performed to find enough impulse responses that fulfil the criteria.

Table 2 Sign restrictions

Shock/variables	Inflation	Output	Sovereign stress indicator	Shadow rate	Money market spread
Unconventional monetary policy	?	?	?	-	-

My baseline model includes output, inflation, the shadow rate, a sovereign stress indicator and a money market spread. When using sign restrictions, an expansionary monetary policy shock is identified by imposing the sign restrictions depicted in table 2. A question mark means that the variable is left unrestricted. According to theory, the shadow rate decreases on impact because it is the policy rate variable. The money market spread decreases because of the dampening effect of the shock on the interest rate. The negative restrictions are imposed for one month, after which they are no longer restricted to move in any direction. Even though from theory it also follows that output and inflation would rise following an expansionary monetary shock, I explicitly leave them unrestricted as they are the variables of interest.

By leaving inflation unrestricted, one problem remains: the potential presence of the prize puzzle. In many studies into monetary policy effectiveness, a remarkable finding is that inflation temporarily increases before it decreases following an interest hike. To avoid the prize puzzle, many studies opt for applying sign restrictions in combination with zero restrictions to limit the response of inflation upon impact (for example Elbourne et al., 2018; Boeckx et al., 2017; Burriel & Galesi, 2017). The reason why I leave output and inflation unrestricted is that sign restrictions emerged as a response to overidentifying strategies. By combining zero restrictions to the sign restrictions identification strategy, I potentially overidentify the shock I am trying to find. Given the fact that I conduct sign restriction identification to check for robustness of a model that potentially uses an identifications strategy that overidentifies, I want the sign restriction identification to be as parsimonious as possible.

Sign restrictions are imposed ex-post. This means that they are imposed on impulse response functions after they have been created. To do this, the VAR model needs to be estimated in a Bayesian VAR. Using the Bayesian method, many impulse response functions are estimated but only the ones that satisfy the sign restrictions are kept. This continues until a prespecified threshold for accepted draws is reached. Once enough impulse response functions have been found that meet the sign criteria, an impulse response function graph can be created using the median of the accepted impulse response functions. The sampling uncertainty is indicated by the error bands of the 16^{th} and 84^{th} percentile. These bands share similarities with the standard errors in a regular impulse response function graph, but there is one major difference. In the Bayesian case, the error bands do not say anything about the precision of the estimation but rather about uncertainty of the sampling (Danne, 2015). More specifically, imposing sign restrictions using a Bayesian VAR method works as follows

1. A structural VAR is estimated to get the coefficient matrix and the error- covariance matrix.
2. The errors are orthogonalized to make them uncorrelated using a Cholesky decomposition. The Cholesky decomposition is not used to identify the shocks but merely to make sure the errors terms are independent from each other.
3. Using the orthogonalized errors, impulse response functions are created.
4. The impulse response functions are multiplied with a randomly drawn impulse vector from one of the estimated structural VARs. An impulse vector is one column in the B matrix (the matrix containing the error terms).
5. If the impulse response function satisfies the sign restrictions it is kept, if not it is thrown away.

These steps are repeated until the threshold that has been set at the beginning of the minimum number of accepted draws has been reached. I have set this threshold at 1000. The number of draws taken from the distribution is 2000 and from this 2000 in turn 1000 sub draws are taken. The criteria for keeping and rejecting draws are set by the Penalty Function Method created by Uhlig (2005). I opted for this method specifically because it largely mitigates one major problem of sign restrictions. Using sign restrictions, impulse response functions are identified that fit the criteria, but these impulse response functions are not unique. Multiple draws can result in multiple structural equations and shocks each consistent with the data and the imposed restrictions (Danne, 2015). This causes the error bands to display model uncertainty and not, as should be, the sampling uncertainty (Danne, 2015). By creating a weighted sample of all the drawn models (including the rejected ones), the actual model that results is not one of the possible outcomes, but a weighted average of all the outcomes (Danne, 2015)

3.4 Vector autoregressive model with exogenous variables (VARX)

To estimate the impact of fiscal policy I expand the VAR model into a VARX model by including the primary balance as an exogenous variable. The baseline model and the estimation of the impact of UMP function as the benchmark.

3.4.1 VARX model

The structural from of the VARX model is similar to the SVAR model I use. VARX models are VAR models that include unmodelled or exogenous variables. In a SVAR, all the variables in the system are endogenous variables. This means that all variables are determined within the system. A system of endogenous variables can also be affected by other observable variables that do not appear in the system itself. Those variables are called exogenous variables.

The VARX model looks as follows. The structural form is given by (10)

$$AY_t = c_0 + Z_1 Y_{t-1} + \cdots + Z_p Y_{t-p} + R_0 x_t + \cdots + R_s x_{t-s} + Bu_t \qquad (10)$$

All elements remain the same compared to the baseline model, except for the added R_t and x_t. R is a $n \times n$ matrix containing the coefficients of the exogenous variables. x_t contains the aggregate primary balance of the eurozone as the exogenous variable and is a $n \times m$ vector, with m being the number of exogenous variables that are included. To move from the structural form to the reduced form, the right-hand side is multiplied by A^{-1}, which results in

$$\begin{aligned} Y_t = A^{-1}c_0 + A^{-1}Z_1 y_{t-1} + \cdots + A^{-1}Z_p Y_{t-p} + A^{-1}R_0 x_t + \cdots \\ + A^{-1}R_s x_{t-s} + A^{-1}Bu_t \end{aligned} \qquad (11)$$

Where a simplification gives the form in which the model is estimated

$$Y_t = k_0 + A^* Y_{t-1} + \cdots + A^* Y_{t-p} + R^* x_0 + \cdots + R^* x_{t-s} + \varepsilon_t \quad (12)$$

$$k_0 = A^{-1} c_0 \quad (13)$$

$$A^* = A^{-1} Z_t \quad (14)$$

$$R^* = A^{-1} R_t \quad (15)$$

$$\varepsilon_t = A^{-1} B u_t \quad (16)$$

To identify the structural shock to the VARX system, I will use a Cholesky decomposition. Compared to the baseline model, the identification strategy remains unchanged. Nothing changes for the identification because the exogenous variable does not appear in any of the A or B matrix. To increase comparability, I keep the VARX model as similar as possible to the baseline model. The number of lags, therefore, is also set at one in the VARX model, despite the fact that the Akaike information criteria indicated three lags for the endogenous variables in the specification with an exogenous variable.

3.4.2 Exogeneity

For my purpose, I will include the primary balance as an exogenous variable to the monetary policy VAR system. The reason why fiscal policy does not need to be included endogenously is because I do not intend to model its generation mechanism. As long as this is not the objective is does not need to be in the endogenous vector (Lütkepohl, 2005). However, this does not mean that fiscal policy therefore can be included exogenously. Including the primary balance as an exogenous variable needs further justification.

Three types of exogeneity exist (Engle, Hendry & Richard, 1983). Weak exogeneity, strong exogeneity and super exogeneity. A variable is weakly exogenous if the current values of the endogenous variables do not affect the current values of the exogenous variables. A variable is strongly exogenous if the endogenous variables do not explain past values of the exogenous variables as well. Super exogeneity is the case when the coefficients of the relationship between the endogenous variables and the exogenous variables remain the same even if the values of the exogenous variable changes. More practically is to say that x_t is exogenous if x_t is independent of the error term w_t where $w_t = Bu_t$ (Lütkepohl, 2005). Using this definition, the exogenous variable in the system can be thought of as *observable* inputs to the system while the error term w_t is the *unobservable* input to the system (Lütkepohl, 2005).

The use of the primary balance as an exogenous variable is justified for the following reasons. Firstly, the role division between monetary policy and fiscal policy in the eurozone is such that fiscal policy is concerned with stabilization and monetary policy with stimulation. This means that in determining the fiscal policy, not the level of output or inflation or any other economic indicator is leading, but the level and sustainability of the deficit and the debt. In a panel data set of 28 EU countries Afonso, Alves & Balhote (2019), using regressions to estimate the fiscal policy function and monetary policy function, find evidence that the central bank is indeed mostly concerned with price stability and fiscal policy with debt sustainability. Secondly, fiscal policy is the outcome of a political process, and therefore seldomly optimally calibrated with those economic indicators that the central bank uses in setting monetary policy.

Even if the primary balance is not fully exogenous to the monetary policy, this does not have to be problematic. What is most important is that, from a theoretical perspective, inclusion is justified. Empirically, even the pragmatic definition of exogeneity by Lütkepohl is usually already too restrictive and not a necessary condition to obtain credible VARX results (Lütkepohl, 2005).

3.5 Data

I use monthly data that ranges from January 2009 to February 2018. The choice for this period is motivated by two facts. Firstly, this data range includes the start of unconventional monetary policy and includes all major QE programmes and other unconventional measures. Secondly, it also includes a sustained period where the monetary stance was positive whilst the fiscal stance consolidative. Although these justifications are also valid for the months after February 2018, the shadow rate that I use in the analysis is not available for later dates.

To increase the data available for estimating the many parameters in the VAR system, monthly data is used. GDP is only reported in quarterly frequency, therefore the data on real GDP is interpolated using the proportional Denton method with the monthly index of industrial production as the reference series. This is expected to result in minor measurement errors that might make the monthly GDP data smoother than the true timeseries. Nonetheless, interpolation of output data is a common approach in the monetary VAR literature to increase the number of observations in timeseries analysis (see for example Boecxk et al., 2017; Elbourne et al., 2018).

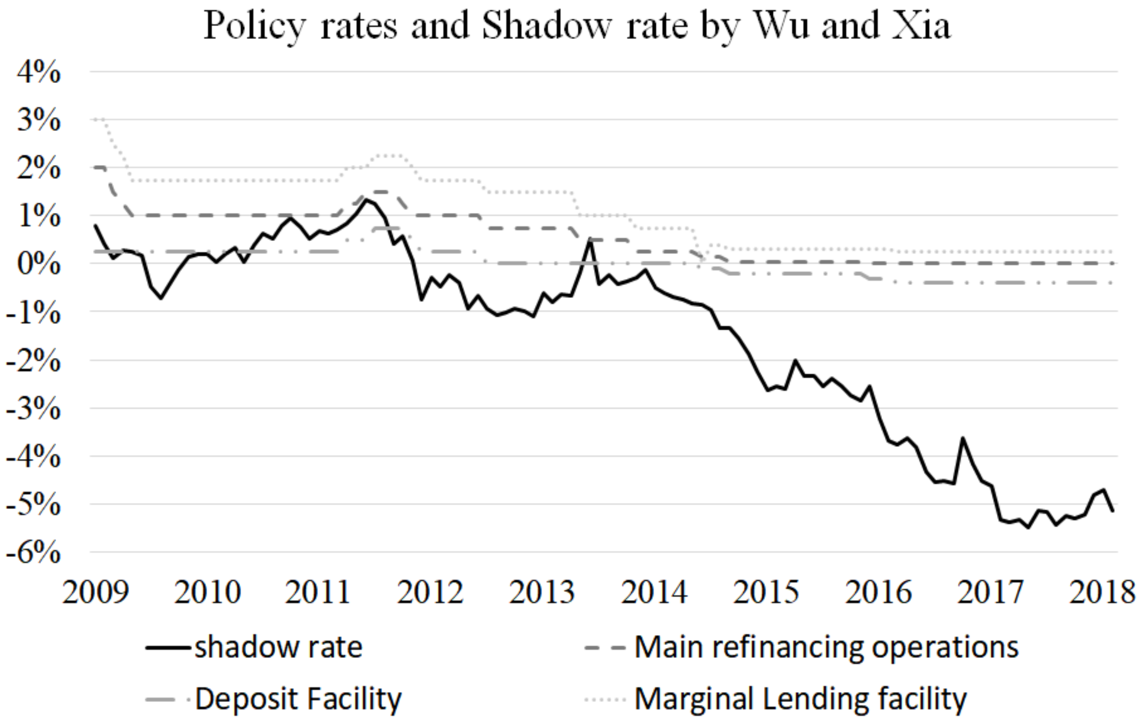

Figure 1 - Graph of the three policy rates of the European Central bank and the shadow rate by Wu and Xia (2017)

3.5.1 Stationarity

It is common to only conduct time series analysis on stationary data. However, for VAR models this is not a necessary condition. VAR models do not need to be estimated using stationary series because non-stationarity does not affect the main tool of analysis of VAR models. On the other hand, adding variables in first differences (a common approach to create stationarity) has the risk of losing important information about the dynamics contained in the data and potentially introduces a bias to the system (Sims, 2011). The coefficients in the VAR will be affected by non-stationarity, but since they contain little information due to the complex interdependencies, this is not problematic.

Conducting a VAR analysis on non-stationarity variables is not completely without problems. It can lead to unstable systems. If a system is not stable, the impulse response functions do not return to zero and the effects of a shock never fade off. To guarantee a stable system, I linearly detrended inflation, the sovereign stress indicator, and the shadow rate.

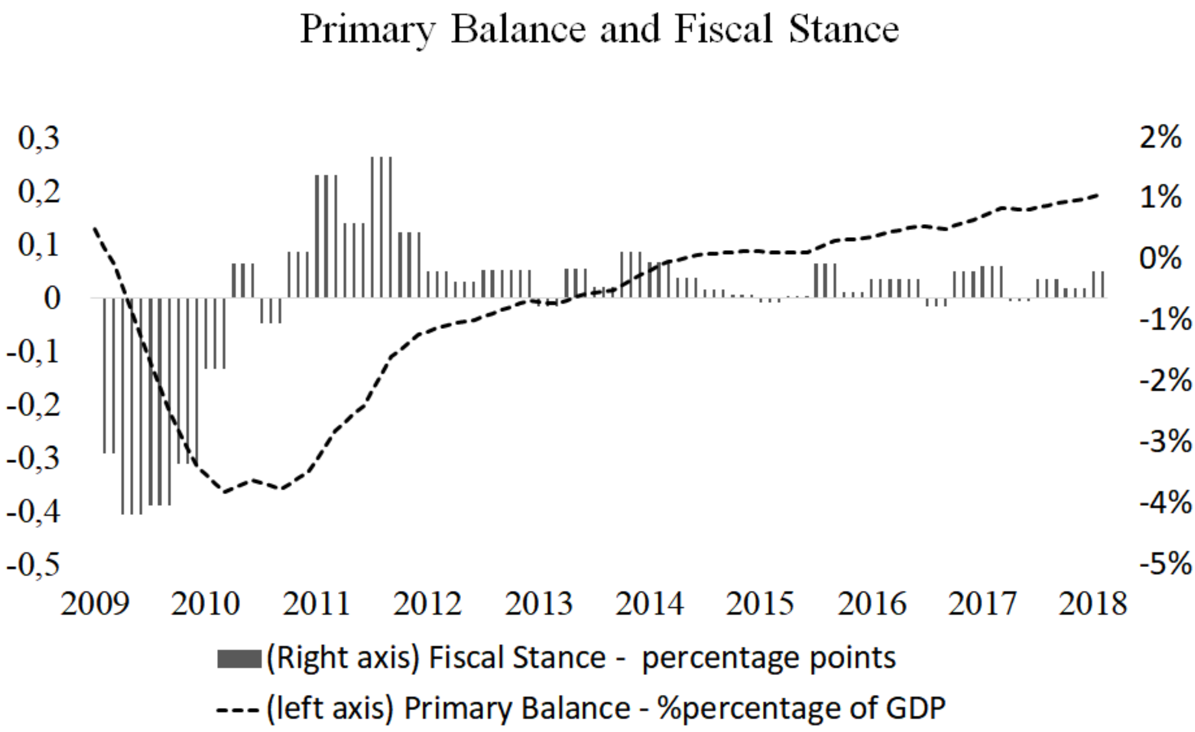

Figure 2 - Graph of the primary balance development in the Euro zone. Numbers are aggregates for the whole eurozone. Fiscal stance above zero means that the primary balance has increased compared to the previous period and vice versa

3.5.2 Endogenous variables

The endogenous variables in the baseline model are presented in table 3 and are the monthly rate of change of inflation, real GDP, the CISS indicator of sovereign stress, the shadow rate by Wu and Xia (2017) and the money market spread defined as spread between the EONIA and MRO rate. Real GDP enters the model in its natural logarithm. All variables, except the money market spread and Real GDP, are detrended. This means that a linear trend has been removed from the time series of the variable. This was necessary to make sure that all the eigenvalues are within the unit circle, a necessary condition to have a stable VAR system.

Table 3 Endogenous variables

Variable	Measurement	Definition	Transformation
Inflation	Percentage	Monthly rate of change of inflation	Linearly detrended
Output	Billions of euros	Absolute value of GDP	Log transformed
Sovereign stress indicator	Indicator from 0 to 1	Indicator for sovereign stress	Linearly detrended
Shadow rate	Percentage	Shortest maturity interest rate on ELB-adjusted yield curve	Linearly detrended
Money market spread	Percentage	Difference between EONIA-MRO	Linearly detrended

The sovereign stress indicator is a measure of the extent of stress in the sovereign debt market and ranges from 0 to 1 with one being complete stress and zero no stress at all (Garcia-de-

Andoain & Kremer, 2017). The eurozone measure is an average of the individual eurozone countries. This makes it a proper gauge for eurozone sovereign debt stress rather than merely an indicator of sovereign stress in any one of the member states. This is important because the ECB is not allowed to buy government debt of a country in need and therefore this should not be present in my monetary policy function. The EONIA-MRO spread is also called the money market spread and is the difference between the overnight interest rate and the main refinancing operations rate set by the ECB.

3.5.3 Shadow rate

Instead of using the policy rate as a proxy for monetary policy, I use the shadow rate by Wu and Xia (2017). The regular policy rate is not a proper indicator of the monetary stance since it is at the ELB. This refers to the situation where the policy rate is already at zero and cannot go any lower. In other studies, assets on the balance sheet of the ECB have been used as proxies for unconventional policy (for example Boeckx et al., 2017 and Wieladek & Pascual, 2016). However, QE purchases are announced in advance, rendering it difficult to model exogenous unconventional monetary policy shocks. Elbourne (2019) empirically shows that the shocks identified by papers using the central bank balance sheet suffer from the foresight problem. He demonstrates that he can create equally likely impulse response functions using random numbers as the policy instrument as the papers using the balance sheet.

The shadow rate can be interpreted as interest rates which would have occurred in the case cash would not exist. If cash does not exist, interest rates can decrease below zero (Kortela, 2016). In that sense, the major difference between the shadow rate and the regular policy rate is that the former is not constrained by the ELB. But for the shadow rate to be able to go below zero, it needs to be able to capture the effects of unconventional monetary policy. It does so by decomposing the yield curve into a shadow rate yield curve plus a call option offering a payoff to holding a physical currency (Damjanović & Masten, 2016). The call option is necessary to rule out arbitrage opportunities that might arise when the yield curve goes below zero in an ELB environment (Black, 1995). The shadow rate is defined as follows:

$$\underline{R}(t,\tau) = R(t,\tau) + Z(t,\tau) \qquad (17)$$

Where $R(t,\tau)$ is the shadow rate when the ELB has not been reached, and $Z(t,\tau)$ the call option when the ELB is present (Damjanovic & Masten, 2016). The actual shadow rate that I used is derived from the shortest maturity interest rate on the ELB-adjusted yield curve (Wu & Xia, 2017).

A problem with the shadow rate is that it is sensitive to the choice of the lower bound (Kortela, 2016). The lower-bound needs to be correctly specified and must be close to reality to get credibly results. Fortunately, the shadow rate by Wu & Xia (2017) uses a time-varying lower bound making the problem less relevant. Moreover, the Wu & Xia shadow rate has been successfully applied in other papers already, showing that it is capable of correctly capturing the effects of the unconventional policy in the eurozone (see Elbourne et al., 2018; Antilla, 2018). This is also the reason why I opt for the shadow rate by Wu & Xia, and not the one by Krippner (2018). Krippner's shadow rate shows monetary tightening during periods where there was no tightening. The Wu & Xia shadow rate does not have these unexpected movements and is therefore preferred.

3.4.5 Exogenous variable - Fiscal policy

In the VARX model, I use the primary balance as the proxy for fiscal policy. The primary balance of the eurozone is the sum of the primary balances at the national level. A positive primary balance means that, on the aggregate level, the eurozone governments are lending money. A negative primary balance means the opposite, they borrow money.

Table 4 Exogenous variables

Variable	Measurement	Definition	Transformation
Primary balance	Percentage	Government budget balance as percentage of GDP	-

Finding a proper measure of fiscal policy is not as straightforward as it may seem. Fiscal policy broadly consists of three elements, automatic stabilizers, interest payments on government debt and discretionary measures that affect the economy by altering public spending and revenue (Bankowski & Ferdinandusse, 2017). For the effect of fiscal policy, I am interested in the discretionary element of fiscal policy. Interest payments on existing debt are filtered out easily by using the primary balance, as I have done. However, identifying the discretionary element is difficult to measure in real time. This is the case because the position of a country in the business cycle is hard to determine (Bankowski & Ferdinandusse, 2017). It might thus be the case that the primary balance does not correctly indicate the fiscal stance of a country. Some papers use the change in the primary balance as an indicator of fiscal policy (Bankowski & Ferdinandusse, 2017). However, for my purpose I am interested in whether fiscal policy is accommodating or consolidating, not in the degree to which fiscal policy is accommodative or consolidative. This measure of the type of fiscal policy does not add any valuable information to my analysis.

4. Results

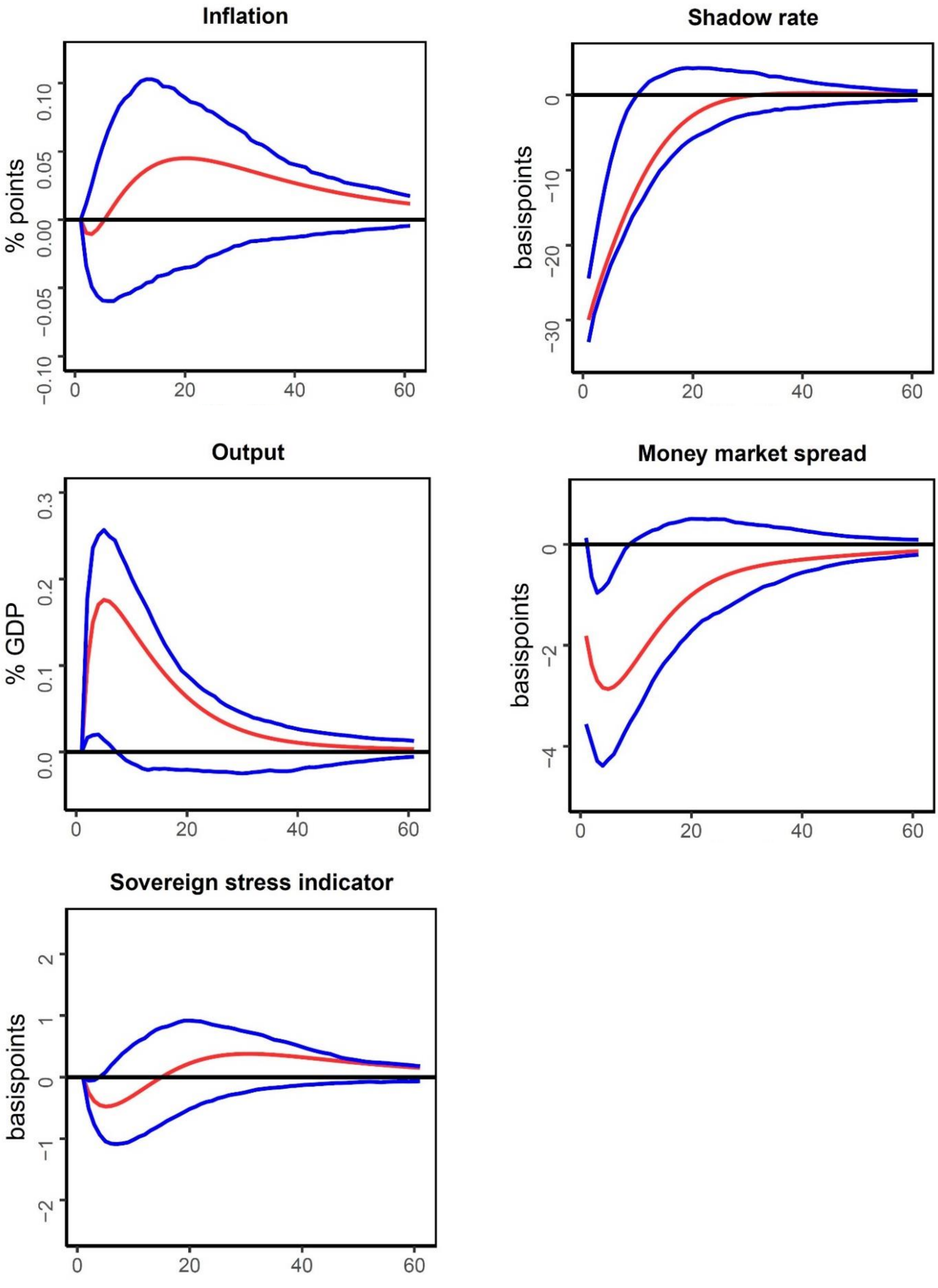

Figure 3 Impulse response functions (red line) following a one standard deviation of the error term of the monetary policy function to the other equations in the system. Blue lines are the 90% confidence interval obtained by 1000 bootstrapping runs. Bootstrapping mitigates some of the problems with traditional way of obtaining standard errors in VAR systems, but problems remain (see Stock & Watson, 2001)

In this chapter, I will first discuss the results of the baseline model using a Cholesky decomposition. After this I compare these results with the results from the baseline model using sign restrictions to assess the robustness of the results. Finally, I will discuss the results of the VARX model, that includes the impact of fiscal policy on monetary policy effectiveness.

4.1 Baseline model

In figure 3, the impulse response functions of a one standard deviation unconventional monetary policy shock are depicted. An unconventional monetary policy shock leads to a drop of 30 basis points in the shadow rate. The shadow rate returns to zero within 2.5 years, which implies that the unconventional monetary shock has a persistent character. This is consistent with the monetary policy that we have observed between 2009 and 2018, where monetary stimulus was persistent and did not return to a 'normal' after a period of monetary stimulus. A 30-basis point drop in the shadow rate leads to an increase of 0.1759% of GDP within half a year after the impact of the shock. The effect on output is still present after 5 years indicating that an expansionary unconventional shock has a persistent effect on output. However, most of the effect materializes in the short-run, showing that UMP affects output more in the short-run than in the long-run. This is compatible with the general notion that monetary policy is only able to temporarily impact output.

In contrast to the effect on output, the impact on inflation is more concentrated in the long term. Inflation increases with almost 0,045% following the shock, however, the peak is only reached after 20 months. This indicates that the inflationary impact of inflation becomes stronger over time. Moreover, its effect lasts longer as the shocks fades off in a much slower rate than for output (indicated by the flatter slope of inflation compared to output). The prize puzzle is present, as following an expansionary monetary policy shock, inflation drops slightly before it increases. The error bands in the impulse response function of inflation are nowhere above or below zero, which indicates that the effect is nowhere along the line significantly different from zero. The error bands, constructed using the standard errors, have their shortcomings for highly persistent variables (Stock & Watson, 2001) and concluding that there is no effect would be invalid. However, it does mean that effect of an unconventional monetary policy shock on inflation is inconclusive.

As in almost all studies investigating unconventional monetary policy shocks in the eurozone, I find a smaller effect on inflation than on output. My output response is somewhat higher than what has been found before. Most relevant in that respect is to compare it to Elbourne et al. (2018), a recent study where the shadow rate is used as well. However, a great deal of the unconventional policy was yet to be conducted when Elbourne et al. stopped, so it is therefore not surprising that I find a more pronounced effect.

As expected, the decrease in the shadow rate, decreases the money market spread. This means that the shadow rate is effective at lowering the interest rates in the money market. The extent to which it is able to lower the spread is small. The spread is only decreased with nearly three basis points. However, given the already low level of interest rates, it is not that surprising. Less expected is the effect of the unexpected monetary policy shock on the sovereign debt stress indicator. Following an expansionary shock, the stress is somewhat decreased but only marginally. In addition, the effect is ambiguous as the sovereign debt stress increases after 1.5 years. This suggest that the accommodative monetary policy by the ECB can take away investors' fears in the short run but not in the long run. This is not surprising given that in the long run the actual fiscal position of a country is much more important for sovereign stress than its ability to refinance its debt on the short-term.

All in all, the baseline model suggests that the unconventional monetary policy implemented between 2009 and 2018 has raised both output and inflation and lowered spreads and sovereign stress.

4.2 Robustness of the baseline model

In figure 4, the impulse response functions using the sign restriction identification scheme are depicted. First off, the results of the baseline model are largely confirmed by the model using sign restrictions. This confirms the results of the baseline model and increases the confidence in the identification scheme I use in the baseline model and I will use in the VARX model. Zooming in on the results of the model with sign restrictions, however, there are differences. Most remarkable is the drop in the peak of output. Using sign restrictions, the UMP shock increases output with only about 0,07%. Moreover, the effect fades off quicker as the effect has disappeared after three years. Another difference is the more pronounce effect on the money market spread. Following an UMP shock, the spread now decreases with 8 basis points rather than 3. However, the effect is still small. Inflation seems to have a slightly lower peak and the prize puzzle is, as expected, still present. The effect of inflation is still concentrated on the medium long term.

Overall, the results of the sign restrictions largely confirm what I found using the baseline model. The output peak is considerably smaller, but the difference is not large enough to question the trustworthiness of the baseline model. Wieladek & Pascual (2016) find similar

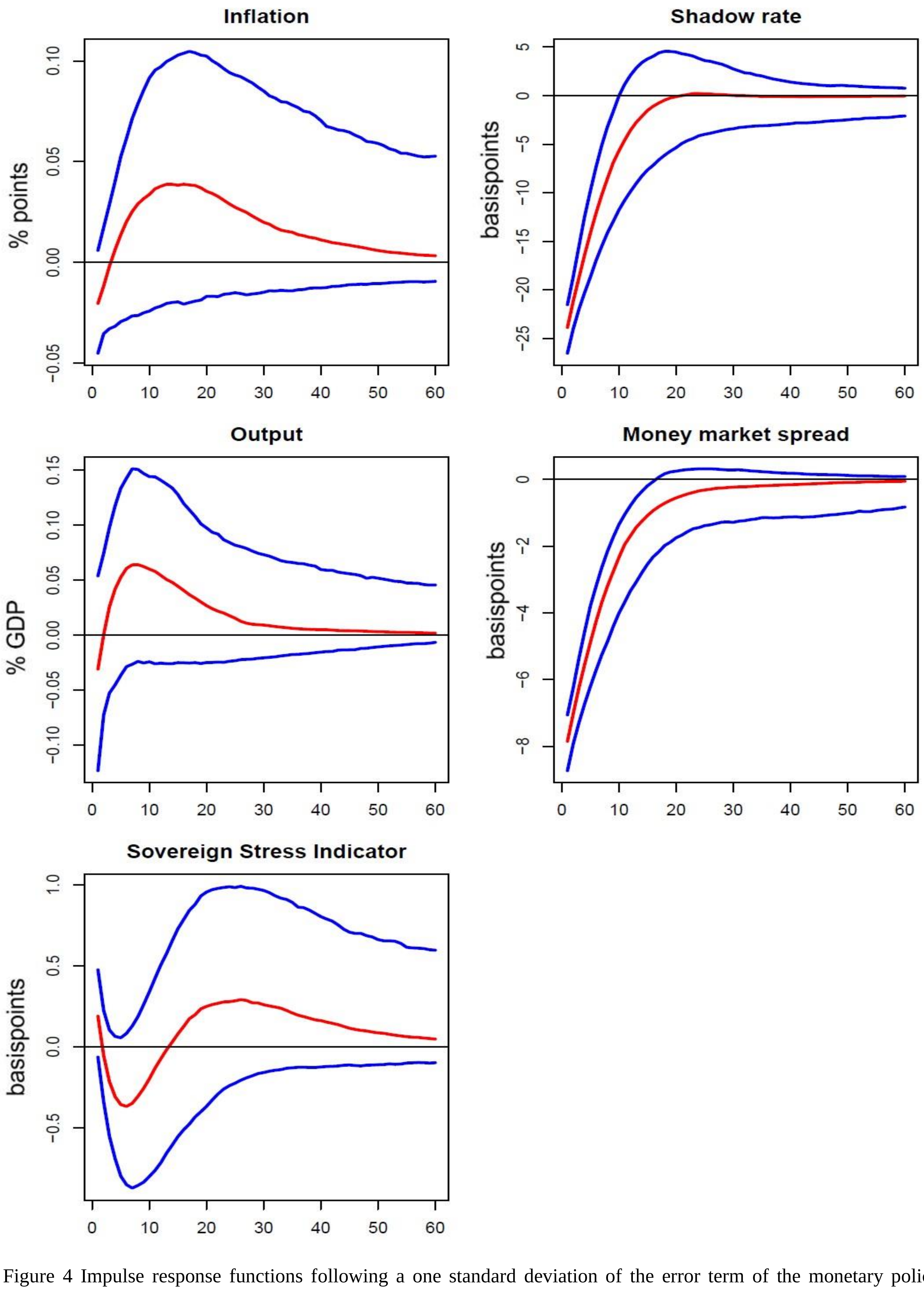

Figure 4 Impulse response functions following a one standard deviation of the error term of the monetary policy function to the other equations in the system. The red line is the median response and the blue lines indicate the range in which 68% of the models fall that satisfy the sign restrictions.

differences in magnitude of output by using a recursive identification scheme and sign restrictions. Moreover, the effects might be more muted because the identified shock in the sign restrictions model is smaller than in the recursive identification scheme. Where in the sign restrictions model, the shock is 25 basis points, the shock is 30 basis points in the recursive identification model.

4.3 Effect of fiscal policy

Now that it has been demonstrated that the baseline model produces credible results, the baseline model can be extended with the primary balance as the exogenous variable. By comparing the impulse response function and the peak response in the baseline model with the extended model, the effect of fiscal policy on the monetary policy effectiveness can be estimated.

In figure 5, the impulse response functions of the VARX model are depicted. Something that immediately stands out is the similarity between the baseline model and this model that includes the primary balance as an exogenous variable. As can also be seen in table 5, the responses for all variables except inflation are similar to the baseline model. However, one difference stands out: the inflation peak is halved compared to the baseline model. The duration of the effect on inflation has not changed, as the effect is still present after more than five years. Since the specification of the VARX model is completely equal to the baseline model, this suggest that the primary balance has a negative impact on the ability of UMP to increase inflation.

Table 5 Peak response comparison

Variable	Baseline model	VARX-model
Inflation	0.04505	0.0208
Real GDP	0.1759	0.1624
Sovereign stress indicator	-0.4788	-0.4452
Shadow rate	-29.9524	-29.8201
Money market spread	-2.8680	-3.1593

Surprisingly, output is only affected marginally with a response peak that is about 0,1% lower. Even though contractionary fiscal policy is known to affect the demand and supply of credit, I barely find any results that indicate that this type of fiscal policy has made the UMP less effective. The sovereign stress indicator is also unaffected, which points in the direction that unconventional monetary policy does not become more effective in lowering sovereign stress in an environment where it is combined with contractionary fiscal policy. This confirms the importance of actual fiscal characteristics as a factor in determining sovereign stress.

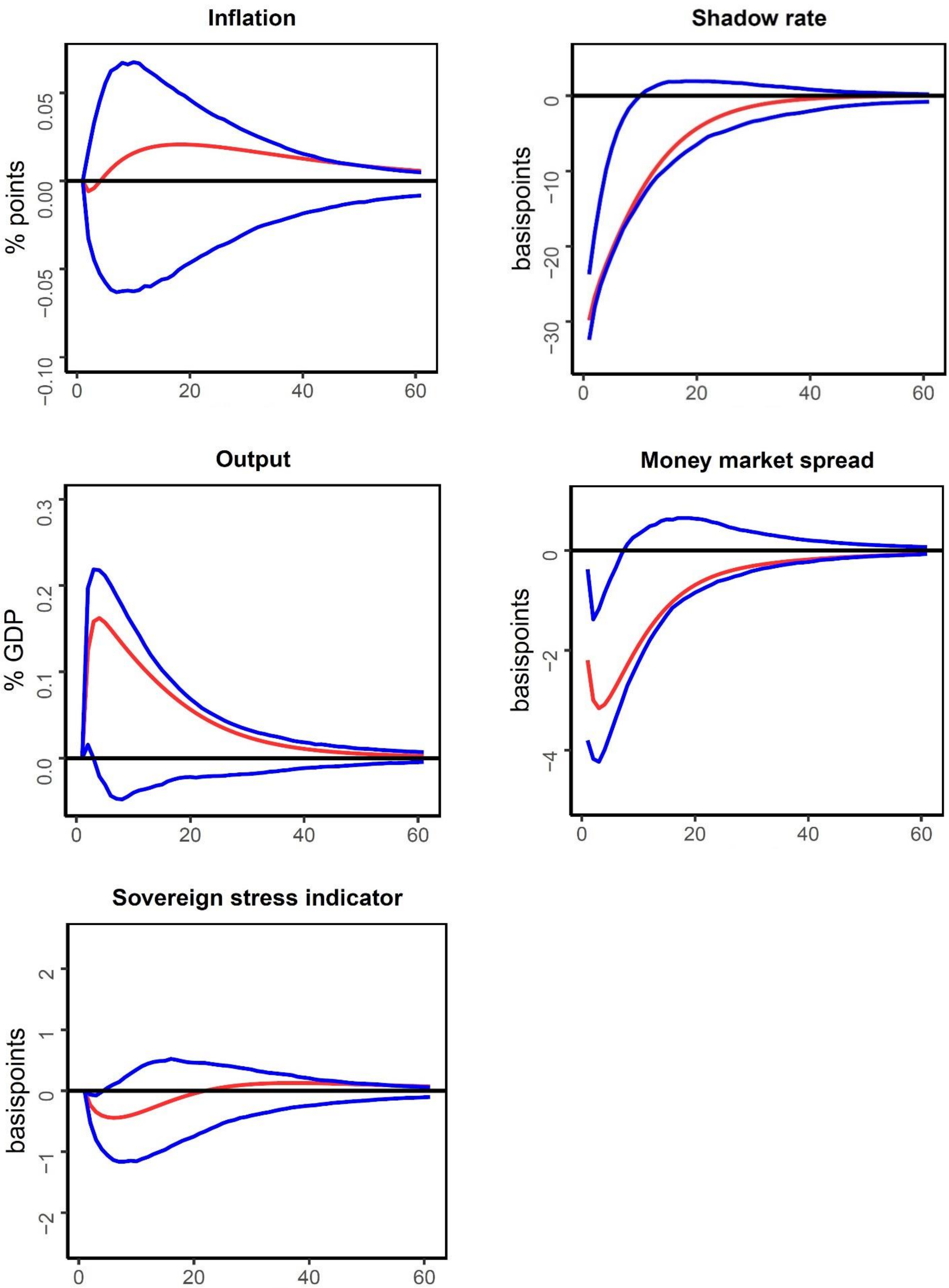

Figure 5 Impulse response functions (red line) following a one standard deviation of the error term of the monetary policy function to the other equations in the system. Blue lines are the 90% confidence interval obtained by 1000 bootstrapping runs.

5. Discussion

I find that between 2009 and 2018, fiscal policy has made unconventional monetary policy slightly less effective in raising output. Having said that, the effect however is minimal and economically insignificant. A potential explanation could be that the measure I use for fiscal policy is not good at capturing those fiscal policies that particularly affects credit demand, which are the policies that are likely to impact UMP effectiveness in raising output the most. As Eggertson (2011) and Albertini et al. (2014) have shown, the type of fiscal policy matters for the overall effectiveness of the fiscal multiplier under an ELB spell. This is likely to matter for monetary policy effectiveness under a contractionary fiscal policy spell as well. If these measures are not reflected well in the primary balance, this could explain the absence of a clear effect.

I do find an economically significant effect on inflation. The peak response of inflation following an UMP shock is halved when the model is expanded to include the primary balance, which was predominantly positive (indicating a surplus on the budget). I assert that this effect might be due to the negative inflation sentiment caused by sustained contractionary fiscal policy of the years following the global financial crisis and the resulting impairment of the functioning of the signalling channel.

UMP functions for a great deal through the signalling channel (Altavilla et al., 2015). By committing to long-term purchasing of assets on the markets, the central bank signals to the market that it is committed to keeping interest rates low and thus committed to raising inflation. This channel only functions if the commitment is deemed credible by the markets. One can question the functioning of such a delicate signalling channel if at the same time governments are cutting spending. Economic actors are very aware of the political mechanics that drive this fiscal policy and the ensuing persistence of this political conviction for the need for fiscal consolidation. This could result in an impaired transmission through the signalling channel of an expansionary UMP shock. Markets know that if governments keep cutting their spending, inflation is not likely to increase as this directly impacts the purchasing power of consumers. However, more research is necessary into the signalling effects of fiscal policy on inflation expectations by economic agents.

My results show that the ECB is currently in an awkward place. On the one hand, the ECB is concerned to end up in a situation where their discretionary room for manoeuvre becomes constrained due to rising debt levels and the ensuing presence of fiscal dominance. On the other hand, by maintaining positive primary balances to lower national debt levels, eurozone governments make the UMP policies of the ECB less effective rendering the ECB unable to achieve its goal of two percent inflation.

The fact that this is becoming more and more a true dilemma for the ECB and that fiscal dominance is not some distant threat that is only relevant for developing countries was demonstrated recently when Lagarde issued a statement that read that it is not the job of the ECB to close spreads. Immediately, yields on highly indebted eurozone countries started to increase and threatened the ability of these countries to refinance their debts. This indicates that even a small rise in the policy rate has the potential to trigger debt sustainability problems in the Eurozone. This could already imply that to some extent, fiscal policy is dominant over monetary policy, limiting the room for manoeuvre of monetary policy. As this situation develops, the ECB will be less and less able to credibly commit to any type of policy, creating even larger problems for the ECB and the eurozone at large.

6. Conclusion

The goal of this research was threefold. Firstly, I aimed to estimate the impact of UMP on output and inflation on the eurozone economy between 2009 and 2018. By employing a SVAR model to estimate the effectiveness of UMP and using a recursive identification scheme and sign restrictions, I find that an expansionary unconventional monetary policy shock increases output on average between the two identification schemes with about 0,12% and inflation with 0,4%.

Secondly, I quantified the effect of the austerity measures taken between 2009 and 2018 on the effectiveness of UMP. By employing a VARX model, I find that the peak output response is affected marginally while the persistence of the output effects remains unaffected. The peak inflation response is affected considerably as it is halved compared to the baseline model. This indicates that the fiscal policy between 2009-2018 has made the UMP less effective in increasing inflation.

Thirdly, I aimed to contribute to the understanding of the muted effect of UMP in the eurozone. My results do not contribute greatly to the understanding of why the output effects of UMP are mediocre, as fiscal policy does not seem to affect the ability of UMP to increase output to a great extent. I do find an explanation for the muted effect of UMP on inflation, as I find that fiscal policy lowers UMP's ability to increase prices.

This thesis is a first effort in quantifying the effects of the austere fiscal policies in the eurozone on the effectiveness of the unconventional monetary policies by the ECB. As such, it is a general model specification where the main objective was to investigate whether there is an effect at all. I find some evidence that points in the direction that fiscal policy has impaired the effectiveness of the UMP.

An interesting research setup to follow up on my results would be to adopt the methodology of Bonam et al. (2017). They apply a VAR model to investigate the impact of the ELB on the size of the fiscal multiplier. They use a dummy to indicate the time periods when the ELB was present. In the setting of my thesis, this methodology could be used in a panel VAR setting over a time period that spans several decades, just like Bonam et al. (2017).Rather than letting the dummy indicate ELB spells, it would indicate periods where fiscal policies were contractionary. It is interesting to see if this effect can be found for longer time periods as well.

This suggested research design, besides offering more insight, also solves one major weakness of my design. I implicitly assume that the mechanism of how UMP functions is the same under accommodative and contractionary fiscal policy. It could be the case that due to the sustained fiscal contraction, monetary policy transmission functions differently in this scenario. In that case, fiscal policy not only affects the outcomes but also the functioning of monetary policy. The suggested research design solves this problem because the dummy makes sure that for period with fiscal contraction, a whole new SVAR is estimated compared to the period when it is not present.

Building on this, it would be interesting to investigate the mechanisms more closely in a VAR setting. Interesting to know would be what transmission channels of monetary policy are mainly affected by fiscal policy. This could be done by adding variables that represent a transmission channel to the VAR that includes a dummy, as just discussed. Using this methodology, my assertion that the signalling channel is affected can be empirically tested.

Overall, my findings are useful for policy makers in the eurozone but do not offer a unidirectional advice about what policy to pursue. On the one hand, my findings suggest that to not harm monetary policy effectiveness, the ECB needs to call upon national governments to increase fiscal spending. On the other hand, if this causes debt levels to rise even further, fiscal dominance might become a real impediment to the operational freedom of the ECB. This suggests that the ECB should only call upon those governments that have enough fiscal space to increase fiscal spending.

7. References

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8. Appendix

8.1 Data sources

Variable	Description	Source
Inflation	HICP Monthly rate of change. 2015=100 [prc_hicp_mmor]	Eurostat
GDP	Real GDP chain linked values (2010). Seasonally and calendar adjusted data. Data transformed from quarterly to monthly using proportional Denton method [namq_10_gdp]	Eurostat
SovCISS	Composite indicator of Sovereign Stress of Euro area with equal country weights. Series key: CISS.M.U2.Z0Z.4F.EC.SOV_EW.IDX	ECB data warehouse
Shadow rate	Shadow rate used from Wu and Xia, downloaded from their website	https://sites.google.com/site/jingcynthiawu/home/wu-xia-shadow-rates
EONIA	Rate for the overnight maturity calculated as the euro short-term rate plus a spread of 8.5 basis points	ECB data warehouse
MRO	Main refinancing operations ECB. If rate changed within a month, the rate that it changed into counts for the whole month	ECB website
Primary Balance	Aggregate government primary deficit(-) or surplus(+) (as % of GDP) Series key: GFS.Q.N.I8.W0.S13.S1._Z.B.B9P._Z._Z._Z.XDC_R_B1GQ_CY._Z.S.V.CY._T Balance of whole eurozone	ECB data warehouse