“The cost channel of monetary policy transmission: Evidence from the Euro Area”

TESIS PARA OPTAR AL GRADO DE
MAGÍSTER EN ANÁLISIS ECONÓMICO

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Santiago, Diciembre 2018.

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Abstract

This paper studies the validity of the cost channel of monetary policy transmission in the euro area. The idea behind the aforementioned channel is that an increase in short-term interest rates, and in turn lending rates, puts upward pressure on inflation. The reason is that firms borrow funds in order to pay for their factors of production. An increase in interest rates increases the cost of labor and in turn firms will increase their prices to recoup the costs. In order to test this effect an interest rate augmented Phillips curve was jointly estimated with a Taylor rule. This study found no empirical evidence in favor of the cost channel with the potential reasons being small sample bias or misspecification in modelling monetary policy by using the Taylor rule.

Keywords: Phillips curve, Taylor rule, Euro Area, Monetary transmission, Cost channel

JEL classifications: E31, E32, E52

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I.Introduction

Monetary policy has been in the spotlight throughout the crisis. It is the policy tool most relied on to guide economies and target inflation at a healthy level as to allow for agents to optimize consumption and investment. While academic discussion has been focused on unconventional measures taken by central banks, it is essential to evaluate whether conventional policy is based on solid theoretical ground. Traditionally, and according to the ECB, the central bank sets the interest rate according to the inflation rate it wishes to achieve. By setting the short-term rate it can affect money-market interest rates and, in turn, lending and deposit rates. This is the so-called interest rate channel. However, many authors have investigated the idea that when the central bank increases interest rates, the inflation rate might go up instead of decreasing. This happens because many firms get funding from commercial banks in order to finance their production costs. An increase in interest rates will increase their borrowing costs, forcing firms to increase prices. This is called the cost-channel of monetary policy transmission.

Many authors have researched the validity of this channel. Barth and Ramey (2001) examine three types of shocks, a negative technology shock, a negative demand shock and a monetary policy shock in the form of an increase in the federal funds rate. They find a rise in the federal funds rate has similar effects to a productivity shock as productivity declines and real wages fall. The authors state that a cost-channel of monetary transmission exists due to the fact that the price-wage ratio rises when monetary policy tightens. Ravenna and Walsh (2006) state that the traditional Phillips curve is limited in the sense that it does not allow for a tradeoff between inflation stabilization and the output gap. By estimating an expectations equation with four lags of unit labor costs, GDP deflator inflation, a commodity price index inflation, the term spread, the nominal interest rate, wage inflation and the output gap, they estimate a two stage GMM and find evidence for a cost-channel of monetary policy. Chowdhury et al. (2006) estimate an "interest-rate" augmented Phillips curve that replaces the output gap with an estimate for real marginal costs that comprise real unit labor costs and interest costs. The authors find that the coefficient of this term is statistically significant for many of the countries included in their sample.

This paper builds on the work of Chowdhury et al. (2006) by estimating an augmented Phillips curve for the Euro Area and the nine out of the eleven founding members of the Euro. Moreover, the literature (Barth and Ramey, 2001; Chowdhury, 2006) acknowledges that interest rates and inflation have a two-way relation. The Phillips curve alone will produce biased results since it is not only interest rates that affect inflation. Central banks set interest rates in response to inflation. In light of this, this paper will estimate two equations, a forward-looking and "interest rate" augmented Phillips curve and an approximation of a monetary policy rule that central banks follow. A two-stage simultaneous GMM estimation will be used along with HAC[2] standard errors to account for possible heteroskedasticity and autocorrelation. Moreover, since time series data are used, stationarity tests are run, and first-differences of each variable are used. In addition, tests for potential structural breaks are run and dummy variables are used for the countries where the presence of a structural break turned out to be significant. Lastly, after the model is estimated the Hansen J-test is run to test for the validity of the instruments.

The paper is structured as follows; Section II goes over the literature on the topic, Section III covers the methodology and constructs the two equations to be estimated. Section IV analyzes the data, covers trends and outliers and discusses each variable used in the models including the instrumental variables. Moreover, some diagnostic tests are run and explained in this section. Section V outlines the results of the model estimation. Section VI discusses the results in more detail and covers some of the limitations of the research method. Finally, Section VII concludes.

[2] HAC: Heteroskedasticity and autocorrelation robust standard errors.

II.Literature Review

Monetary policy transmission channels

The most traditional channel of monetary policy transmission is the interest rate channel. According to the ECB the interest rate channel states that contractionary monetary policy lowers the level of investment by firms since the cost of borrowing increases. In turn, aggregate demand falls and so does inflation. In order for this channel to be effective, however, prices need to be sticky so that nominal changes in the interest rate translate to real changes. In addition, banks need to adjust their interest rates according to the short-term rate set by the Central Bank, otherwise monetary policy will not be transmitted to the real economy.

The exchange rate is an additional channel. It states that a relative change on the domestic interest rate will automatically affect the exchange rate and the balance of payments account. If for example interest rates rise in country A relative to country B, investors will prefer to hold assets denominated in country A's currency. In turn, country A's currency will appreciate. Since foreign goods are now relatively cheaper country A will experience a worsening of its current account. Moreover, the relative decrease in the price of imports will have a negative impact on inflation.

The bank-lending channel in the Eurozone is based on changes in the policy rate, which in turn affects the cost of external financing for banks. During a crisis, when the ECB cuts the benchmark rate, money market rates also drop making it easier for banks to access liquidity (ECB, 2018).

In their paper, "Inside the black box: The credit channel of monetary policy transmission", Bernanke and Gertler (1995) point out that the nominal interest rate set by the Central Bank should primarily affect short-term interest rates. However, what is observed in reality is that monetary policy has an effect also on demand for long-lived assets such as housing. Their explanation is that monetary policy affects firms' balance sheets and thus there is a balance sheet channel of monetary transmission. If, for example, interest rates increase then a firm will have to make higher payments on its newly issued debt and thus its financial position will worsen. Keeping this in mind, lenders will demand a higher premium to compensate them for monitoring costs and the risk of default. Movements in risk premia affect investment decisions and the spending pattern of firms. The same reasoning could be also extended to include consumers since they also have to borrow to finance their consumption. A change in interest rates affects the balance sheets of individuals and households. In turn the willingness of banks to lend deteriorates and, in the case that borrowing from a commercial bank is the sole option for households, expenditure in durables will drop (Mishkin, 1995).

A credible central bank is able to influence not only short-term interest rates but also long-term rates, indirectly, by committing itself to a certain monetary policy stance. Economic agents rely on expectations about future short-term interest rates in order to determine investment and consumption in durable goods, such as real estate. By being able to shape these expectations the Central Bank can influence long-term rates and thus, the prices of those goods. This is the so-called expectations channel (ECB, 2017). Credibility is very important for monetary policy transmission. If the investors do not trust that the central bank will adhere to a pre-specified level of inflation, then this will affect their decisions and in the end prices. An instrument in the hand of central banks to enhance credibility is forward guidance[3].

Lastly, the cost-channel of monetary policy transmission states that changes in the cost of finance affect a firm's marginal costs, if we assume that firms depend on external finance in order to pay their factors of production. The increase in marginal costs will then translate into higher prices assuming that firms cannot adjust wages immediately. Among the authors that have found supporting evidence for this channel are Barth &Ramey (2001), Christiano, Eichenbaum & Evans (2005), Ravenna & Walsh (2006), Chowdhury et al. (2006) and Tillman (2007) while Rabanal (2007) find a zero probability of a rise in inflation due to contractionary monetary policy. He attributes this effect on the low flexibility of prices compared to wages. The approach and findings of these authors that have dealt with the cost channel will be discussed in the section below. Wage flexibility will be also touched upon in the last section of the literature review to address the reason that led Rabanal (2007) come to such a restrictive conclusion.

[3] Forward guidance refers to the idea that the central bank communicates its intentions regarding future monetary policy with the public (ECB, 2017)

Empirical evidence on the cost-channel of monetary policy transmission

The literature that has dealt with empirics and arguments to support this channel is extensive and part of it is discussed below.

Barth and Ramey (2001), show that effects resulting from changes in the short run interest rate, set by the Central bank, differ significantly from demand shocks in their effects on output, productivity and real wages. They study the impact of these shocks on the economy as a whole and on the industry level, in order to determine in which industries, the cost-channel of monetary policy transmission is more pronounced. On the aggregate level the authors consider three types of shocks. A negative technology shock, a negative demand shock[4] and a monetary policy shock in the form of an increase in the federal funds rate. In this setting the economy is shocked via a change in monetary policy rather than monetary policy reacting to economic variables, thus it is an exogenous variable. The authors find that the shock on the federal funds rate is similar to that on technology regarding the effects on productivity and real wages. More specifically, both shocks cause a decline in productivity and real wages while the opposite holds for the demand shock. On the industry level, they mainly focus on how the P/W ratio, also known as the real product wage, is affected by contractionary monetary policy. In 10, out of a total of 21 industries, output declines and the ratio of prices to wages rises as a response to an increase in the FFR[5]. This is evidence in favor of the cost-channel of monetary transmission. What is striking, however, is that when the sample is split into two periods the earlier period, from 1959 to 1979 provides strong support for the cost-channel while the same is not observed from 1983 to 2000. The authors give a few reasons as to why this might be the case. First of all, "the private-sector financial innovations beginning in the 1970s and the deregulation of the early 1980s led to more efficient and less regionally segmented financial markets" (Barth and Ramey, 2001). Another reason might be that during the later period external financing became easier as firms could choose between alternative sources of funding. Moreover, during the former period Central Banks would combine monetary policy with credit actions. For example, after increasing the short-term interest rate the Federal Reserve would put restrictions on the amount of loans banks can give out. Romer and Romer (1993) elaborate more on this matter. According to them when the amount of loans that banks can give out is restricted, "it becomes more

[4] The number of hours worked is used as a proxy for the demand shock (Barth & Ramey, 2001)
[5] FFR is the Federal Funds Rate

difficult for certain borrowers to obtain loans and some of them are forced to pay a premium for funds that is not justified by simple differences in risk" (Romer and Romer, 1993). In this case, firms might increase prices to absorb the increase in borrowing costs. So, on the industry level the conclusion is that the cost-channel is present more strongly from 1959 to 1979.

Christiano, Eichenbaum and Evans (2005) study the behavior of inflation following monetary policy shocks in the presence of staggered wages and prices. The Calvo style price and wage determination used in this paper attaches probabilities to whether firms will reset prices in any period in the future. Moreover, the authors assume that there is habit formation in consumption preferences, there are adjustment costs to investment and there is variable capital utilization. They estimate a VAR model for the US for the period from 1965 to 1995 that includes variables such as inflation (APR)[6], interest rate (APR), investment, productivity, real wages, output, profits and consumption. For most of the variables the data and the model's estimations coincide. More specifically the model accounts for the movement in consumption, investment, profits and productivity which first start increasing and after they have reached their peak they start moving downwards again. The model is also successful at accounting for the dynamic response of inflation and output. During the first three years of the shock, inflation remains relatively steady and afterwards it starts rising. Output continues to rise even after wage and price contracts are reoptimized, which highlights the important role that staggered contracts play in determining the effects of monetary policy shocks. In order for the model to perform well, however nominal wages rigidities are necessary while price rigidities do not change the results significantly.

Ravenna and Walsh (2006), in an analysis of the US economy between 1960-2001 also find evidence for the existence of a cost-channel of monetary policy. They recognize the limitation of the baseline New Keynesian framework, namely that there is no trade-off between stabilizing inflation and stabilizing the output gap[7]. The authors claim that this is not the case in the presence of a cost-channel. Their model consists of households that maximize their utility, monopolistically competitive firms that maximize expected profits, intermediaries that receive deposits and give out loans with an interest rate R_t. Then they proceed to test the following equation.

[6] APR: annualized percentage points

[7] The New Keynesian Phillips curve takes the form $\pi_t = \beta E\pi_{t+1} + \delta (y - y*)$, where $E\pi_{t+1}$ is expected inflation and $(y - y*)$ is the output gap defined as the difference between output and natural output (in the presence of flexible prices). As can be seen from the equation, the two goals of stabilizing output and inflation are not mutually exclusive. "Stabilizing inflation also stabilizes the output gap" (Blanchard, Gali, 2007)

$$E_t\left\{\left(\omega\pi_t - [(1-\omega)(1-\beta\omega)\tau]\left(\hat{s}_t + \alpha\hat{R}_t\right) - \omega\beta\pi_{t+1}\right)\boldsymbol{z}_t\right\} = 0 \qquad (1)$$

where $\boldsymbol{z}_t$ is a vector that "includes four lags of unit labor costs, GDP deflator inflation, a commodity price index inflation, the term spread[8], the nominal interest rate, wage inflation and the output gap". Equation 1 might seem complicated but for this paper what matters is the magnitude and significance of parameter α in order to reach a conclusion about the relevance of the cost-channel. The null hypothesis is: $H_0: \alpha = 0$. In order to test this hypothesis Ravenna and Walsh (2006) use a two-stage GMM (Generalized Method of Moments) estimator and they find α to be 1.276, which is not significantly different from 1. Thus, the null hypothesis is rejected and supportive evidence for the cost-channel is found.

Chowdhury et al. (2006) provide supporting evidence for a cost channel of monetary policy as well. The authors estimate an "interest-rate-augmented" Phillips curve that takes the form:

$$\pi_t = \gamma_f E_t\pi_{t+1} + \gamma_b\pi_{t-1} + xs_t + x(1+\varphi_R)R_t \qquad (2)$$

Where π_t represents the difference in the logarithms of actual inflation and steady state inflation, $E_t\pi_{t+1}$ refers to expectations about future inflation and π_{t-1} is past inflation. Real unit labor costs are added in the equation as s_t[9], R_t is the risk-free interest rate and $(1+\varphi_R)R_t$ is the lending rate. Equation (2) is estimated using quarterly data of G7 countries[10] from 1980 to 1997. The authors find a positive and significant effect of the unit labor costs and the interest rate on inflation in all countries but Germany and Japan. Thus, according to them the cost-channel affects the transmission of monetary policy in the UK, US, France, Italy and Canada. However, the UK and the US exhibit more pronounced effects something that the authors attribute on the "interest rate pass through"[11] which is higher in the aforementioned countries and lower in Germany and Japan.

In order to determine the relevance of the cost channel of monetary transmission, Tillman (2007) employs a New Keynesian Phillips curve framework. The Phillips curve takes the following form.

$$\pi_{t=} \varphi E_t\pi_{t+1} + \gamma\varphi_t \quad (3)$$

Where $E_t\pi_{t+1}$ denotes the expectations of future inflation and φ_t represents the difference between real marginal costs and the steady-state value. Tillman also uses the Calvo pricing

[8] The term spread refers to the difference in interest rates of bonds with different maturity.

[9] $s_t = \frac{w_t l_{it}}{y_{it}}$, where w_t is the wage rate, l_{it} are firm specific labor inputs and y_{it} is output.

[10] Canada, France, Italy, UK, US, Germany and Japan.

[11] The extent to which higher monetary policy rates translate into higher lending rates of financial intermediaries (Chowdhury et al., 2006).

method and thus the inflation rate depends on the probability that firms will adjust their prices in a next period. While most of the empirical papers studying this channel have focused their attention on the United States, Tillman includes the US, as well as the UK and the aggregate Euro Area in his research. For the US and the UK, the data covers the period from 1960 to 2004 while the sample for the Euro Area is from 1970 to 2003. Since the European Central Bank was not yet established in that period the author uses the weighted short-term interest rate of the Euro Area member countries as a representative of the short-term interest rate. The focus of the paper is solely on the supply side effects of monetary policy and refrains from testing for the relevance of the demand channel. However, he acknowledges the importance of the demand channel as the main channel of monetary policy transmission. In order to determine the appropriateness of the forward-looking Phillips curve the author compares the inflation estimates of the VAR model with actual inflation data. The results show that, in the US when the cost-channel is present the correlation between estimated and actual inflation is 0.95. This number drops to 0.85 when the cost-channel is removed from the equation. For the UK the effect is not significant. The results for the Euro Area are similar to those of the US. Overall, the conclusion of the paper is that the cost-channel of monetary policy transmission improves the fit of the model estimates to real inflation data.

In his paper, Rabanal (2007) acknowledges the limitation of the VAR model to capture the forward-looking nature of Central Banks. When a Central bank increases the short-term interest rate it might be because it has foreseen a future increase in prices. Thus, the contractionary monetary policy was not responsible for the increased inflation but rather its purpose was to revert this effect. If this is indeed the case, then any observed price increase might be due to the misspecification of the model and not because of a possible cost-channel of monetary policy.

In order to distinguish between these effects, the author constructs a DSGE model, using a Bayesian approach, for the United States that includes output, inflation, interest rates and real wages. Even when the cost-channel is included in the model, large rigidities in real wages and a non-volatile rental rate of capital are necessary conditions for nominal interest rates and inflation to move in the same direction. However, these features are not found in the data. Instead the authors report a high degree of price stickiness and a low degree of wage stickiness. Overall, they find a zero probability of an increase in inflation occurring as a result of contractionary monetary policy. They base this effect on the low flexibility of prices compared to wages. This will be elaborated in more detail below.

Employment protection in the United States versus Europe

In order for the prices to move in the same direction as interest rates, and thus for the cost-channel to hold, some degree of wage stickiness is necessary. If this is not the case then, when lending rates rise, and firms are faced with higher costs of production, they will choose to lower wages instead of increase prices in order to absorb the rising costs. As mentioned above, Rabanal (2007) refers to the "high degree of price stickiness and the low degree of wage stickiness" as a reason that the cost-channel of monetary policy cannot be supported empirically. The paper of Rabanal, however, is based on US data. In order to have a better idea of wage adjustments in the euro area, which is the focus of this paper, figure 1 was retrieved from the OECD. It depicts how the indicator employment protection differs among countries. According to the OECD the indicator of employment protection measures how difficult it is for firms to lay-off employees and the complexity of the procedures regarding hiring and firing workers that have a permanent contract. As can be seen for the figure below most of the countries in the euro area are shown to have a darker shade compared to the United States, which means that the euro area has higher employment protection. If we assume that the indicator of employment protection can be used as a proxy for the ease with which employers can adjust wages[12], then from *Figure 1* we can infer that wages are more flexible in the US that in the euro area and that might be a potential reason why Rabanal (2007) finds no evidence supporting the cost-channel of monetary policy.

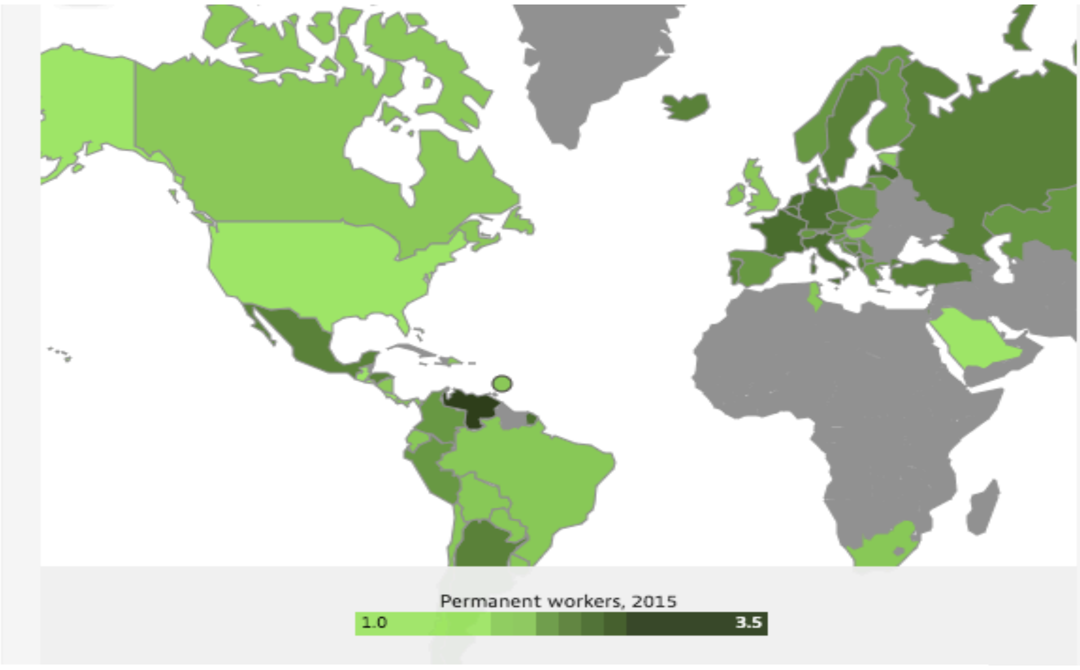

Figure 1: Indicators of Employment Protection; Source: OECD

[12] This assumption is quite realistic since the harder it is for firms to dismiss workers, the tougher it will be to adjust the wage that is mentioned in the contract.

A common assumption in all the aforementioned papers is that firms pay their factors of production before receiving the profits from the sales. Otherwise firms would not need external finance and the nominal interest rate would not affect the marginal costs. This assumption will also be taken in this paper. The difference with the existing literature is that attention will be focused on the euro area after the establishment of the European Central Bank. More specifically, quarterly data will be used from 1999 until 2016. As mentioned above only Tillman (2007) investigates the relevance of the cost-channel for the Euro Area. However, the author studies a period in which the euro area still did not exist and uses weighted interest rates of the countries involved. This limits our possibility to comment on the role of the ECB in the development of the economy. In the next section an overview of the method used in this paper as well as the data will be presented.

III.Research Method

The research method used in this paper depends highly on the work of Gali et al. (1999) and Chowdhury (2006). The former derive a Phillips curve where the inflation rate is determined by real marginal costs instead of the output gap. Moreover, they use future expected inflation in their model and not past inflation values like the case of the traditional Phillips curve. This is the so-called New Phillips Curve (NPC). Apart from taking into consideration a forward-looking approach to price setting, the authors allow for the possibility that some firms set their prices according to past inflation rates and thus they include lagged values of inflation in their estimation. They find supporting evidence for the marginal costs in determining inflation, as well as for future and lagged inflation rates. However, expectations about future inflation rates seem to be of higher significance. In a similar paper Sbordone (2002) also finds evidence in favor of the importance of labor costs and inflation expectations in determining inflation rates. Gali and Gertler (2001) point out the limitation of the traditional Phillips curve in predicting inflation rates in Europe and find that the New Phillips curve is a better predictor of Euro Area inflation rates during 1970-1998.

Since a version of the NPC used in Gali and Gertler (1999) will also be used in this paper it is important that we go through the steps necessary to derive it. First of all, it is assumed that there is monopolistic competition between firms and following Calvo (1983) firms will adjust their prices each period with probability $(1 - \vartheta)$. Thus, the overall price level is $p_t = \theta p_{t-1} + (1 - \theta)p_t^*$, since a fraction ϑ of firms keep the prices of last period. Then we have $\pi_t = p_t - p_{t-1}$.

The "hybrid Phillips curve" estimated in Gali and Gertler (1999) takes the form:

$$\pi_t = \lambda * mc_t + \gamma_f \, E_t\pi_{t+1} + \gamma_b\pi_{t-1} \qquad (4)$$

where mc_t are real marginal costs at time t, $E_t\pi_{t+1}$ is expected future inflation and π_{t-1} is past inflation. In order to obtain real marginal costs, we need a production function, which in this case is the Cobb-Douglas production function $Y = A_t K_t^a L_t^{1-a}$, with A_t representing technology, K_t capital and L_t labor. The marginal cost is then equal to the real wage rate $\frac{W_t}{P_t}$ divided by the marginal product of labor, $\frac{\partial Y_t}{\partial L_t}$. Thus $MC_t = \frac{W_t L_t}{(1-a)P_t Y_t}$. Gali and Gertler (1999) define the ratio $\frac{W_t L_t}{P_t Y_t}$ as S_t and s_t is the "percent deviation from the steady state" (Gali, Gertler, 1999). Thus, the final equation they estimate is:

$$\pi_t = \lambda s_t + \gamma_f \, E_t\pi_{t+1} + \gamma_b\pi_{t-1} \qquad (5)$$

However, the interest of this paper is to find evidence about the relevance of the cost-channel of monetary policy transmission. An assumption that is made for this channel to have real effects if that firms borrow money from financial intermediaries in order to pay for the factors of production since they receive their revenues after these production factors have to be paid out. In order to depict this effect, following Chowdhury et al. (2006), marginal costs are assumed to be a function of the lending rate charged by banks. Thus, we have,

$$MC_t = \frac{W_t L_t}{(1-a)P_t Y_t} * R \qquad (6)$$

$$MC_t = \frac{R * S_t}{(1-a)} \qquad (7)$$

As mentioned also in Chowdhury et al. (2006) the log-linearized version takes the form $mc_t = R_t + s_t$, where R_t is the lending rate that firms have to pay on their loans. If we combine this with the "hybrid Phillips curve" mentioned above we get the following "interest-rate-augmented Phillips curve" (Chowdhury et al., 2006):

$$\pi_t = \alpha E_t\pi_{t+1} + \beta\pi_{t-1} + \gamma mc_t \qquad (8)$$

$$\pi_t = \alpha E_t\pi_{t+1} + \beta\pi_{t-1} + \gamma(R_t + s_t) \qquad (9)$$

This is one of the equations that will be estimated in this paper.

A limitation that has been pointed out very often in the literature (Barth and Ramey, 2001; Chowdhury, 2006) is that the above specification does not capture the fact that central banks take into account expectations about future inflation when conducting monetary policy. If we assume that lending rates are set in accordance with the short-term interest rate set by the central bank, meaning that when a CB changes the short-term rates banks adjust the interest rate they charge on their loans accordingly, then the aforementioned Phillips curve will produce biased results. This is because even though interest rates affect inflation, the opposite also holds, meaning that inflation also has an effect on interest rates due to the reaction of the Central Bank.

Chowdhury et al. (2006) propose a solution to this problem. They estimate the interest-rate-augmented Phillips curve jointly with a Taylor rule by using simultaneous GMM. Their results imply that the cost-channel still has a significant effect on inflation not only because the Central Bank reacts to inflation expectations but because higher interest rates imply higher costs of production for firms. Barth and Ramey (2001) account for this issue by including the forecasts of the Federal Reserve for inflation and output in the equation they estimate, and they find no significant differences in their results. This is "good news" for the cost-channel of monetary policy transmission.

The "traditional" Taylor rule takes the form (Taylor, 1993; Gerlach-Kristen, 2003):

$$r_t = \rho + \pi^* + \alpha_\pi(\pi_t - \pi_t^*) + a_y(y_t - \overline{y_t}) \quad (10)$$

where ρ is the real interest rate which is assumed to be constant, π^* is the inflation rate that the central bank wishes to achieve and $y_t - \overline{y_t}$ is the output gap, the difference of actual output from potential output. Woodford (2001) argues that the traditional Taylor rule is successful in stabilizing output and inflation in the US but suggests that it can be improved by changing the way potential output is measured and allowing real interest rate to vary. In a working paper for the ECB, Gerlach-Kristen (2003), however, shows that once the non-stationarity of the data is taken into account the traditional Taylor rule does not explain euro area data well. Reaction functions that depend on expectations about future inflation rates have seen more support from the literature. In a different working paper of the ECB, Evans and Honkapohja (2002) find that expectation-based reaction functions improve stability. Lastly, Clarida, Gali and Gertler (1998) estimate a forward-looking reaction function that contains output and inflation expectations instead of their gaps and they find that since 1979, the Central Banks in Germany, Japan and the US have been forward-looking.

The reaction function that will be used in this paper is similar to the traditional Taylor rule. However, since it appears that the Central Bank takes into account inflation expectations when conducting monetary policy, a variable for expected future inflation rates will be added in the equation.

In summary, the following two equations will be estimated:

$$\pi_t = \alpha E_t \pi_{t+1} + \beta \pi_{t-1} + \gamma (R_t + s_t) \qquad (11)$$

$$r_t = \alpha_\pi (\pi_t - \pi_t^*) + a_y (y_t - \overline{y_t}) + \rho E \pi_{t+1} \qquad (12)$$

The two equations above will be estimated jointly by Generalized Method of Moments (GMM) estimation for the euro area during the period 2000-2016. GMM solves the problem of endogeneity since for each equation, instruments have to be specified. In addition, Baum, Schaffer and Stillman (2003) state that in the presence of heteroskedasticity the GMM estimator is more efficient than the instrumental variables regression.

The difference of this research from the work of Chowdhury et al. (2006) is that the attention is focused on the whole euro area while Chowdhury only includes France, Germany and Italy, together with the US, UK and other countries. The period on which the authors based their research also differs from the current paper. More specifically Chowdhury et al. estimate their model for the time period 1980 to 1997 while this paper will study the time period of 2000-2016. Moreover, Chowdhury et al. estimate two reaction functions, one that only includes the expected inflation rate and one that includes only current inflation. In this paper current and future inflation are combined and the output gap is added to form equation (12).

IV.Data Analysis

The model specified above will be estimated by using both aggregate data for the euro area as a whole as well as data for nine out of the eleven founding members of the eurozone, namely Austria, Finland, France, Germany, Italy, Luxembourg, the Netherlands, Portugal and Spain. Countries that joined the eurozone after 2000 were not added in the analysis due to data availability.

Analysis of aggregate euro area data.

The Harmonized Index of Consumer Prices (HICP) will be used as an indicator for inflation. According to the ECB, HICP “measures the change over time in the prices of consumer goods and services acquired, used or paid for by Euro Area households”. An advantage of the HICP as a measure of inflation is the fact that it accounts for the differences in definitions used by each single country when measuring inflation (Astin, 1999). In other words, it makes sure that differences in inflation rates are not due to the different criteria applied by member-states when measuring inflation, but they reflect differences in purchasing power. This is why it is called a harmonized index. However, the overall index includes energy and food prices. The prices of these commodities can be very volatile or overshoot for a short period of time and then return to their initial level. Peersman and Van Robays (2009) find that oil shocks explain 39% of the volatility in the HICP from 1999 until 2008. The ECB monthly bulletin of December 2014 states that "the evolution of oil prices has accounted for a noteworthy part of the decline in headline HICP inflation since late 2011".

This becomes clearer in *Figure 2*, which depicts headline and core inflation. The distinction of the two becomes more evident during the period 2008-2012. Part of the development of headline inflation was due to oil-price shocks, which are not relevant for the purposes of this paper so they will not be analyzed in more detail. What is important to note however is that these shocks are not under the control of the Central Bank and this is the reason why in the analysis of this paper core inflation will be used. The quarterly data from 2000 to 2016 was gathered from the ECB statistical data warehouse and from *Figure 2* it can be seen that, from 2002 and onwards, core inflation has been slowly trending downwards.

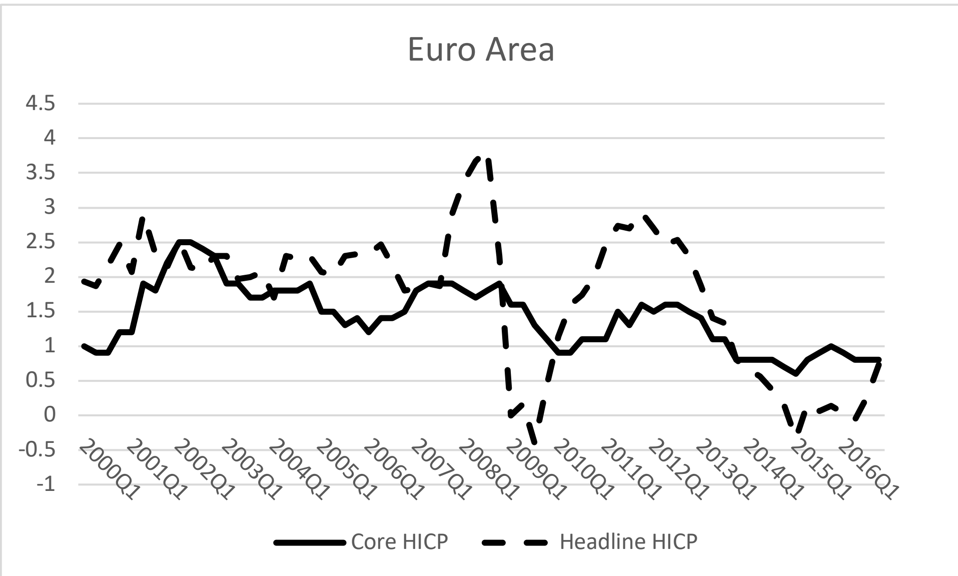

Figure 2: Core & Headline inflation; Source: ECB

Next, quarterly data for expected future inflation were gathered from the ECB survey of Professional Forecasters, whose participants are "experts affiliated with financial or nonfinancial institutions based within the European Union". Expected inflation is depicted in *Figure 1* of the appendix together with core inflation and it is evident from the figure that expected HICP has been following core HICP closely.

As a proxy for the bank lending rates I used the annualized agreed rate on revolving loans and overdrafts, which are arrangements that allow the borrower to obtain a loan, repay it and then take the loan out again. The quarterly data were found from the ECB statistical data warehouse. The data for the money market rate needed to estimate the Taylor Rule in equation (12) were extracted from Eurostat. However, these two interest rates are not completely unrelated.

Bondt (2005), finds that after the introduction of the euro, money market interest rates adjust almost immediately to the short-term interest rate set by the central bank. Also, since 1999 bank interest rates on deposits and loans respond more rapidly to changes in market interest rates.

Sorenser and Werner (2006), in an ECB working paper, use monthly data from the period 1999 to 2004 to estimate the extent to which money market rate changes pass-through to interest rates charged by banks in the Euro Area. They find that bank interest rates do not adjust immediately to changes in market interest rates, however, they do react significantly to misalignments in market rates by adjusting towards their long-run equilibrium. Moreover, their findings suggest that the interest rate pass-through differs significantly across the euro area, with Spain adjusting somewhat faster. This point is important because it highlights the fact that there are differences across member states and the results that hold for the euro area as a whole might be different for each single country. In other words, we might find that the cost channel of monetary policy holds only in some of the euro area member states.

Below the evolution of money market interest rates together with bank lending rates is presented. *Figure 3* confirms that bank lending rates move closely with money market rates.

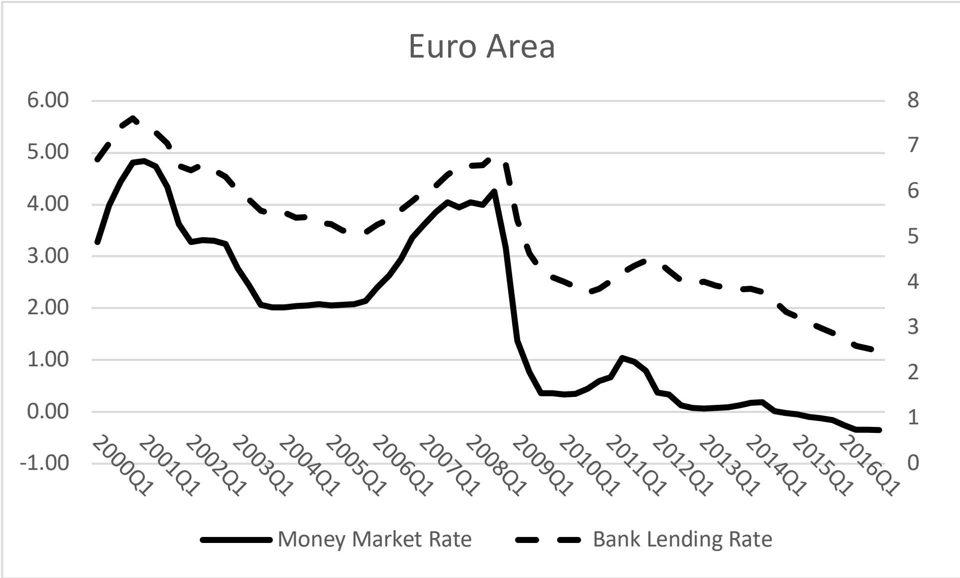

Figure 3: Money-Market rates & Bank Lending rates; Source: ECB & Eurostat respectively

In order to obtain the data for the output gap[13], potential output was interpolated and quarterly interpolated values were then subtracted from the actual output (for which quarterly data is available). Data for potential as well as actual output were gathered from the OECD. *Figure 2* in the appendix shows how the output gaps moves.

Lastly, real unit labor costs are also available at the ECB statistical data warehouse on quarterly frequency. What can be seen from *Figure 4* is that unit labor costs have been trending upwards with a spike around 2008-2009 mostly due to the sharp decrease in headline inflation around that period[14].

[13] The output gap is defined as the difference between actual and potential (GDP if the economy was operating in full employment levels) gross domestic product.
[14] See *Figure 2*.

Figure 4: Unit Labor Costs(Index); Source: ECB

<u>*Analysis of nine euro area countries*</u>

It is also interesting to see whether the significance of the cost- channel of monetary policy transmission differs among individual countries within the euro area. Even though monetary policy is conducted by a single supranational institution, the European Central Bank, the impact in every member state of this monetary policy is different.

For example, inflation rates differ from country to country. In order to estimate equations (11) and (12) the annual growth rate in the Consumer Price Index (CPI) excluding food and energy was obtained from the database of the OECD. *Figure 5* depicts the evolution of the CPI for France, Germany, Portugal and Spain. The rest of the countries can be found in *Figure 3* in the Appendix. All in all, we can see major differences in inflation across countries which are attributed to country specific economic cycles and policy environments. Finland seems to have experienced highly volatile inflation during the whole period[15] that is examined in this paper and thus it will not be studied further. Another outlier when it comes to inflation data is Portugal, in which inflation exceeded 5% in the second half of 2002. For Portugal, thus, a dummy variable will be added for all quarters of 2002.

[15] See *Figure 3* of the appendix

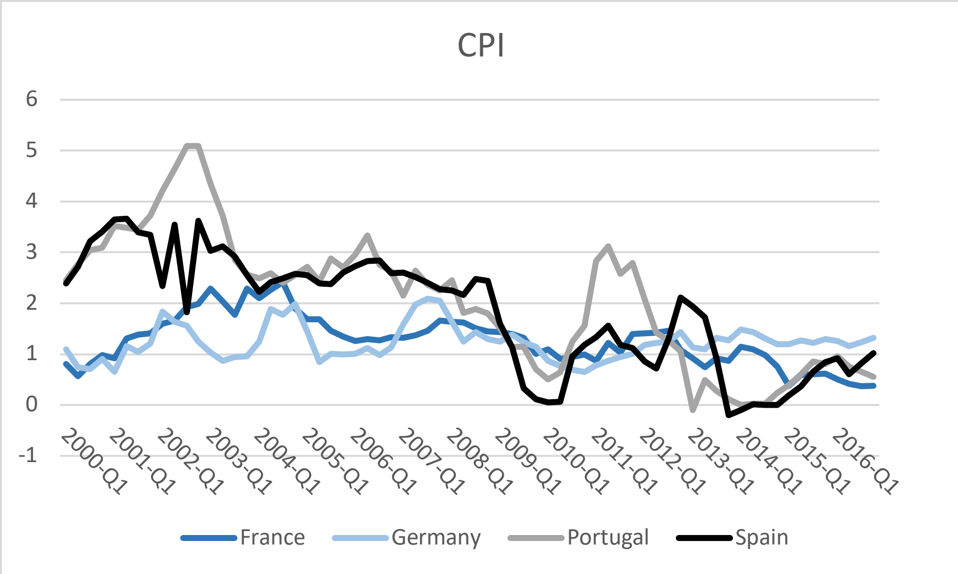

Figure 5: Core inflation(CPI); Source: OECD

Moreover, data for real unit labor costs are available from the OECD and it can be seen that they do not deviate to a great extent from one country to another for the selected countries. The relatively synchronized rise in unit labor costs ended after the financial crisis as Spain and Portugal entered a protracted downturn. *Figure 4* of the appendix shows that the evolution of labor costs for Austria, Italy, Luxembourg and the Netherlands also show relatively synchronized rise. After the Crash of 2008-09, Italy's economy slowed down and thus unit labor costs have deviated from the other countries since then. The change in the trend of unit labor costs will be controlled for by adding dummies for 2008 and 2009, which is the period right after the financial crisis had started.

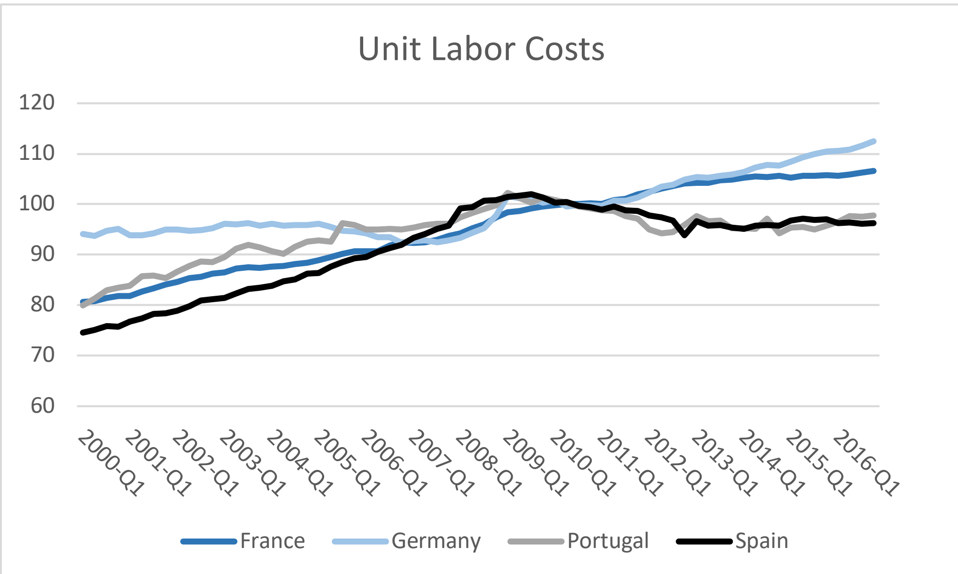

Figure 6: Unit Labor Costs (Index); Source: OECD

Similar to the aggregate euro area, quarterly data for bank lending rates were extracted from the ECB statistical data warehouse and their evolution is similar to the money-market interest rate[16]. Portugal is the main outlier in this figure as lending rates reached 6 % in 2011 when the sovereign debt crisis was at its peak. Since Portugal seems to have been affected more by the sovereign debt crisis there is a need to control for these effects by using dummy variables for all quarters of 2011. The way lending rates developed during the financial and debt crisis were not under the control of the central banks and not controlling for this might produce biased results.

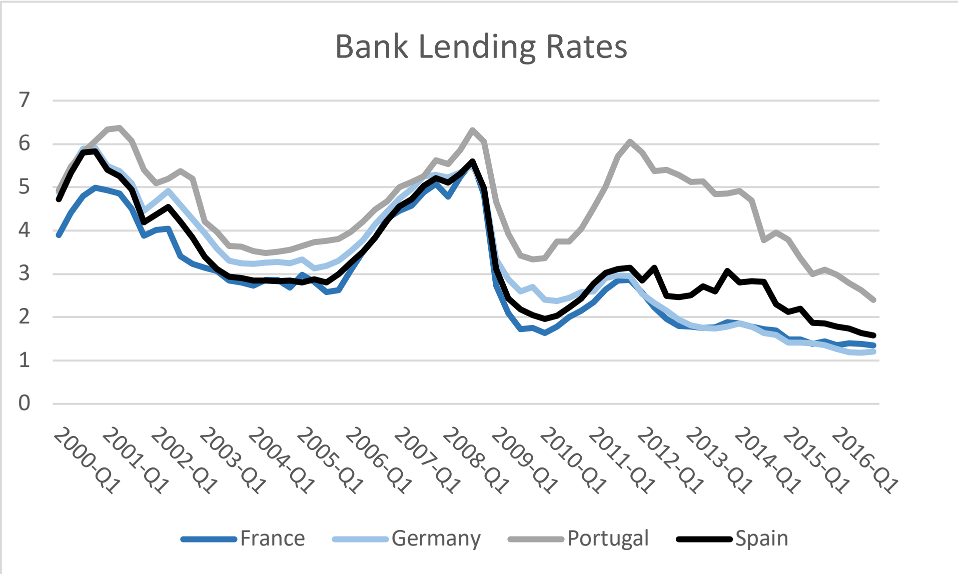

Figure 7: Bank Lending Rates; Source: ECB

Expected inflation as well as money market interest rates are the same as in the case of the aggregate euro area since they are not decided at the country level and individual member-states do not have influence over the values they take.

Lastly the output gap was calculated in a similar way as for the euro area as a whole. First the annual values of potential output were linearly interpolated to create quarterly data, and these were subtracted from actual GDP. The reason this is done is because potential GDP is less volatile than actual GDP and thus interpolated values will be more realistic. The output gap moved in a similar way for all the countries before 2007. After that, however, the output gap started declining and it reached negative territory in 2009. This means that potential output was higher than actual output. The decline in the output gap was more prominent for Portugal and Spain where the output gap kept trending downwards until the end of 2013.

[16] *See Figure 3.*

What can be concluded after analyzing the data for the whole sample of countries is that the effects of the financial and debt crisis should be controlled for. Thus, in summary, I will add dummies for the period 2008Q1- 2009Q4 in the estimation of the Phillips curve. Moreover, only in the case of Portugal a dummy will be added for the year 2002 to control for the abrupt increase in core inflation and another one for 2011 to control the effects of the debt crisis on lending rates.

Instruments

In order to estimate the model, instruments for the independent variables are needed to avoid biasedness in the results coming from variable endogeneity. For the aggregate euro area, the instruments that will be used for equation (11) are the inflation rate excluding energy prices but including food prices and four lags of this measure. Gavin and Mandal (2002) argue that food price volatility has decreased, thus core inflation including food prices could be a good instrument for core inflation. *Figure 6* in the appendix shows that these two measures of inflation have been moving closely together. Additional instruments are the interest rates for government securities together with four lags, four lags of real unit labor costs and four lags of core inflation. Interest rates of government securities follow the movement of lending rates closely[17]. The instruments for equation (12) are four lags of core inflation and the output gap and inflation excluding energy prices together with its fourth lag.

For the individual countries, since there were no complete data available, instead of the treasury bill rates, the money market rates are used as instruments for bank lending rates and their correlation is significant. This was also explained in the data analysis above. The rest of the instruments are the same. Since it is difficult to find instruments for every variable, most of the independent variables were instrumented by their fourth order lag apart from the cases that were mentioned above. The majority of the literature mentioned here uses four lags as instruments when they have quarterly data[18].

In order to more formally assess the relevance of the instruments an OLS regression was run for each one of the equations (11) and (12). In turn the instrumental variables regression (IV) was run and the coefficients of each regression were compared using a Hausman test. The null hypothesis of the Hausman test is that the difference in coefficients is

[17] See *Figure 7* in the Appendix.
[18] See Chowdhury et al. (2006), Gali & Gertler (1999)

not systematic which can be rejected[19] and thus we can conclude that the independent variables of equations (11) and (12) are indeed endogenous and they need to be instrumented. The relevance of the instruments was determined by regressing each independent variable on its instruments and the correlations turned out to be significant[20].

Diagnostic Tests

Before the model is estimated some diagnostic tests are needed in order to avoid biasedness in the results. The first test that is conducted is the augmented Dickey-Fuller unit-root test. This is a test for stationarity of the data and the null-hypothesis is that a time series variable is non-stationary. A variable is stationary if "its mean and variance are constant over time and if the covariance between two values from the series depends only on the length of time separating the two values, and not on the actual times at which the variables are observed" (Hill, Griffiths & Lim, 2012). Since stationarity is very important for time-series the variables are tested. After conducting the Dickey-Fuller test I obtain p-values above the 5% significance level for every variable[21] and thus it turns out that the data are non-stationary. In order to correct for this the first difference of every variable will be used to jointly estimate equations (11) and (12). The first-differenced variables are all stationary.

Another problem found in time-series data is that of multicollinearity among the independent variables. Multicollinearity occurs when one or more variables are correlated with each other. This makes it difficult to distinguish between the separate effects of each variable in the estimation. In the rare case that there exist exact linear relationships among two or more independent variables then we have perfect collinearity and the model cannot be estimated. This does not happen when there is near, but not perfect collinearity. However, the t-statistics will be more significant than in the absence of collinearity and the estimators will be less accurate ((Hill, Griffiths and Lim, 2012). Farrar and Glauber (1967) and Mason and Perreault (1991) report a rule of thumb which states that levels of correlation among independent variables higher than 0.8 or 0.9 are not acceptable as they will generate imprecise estimators. In this paper correlation will be investigated with the use of the correlation matrix

[19] See *Table 8* in the Appendix
[20] See *Table 1* in the Appendix
[21] See *Tables 6 & 7* in the Appendix

reported in *Table 2* of the appendix for the euro area and *Table 3* of the appendix for Austria. The correlation tables for the other countries are not reported but the results are similar.

The correlation between nominal interest rates, lending rates and treasury bill rates always exceeds 0.8. This is both expected and desired. It is expected because banks determine their lending rates by putting a margin on top of money market / policy rates (Fontana and Setterfield, 2009). Treasury bills are the safest assets which means shifts in interest rates affect and are reflected in the interest rates of government bonds and treasuries. Since treasury bill rates are used as an instrument for lending rates as well as short-term rates, high correlation among the three is a desired quality. Similar results hold for the eight individual countries. All in all, we can conclude that there is no severe correlation that exceeds the 0.8 threshold for independent variables that appear in the same equation.

In addition, heteroskedasticity and serial correlation can also be present among time series data. Heteroskedasticity is present when the error terms do not have a constant variance and it is important to correct for this since the t-statistics and p-values will no longer be valid (Wooldridge, 2009). In other words, in the presence of heteroskedasticity we cannot be sure that the significance of the estimators is correct. Serial correlation occurs when the errors are correlated across time and just as in the case of heteroskedasticity, the standard errors and test statistics are no longer valid (Wooldridge, 2009). In order to account for heteroskedasticity and serial correlation in the error term, heteroskedasticity and autocorrelation consistent (HAC) standard errors and weight matrix are used.

Lastly, it is important to test for any structural breaks in the data. A structural break occurs when there is an unexpected shift in the time-series so that the coefficients of the variables differ in different points in time. Even though a graphical representation of the data gives an idea of the period during which the structural break might have occurred, we cannot be sure about what the exact year and quarter is. The Chow test is the most popular test for a structural break, however since the exact quarter of the structural break is unknown, the Chow test requires testing separately for each quarter if we want to determine the actual date of the break. Because of this, this paper will use the Supremum Wald test for a structural break with an unknown break data. The null-hypothesis of this test is that there is no structural break.

After conducting the aforementioned test, I found the existence of a structural break in the France in the fourth quarter of 2004. This effect is significant at the 5% level. Additionally, Spain also had a structural break in its data during the fourth quarter of 2003 which is significant at the 1% level. The test-statistics of the Supremum Wald test can be found in *Table 10* of the Appendix. In order to account for the existence of a structural break, time dummies will be added in the equations for France and Spain. Because of the already small sample size, splitting the data when a structural break is detected would result in a very low number of observations and thus dummy variables are preferred.

V.Empirical Results

Having taken into consideration the results of the diagnostic tests and correcting for non-stationarity, heteroskedasticity, serial correlation and structural breaks, equations (11) and (12) are estimated jointly. *Table 1* presents the coefficients of the joint estimation of the Phillips curve and the Taylor rule including the dummies that were summarized in the data analysis. Namely time dummies for the years 2008-2009 and time dummies for Portugal. Moreover, due to the presence of structural breaks time dummies only in the case of France (2004Q4) and Spain (2003Q4) were added.

Inflation expectations have a positive and significant effect on core inflation for the euro area, Austria, Italy and the Netherlands while no effect is found on the other countries. Moreover, inflation expectations are found to positively affect money market rates in Italy

Table 1: Regression GMM with lending rates, including dummies

	α	β	γ	α_π	α_y	ρ	J-test
Euro-Area	.456** (.23)	.558** (.25)	.0004 (.0007)	-.079 (.39)	.283** (.12)	.046 (.46)	.20
Austria	1.91** (.89)	1.59** (.66)	-.002 (.002)	.49* (.25)	-.005 (.03)	-.27 (.73)	.40
France	-1.36 (1.61)	-.546 (1.49)	.004 (.003)	-1.01 (1.02)	.015 (.09)	5.76 (7.96)	.93
Germany	-.25 (2.05)	- .08 (1.64)	.006* (.003)	-.26 (.24)	.02 (.048)	2.17 (1.84)	.69
Italy	.86*** (.31)	.12 (.30)	.0006 (.0005)	-.26 (.69)	.006 (.036)	2.75*** (.87)	.42
Luxembourg	-1.36 (1.22)	-1.18 (1.74)	.0009 (.0008)	.029 (.22)	.027 (.02)	2.57** (1.09)	.57
Netherlands	1.21* (.72)	.72* (.40)	-.001 (.0014)	-.14 (.45)	.03 (.036)	1.91 (3.43)	.08
Portugal	-1.43 (2.81)	.06 (2.32)	.007 (.012)	.79** (.34)	.013 (.03)	-.935 (2.41)	.39
Spain	-.188 (6.79)	-2.83 (7.09)	.002 (.008)	.657 (1.97)	-.027 (.011)	-.427 (6.73)	.39

**** p<.01, ** p<.05, * p<.10. HAC robust standard errors are reported in parentheses.*

and Luxembourg. These effects of inflation expectations on core inflation and money market rates are depicted by coefficients α and ρ in *Table 1,* respectively. Expectations about higher inflation in the future influence wage settlements which would raise real wages and prices. It also influences how agents behave regarding their decisions about consumption. Also, as it has already been mentioned, when a central bank expects higher inflation in the future, it will raise interest rates now in order to mitigate this effect. However, there are some exceptions. As it can be seen from *Table 1*, in most countries the coefficient of inflation expectations is not significant, and, in some cases, it is even negative. This will be touched upon in more detail in the discussion.

Lagged inflation should also have a positive effect on inflation but that is only the case for the aggregate euro area, Austria and the Netherlands. Lagged inflation is expected to be a good predictor due to inertia, as the factors that drove a rise in inflation the past quarter should have an effect on next quarter's inflation, barring major shocks. The coefficients for lagged inflation are shown in *Table 1* under β.

The coefficient γ is the main interest of this paper since it is the coefficient of the sum of real unit labor costs and bank lending rates and thus it will determine whether or not the cost-channel of monetary policy transmission can be supported by the data. A significant coefficient is only found for Germany. In other words, an increase in the sum of lending rates and real unit labor costs causes an increase in inflation in the specific country only. However, removing lending rates from the Phillips curve and running the regression only with labor costs increases the significance of the coefficient γ from the 10% level to the 5% level[22] which means that the significant result is because real unit labor costs have a positive effect on inflation.

Inflation positively affects interest rates, as can be seen by the coefficient α_π , but again only for a small number of countries, namely Austria and Portugal. This might be due to the fact that the countries of the dataset are part of a monetary union and thus the ECB does not react to inflation in specific countries. However, the fact that we do not find a significant coefficient for the euro area is counterintuitive since the ECB sets the short-term rates in accordance with movements in inflation. Similar results hold when lending rates are removed from the estimation[23].

Lastly, the output gap is found to be significant only for the Euro Area which makes sense since movements in the output gap directly threaten the ECB's inflation target. If the

[22] See *Table 2*
[23] See *Table 2.*

economy is operating above potential output, inflationary pressures build up prompting the central bank to increase interest rates and cool down growth. One reason similar results are not found in the rest of the sample is that the ECB includes only aggregate euro area statistics in its economic analysis.

As we already mentioned, while estimating the model a dummy was added for the years 2008-2009 to control for the effects of the crisis on inflation and short-term interest rates. However, for the majority of the countries in the sample the coefficients of the dummies were not significant[24]. Removing the dummies from the equations though changes the results substantially[25]. Regardless of their insignificance, however, the dummy variables control for time fixed effects during 2008 and 2009. Keeping in mind that during those years there were fluctuations in some of the variables, as analyzed in detail in *section III* the inclusion of the dummies will produce more accurate estimates.

[24] See *Table 9* in the Appendix
[25] See *Tables 4 & 5* in the Appendix

Table 2: Regression GMM without lending rates, including dummies

	α	β	γ	α_π	α_y	ρ	J-test
Euro-Area	.457**	.561**	.0004	-.079	.283**	.046	.20
	(.23)	(.25)	(.0007)	(.39)	(.12)	(.46)	
Austria	1.84*	2.00**	-.002	.45*	-.002	-.14	.47
	(1.11)	(.94)	(.002)	(.25)	(.03)	(.75)	
France	-1.48	-1.06	.004	-.910	.016	4.89	.87
	(1.89)	(2.46)	(.003)	(.88)	(.08)	(6.82)	
Germany	-.138	-.30	.006**	-.26	.03	2.23	.54
	(2.32)	(1.61)	(.003)	(.25)	(.049)	(1.86)	
Italy	.769**	.111	.0008	-.291	.013	2.83***	.35
	(.34)	(.35)	(.0005)	(.70)	(.035)	(.88)	
Luxembourg	-.40	-.19	-.0001	-.002	.032	2.58**	.69
	(3.39)	(5.14)	(.001)	(.24)	(.026)	(1.12)	
Netherlands	1.48	.67	-.002	-.13	.029	1.9	.04
	(.91)	(.43)	(.002)	(.44)	(.036)	(3.37)	
Portugal	-1.45	.107	.007	.799**	.014	-.935	.24
	(.16)	(2.47)	(.01)	(.32)	(.025)	(2.44)	
Spain	4.28	-1.62	-.005	.799	-.035	-1.66	.94
	(6.87)	(4.38)	(.01)	(1.22)	(.08)	(3.92)	

**** p<.01, ** p<.05, * p<.10. HAC robust standard errors are reported in parentheses.*

For the euro area the two equations were estimated using the first differenced GDP deflator, commodity price index and treasury bill rate, as well as four lags of labor costs, HICP, output gap, the treasury bill rate, the GDP deflator and the commodity price index. For the rest of the countries the instruments were similar[26]. However, due to data availability government bond rates were used, instead of treasury bill rates. Since there are more instruments than variables, however, it is important to test for the validity of overidentifying restrictions. In order to test whether the instruments are valid the Sargan's J test was employed. The null-hypothesis of this test is that the overidentifying restrictions are valid and

[26] See *Section IV*.

since all the p-values were above 0.1[27] then we cannot reject the null hypothesis and thus the aforementioned instruments are valid.

In the next section economic an interpretation will be given of the results of the estimation together with explanation for the outliers mentioned above and some limitations of the model.

VI.Discussion and Limitations

In this section the results will be discussed in more detail and possible limitations of the methodology utilized will be examined.

This paper investigates whether the cost-channel of monetary policy exists and is a driving force of inflation. In order to reach a verdict, the simultaneous GMM estimator was utilized to estimate an interest-rate augmented Phillips Curve along with a Taylor rule to simulate the decision making of the central bank in reaction to shifts in the inflation rate and in expected inflation.

The first coefficient estimated measures how expected inflation might influence current core inflation rates. With an interest-rate-augmented Phillips Curve this coefficient is significant for the euro area, Austria, Italy and the Netherlands. The insignificance of inflation expectations in driving inflation in the rest of the countries might be attributed to the fact that the eurozone is not a homogenous economic area and shifts in expectations differ in how they affect behavior in each individual country, rendering each country's estimated effect insignificant. Moreover, the inflation expectations of the ECB might not affect the behavior of economic agents in each country. For example, French workers might not be alarmed by an announcement of the ECB that Euro Area inflation is expected to rise since it might not imply that French inflation will also rise.

Previous period inflation is expected to affect current inflation due to inertia. Thus, insignificant results for lagged inflation for most of the sample were a surprise. The results might be attributed to certain country specific characteristics, such as unique price setting behavior in part of producers, import prices fluctuations, or possibly due to an insufficiently large time series that does not allow for the effects of lagged inflation to appear.

[27] In Tables 1 & 2 of the main text and 4 & 5 of the Appendix the p-values of the Sargan's J test were reported.

More importantly, I did not find any evidence in favor of the cost channel of monetary policy transmission, is which the main interest of this paper. Even though the coefficient γ is significant for Germany, removing the lending rates from the Phillips curve strengthens the significance of the coefficient. This could be attributed to the fact that the data are not long enough for the GMM estimator to reveal the true relationship between inflation and interest-rate augmented real marginal costs. It could also be that lending rates do not affect core inflation and thus the cost channel does not hold in the euro area. However, the insignificance of the unit labor costs in driving inflation points to the deeper problem of lack of sufficient data and small sample bias.

Moving on to the output gap, the Taylor rule assumes that central banks react to changes in the difference between actual growth and potential growth. If the economy is close to full employment and grows much faster than its potential, then the ECB would raise rates to avoid overheating. The results of this paper find significant results for such an effect for the aggregate euro area. This might be due to the fact that even though the ECB's main target is inflation, the output gap is a big determinant of inflation fluctuations. Moreover, as mentioned already, the ECB does not react to individual country statistics which might explain the insignificant results of output gap variable for the rest of the sample.

Finally, for most countries inflation expectations do not seem to affect nominal interest rates. This was not expected since economic agents and central bankers optimize their behavior in accordance with how economic variables might move in the future. The countries for which the coefficient is not significant might be attributed to statistical error or to country specific characteristics. It is possible that persistently low inflation in some countries anchors inflation expectations and agents do not take into account a very low rate of inflation in contracts.

Another important factor that has not been discussed so far is Quantitative Easing, which started in 2015 when the ECB announced that it will buy government bonds and high quality corporate bonds in the secondary market. This unconventional monetary policy means that the central bank cannot be assumed to follow an interest rate based monetary rule. This means that the model estimated here might not explain the data very well. In *Figure 8* actual first-differenced[28] inflation together with the estimates are plotted. In some quarters the values are very close to each other while in others they move in opposite directions. This becomes clearer in *Figure 9* where the residuals are plotted. These are the differences between actual

[28] That is the difference in core inflation from one quarter to the other

and estimated values of core inflation. The largest differences between the first difference of the core inflation that the model estimated and the actual values are found in 2001. In order to control for the effects of QE a dummy is added for the years 2015-2016. After the inclusion of the time dummy, however, the estimated values of core inflation deviate even more from the actual ones[29]. This is counterintuitive since we would expect controlling for an exogenous event such as QE to improve the model estimates. One reason might be that there is too little variability in core inflation as can be seen in *Figure 2,* and thus, even though there was a shift to unconventional measures in monetary policy the effects on core inflation rates were not very pronounced.

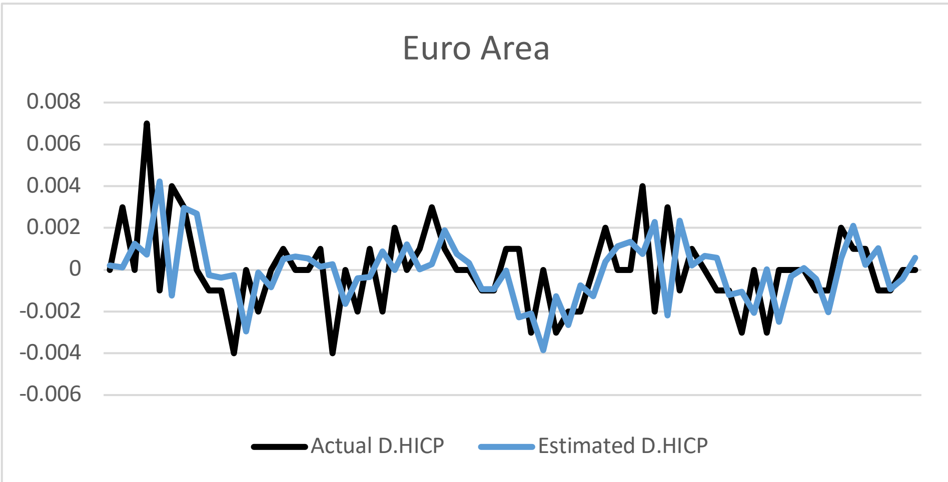

Figure 8: Actual & estimated first-differenced inflation;
Source: Author's Calculations

[29] See *Figure 8* in the appendix

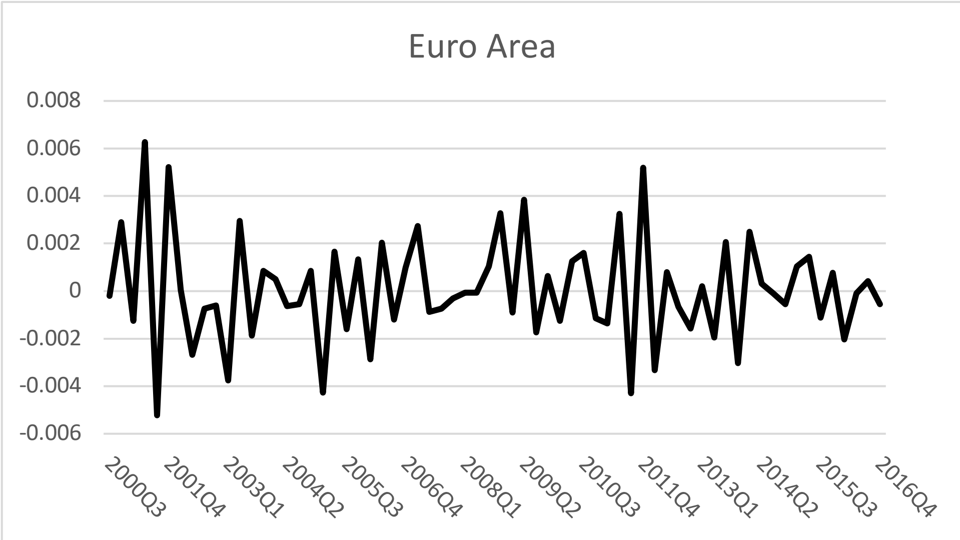

Figure 9: Residuals of first-differenced core inflation for the Euro Area; Source: Author's Calculations

The residuals for Austria[30]show a greater deviation of estimated and actual values with the highest residual being 0.01, which is quite high considering that the highest value for the first- differenced core inflation is 0.07. One reason for this is that the model is better suited to predict inflation for the Euro Area since the ECB responds to changes in aggregate inflation and not to individual country developments.

The reaction function used in this paper predicts money market rates by using actual inflation, expected inflation and the output gap. However, the literature suggests that the ECB might not be using such a stringent approach to setting policy rates. Blattner & Margaritov (2010) suggest that the ECB is "neither backward looking or forward looking but reacts to a synthesis of (…) information. Gerdesmeier & Roffia (2003) find that deviations from the reference value of M3 growth is a significant determinant of policy rate changes. The authors also suggest that the ECB might also have the objective of smoothing out interest rate changes which is then something that should be included in the reaction function of the central bank. Fourcans & Vranceanu (2002) also find that the ECB "smoothens changes in interest rates over time". Finally, the original Taylor contains a term for the equilibrium interest rate and this was not included in this paper due to data availability. This might have also affected the results.

Overall, the results of this paper do not confirm the existence and significance of the cost-channel of monetary policy for most countries. This in contrast to the majority of the

[30] See *Figure 9* in the Appendix(page 49).

existing literature discussed here. One limitation of this paper is data under-availability and thus inadequate observations. Since the main interest was the study of the Euro Area after the establishment of a single currency, the time series where restricted to only 16 years, which if we take quarterly data produce 68 observations for each country. After taking the fourth order lag of some variables and first- differencing the data to correct for non-stationarity, the amount of observations dropped to 63. Lastly, the fact that monetary policy might not follow the Taylor rule specified in equation (12) might have affected the results.

VII.Conclusion

This paper tried to test the validity of the cost-channel of monetary policy transmission in the euro area from 2000 to 2016. The idea behind this channel is that an increase in the interest rate charged by banks increases costs of production for firms since they have to borrow in order to pay for their factors of production. In turn firms will increase their prices to recoup these costs. Thus, interest rates will move in the same direction as prices, which is the opposite of what the traditional interest rate channel would suggest.

An interest-rate- augmented Phillips curve and the Taylor Rule were jointly estimated by Generalized Method of Moments estimation and instruments were included to take into account the endogeneity of the independent variables. Tests were run for stationarity and multicollinearity and the first difference of each variable were used in order to run the regressions due to non-stationarity of the variables. Autocorrelation and heteroskedasticity were also takes into account by reporting HAC robust standard errors. The results show that only Germany has a significant coefficient for the sum of bank lending rates and unit labor costs. However, when lending rates are removed from the equation the significance level rises, which means that the inclusion of the bank lending rates worsens the results.

There are many reasons why this study could not find supporting evidence in favor of the cost-channel. First of all, the time series data is short which might not allow for significance in the results. More specifically, the data range from 2000 to 2016 after the eurozone was established. In this period there are also many “shocks” like the financial crisis, the sovereign debt crisis and Quantitative Easing. It is thus difficult to distinguish between changes in inflation due to increases in the cost of production and due to the aforementioned events. The model fit was investigated further by plotting the actual inflation data together with the estimates of the model. In order to control for the effects of QE a dummy variable was included in the regression which worsened the difference between actual and estimated values. This result might point to the fact that the model used here does not describe the data very well and a different reaction function should have been used but, as mentioned above, it is difficult to distinguish between the different factors that might have led to the results of *section V*.

A suggestion for further research would be to use an alternative reaction function that the one used in this paper. In addition, the estimated coefficients depend on the choice of instrumental variables. A different set of variables might result in better coefficients. Using four lags also means that 4 observations are lost, and the sample size is reduced which, given the already low number of observations, might result in small sample bias. Using longer time series would significantly reduce any small sample bias but getting data before 2000 might not be suitable for studying the effects of ECB monetary policy.

Appendix

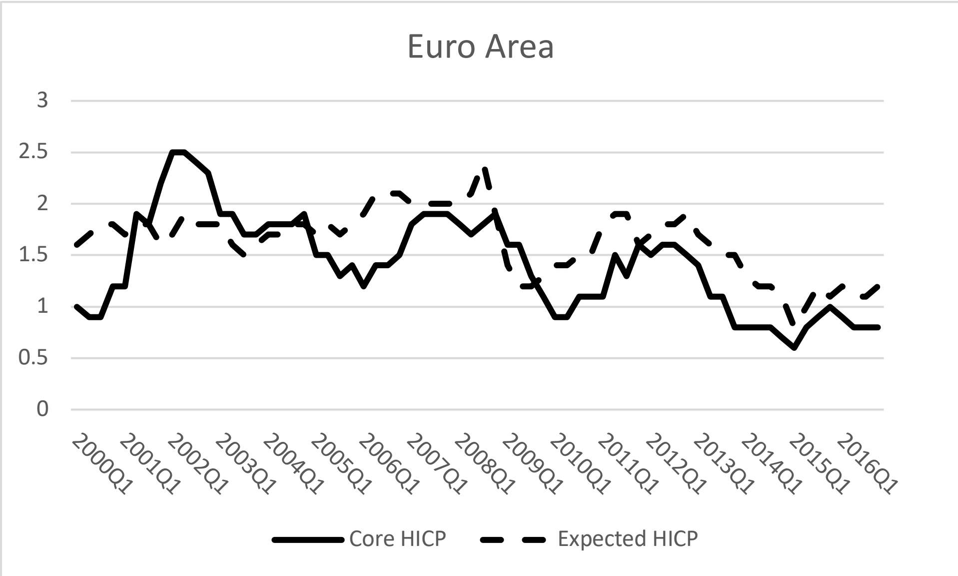

Figure 1: Core & Expected inflation; Source: ECB

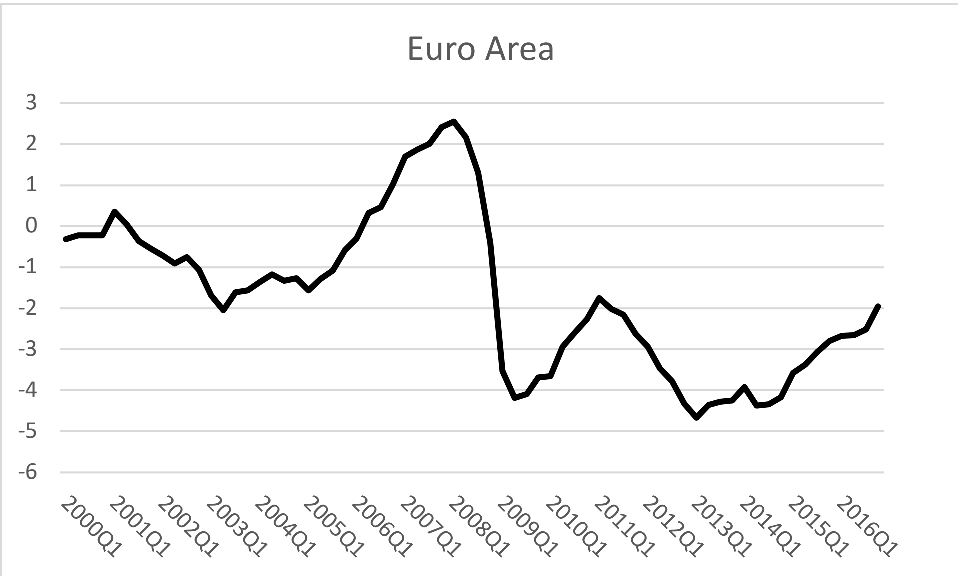

Figure 2: *Output Gap; Source: OECD*

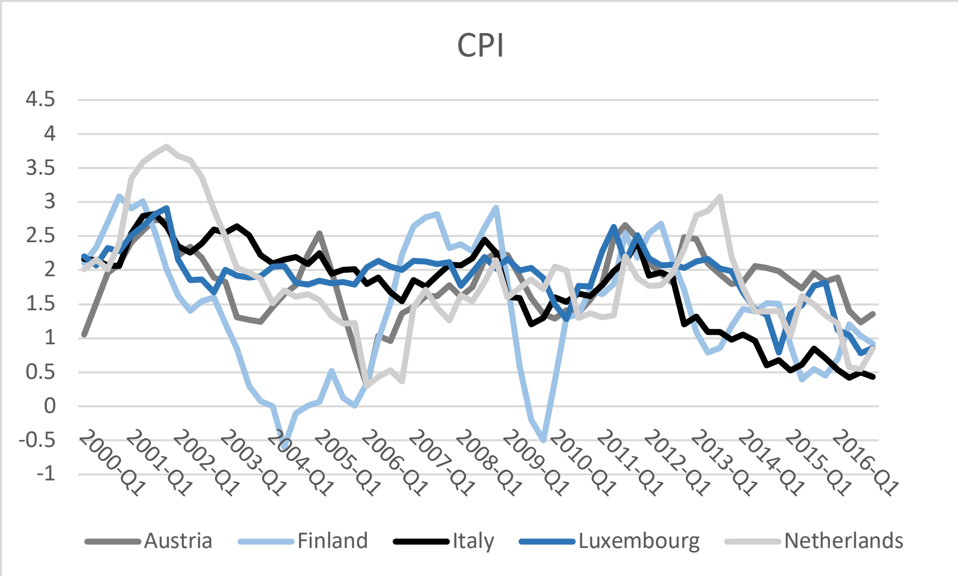

Figure 3: Core inflation(CPI); Source: OECD

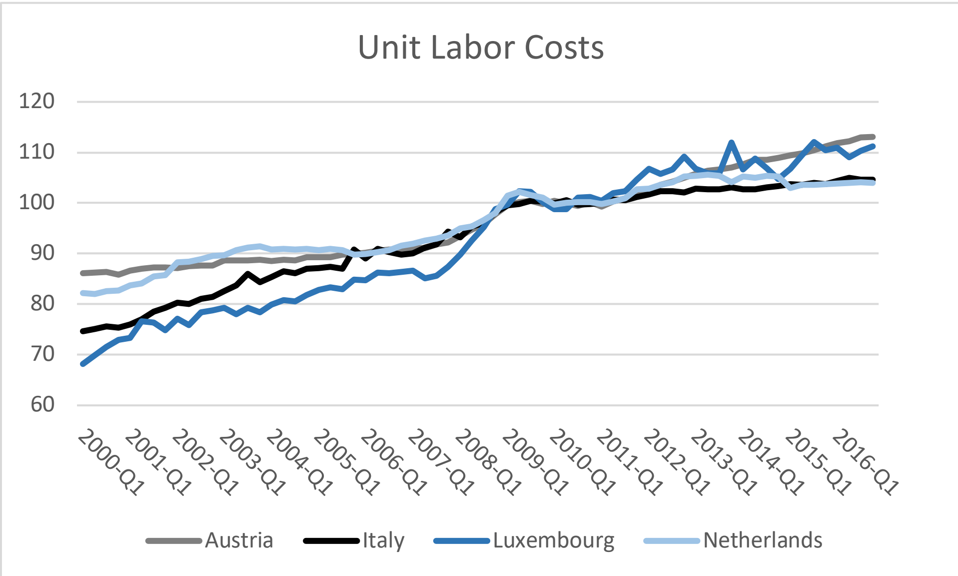

Figure 4: Unit Labor Costs (Index); Source: OECD

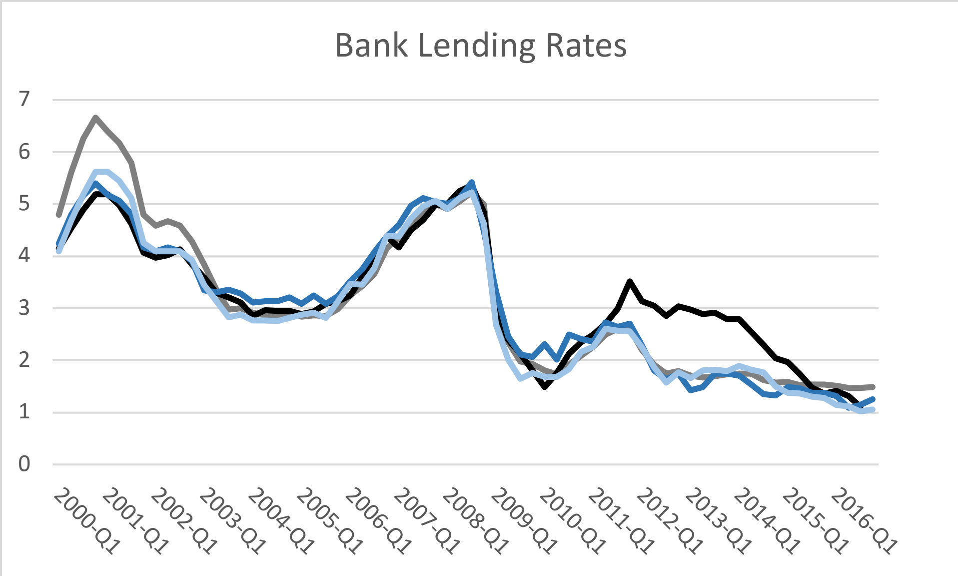

Figure 5: Bank Lending Rates; Source: ECB

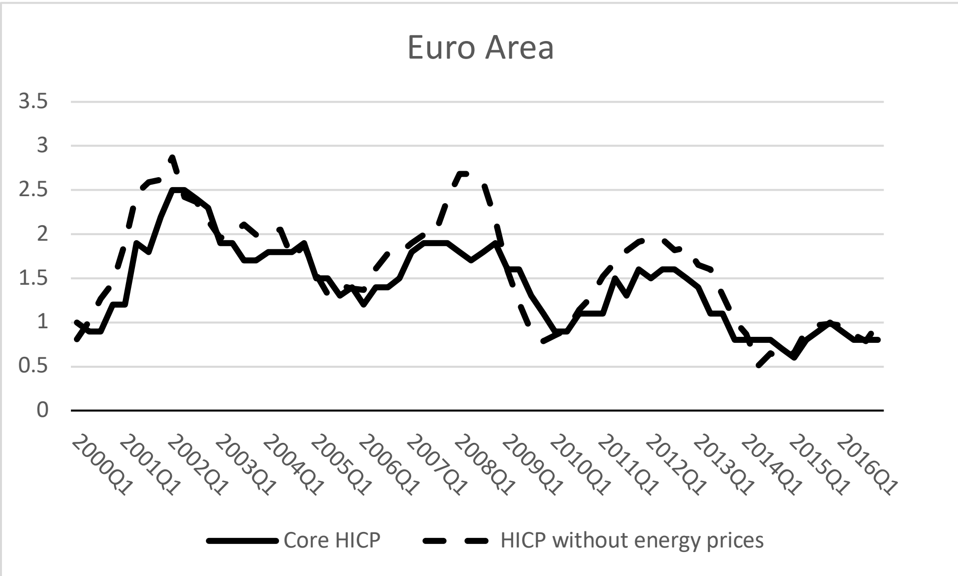

Figure 6: Core HICP& HICP without energy prices (including food); Source: ECB

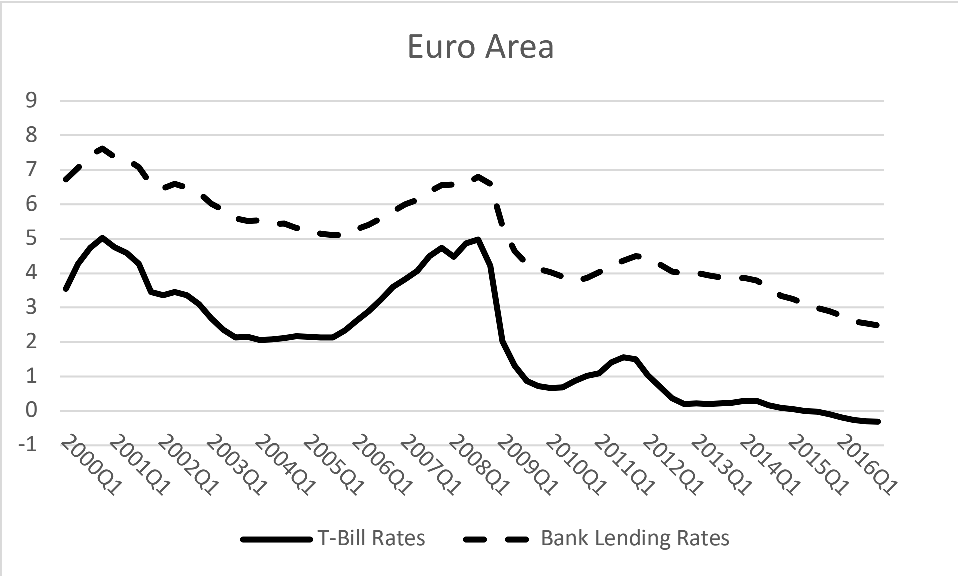

Figure 7: T-Bill rates & Bank Lending rates;
Source: IMF & Eurostat respectively

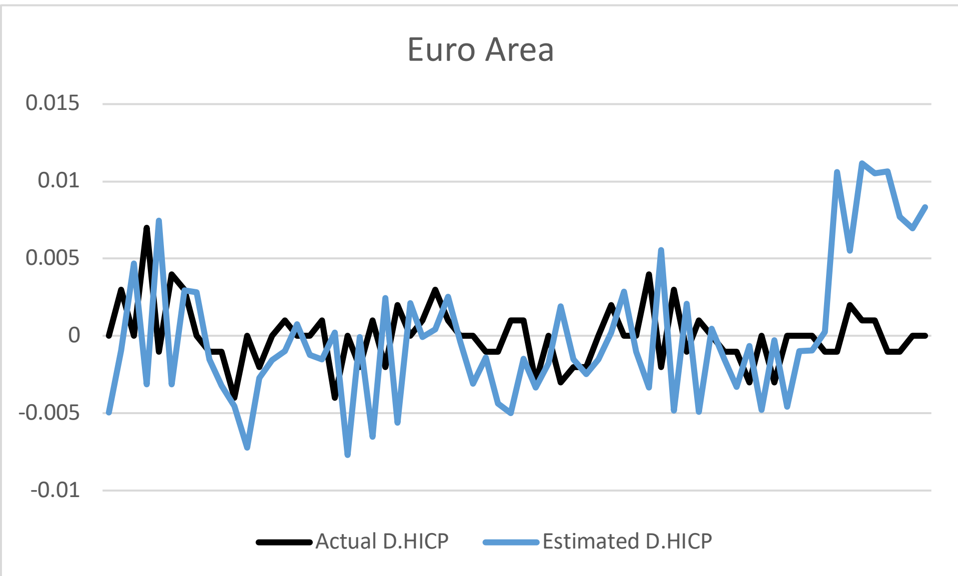

Figure 8: Actual & estimated first-differenced inflation (controlled for QE); Source: Stata Calculations

Table 1: *Relevance of the instrumental variables*

	Core Inflation	Expected Inflation	L.Core Inflation	Lending Rates	Labor Costs	OutputGap
Core – Food						
Euro Area	0.45***	0.40***	0.45***			
Austria	0.62***	0.21***	0.43***			
France	0.46***	0.33***	0.33***			
Germany	0.43***	0.33***	0.32***			
Italy	0.57***	0.25***	0.48***			
Luxembourg	0.67***	0.39***	0.51***			
Netherlands	0.43***	0.09**	0.27***			
Portugal	0.63***	0.10***	0.46***			
Spain	0.77***	0.20***	0.61***			
L4.Core – Food						
Euro Area	0.51***	-0.15	0.51***			
Austria	0.11	-0.07	0.20			
France	0.22***	-0.07	0.21***			
Germany	0.18**	-0.002	0.24***			
Italy	-0.13	-0.08	-0.01			
Luxembourg	-0.19**	-0.02	-0.12			
Netherlands	0.25***	0.01	0.34***			
Portugal	0.06	-0.07**	0.11			
Spain	0.26**	0.09*	0.44***			
L4.CoreInflation						
Euro Area	-0.13	-0.25**	-0.13			
Austria	-0.04	-0.08	0.07			
France	0.26***	0.18*	0.41***			
Germany	-0.14	0.10	0.05			
Italy	0.41***	0.15	0.40***			
Luxembourg	0.06	0.14	0.25*			
Netherlands	-0.05	-0.11	0.06			
Portugal	0.23*	0.15***	0.39***			
Spain	-0.19	-0.08	-0.17			
Money Rates						
Euro Area						
Austria				0.81***		
France				0.78***		
Germany				0.72***		
Italy				0.69***		
Luxembourg				0.77***		
Netherlands				0.86***		
Portugal				0.45***		
Spain				0.70***		
L4.Money Rates						
Euro Area						
Austria				0.03		
France				-0.08*		
Germany				0.11***		
Italy				-0.07		
Luxembourg				0.01		
Netherlands				-0.06**		

Portugal	-0.11		
Spain	-0.09		
L4.LaborCosts			
Euro Area		0.94***	
Austria		1.04***	
France		.95***	
Germany		1.06***	
Italy		0.91***	
Luxembourg		0.93***	
Netherlands		0.88***	
Portugal		0.73***	
Spain		0.85***	
TBill Rate			
Euro Area	0.62****		
Austria			
France			
Germany			
Italy			
Luxembourg			
Netherlands			
Portugal			
Spain			
L4.TBill Rate	0.20***		
Euro Area			
Austria			
France			
Germany			
Italy			
Luxembourg			
Netherlands			
Portugal			
Spain			
L4.OutputGap			
Euro Area			0.61***
Austria			0.60***
France			0.72***
Germany			0.33***
Italy			0.77***
Luxembourg			0.49***
Netherlands			0.65***
Portugal			0.80***
Spain			0.92***

***p<0.01, **p<0.05, *p<0.1

Table 2: Correlation table for the Euro Area

	dHICP	L.dHICP	dExpected lnflation	dLendingrates	dLaborcosts	dNominal Rates	dOutput Gap
dHICP	1.0000						
L.dHICP	-0.0166	1.0000					
dExpectedI~l	0.1491	0.0821	1.0000				
dLendingRa~s	0.2179	0.0883	0.4958*	1.0000			
dLaborCosts	0.1197	0.1242	-0.3475*	-0.2862*	1.0000		
dr	0.1770	-0.0715	0.5829*	0.8533*	-0.5434*	1.0000	
dGap16	0.1077	-0.0943	0.4376*	0.5444*	-0.7307*	0.7166*	1.0000
dTBillRate	0.1796	-0.0214	0.5469*	0.9056*	-0.4764*		0.7103*
dFood	0.4670*	0.1938	0.3644*	0.4235*	-0.1550	0.4362*	0.5055*
L4.dFood	0.1222	0.5249*	-0.0852	-0.0463	0.5379*	-0.295*	-0.4225*
L4.dHICP	-0.0715	0.0336	0.0629	-0.0170	0.2167	-0.0665	-0.1061
L4.dLaborC~s	-0.3558	* -0.2429	-0.0610	-0.3311*	-0.0128	-0.2365	-0.2070
L4.dTBillR~e	0.3213*	0.2322	-0.0836	0.0790	0.3594*	-0.0499	-0.1151
L4.dGap16	0.3086*	0.3473*	-0.1037	0.1874	0.3701*	0.0143	-0.0677

***p<0.01, **p<0.05, *p<0.1

	dTBillRate	dFood	L4.dFood	L4.dHICP	L4.dLendingRates	L4.dTBillRates	L4.dOutputGap
dTBillRate	1.0000						
dFood	0.4294*	1.0000					
L4.dFood	-0.2234	-0.1856	1.0000				
L4.dHICP	-0.0864	-0.1030	0.4682*	1.0000			
L4.dLaborC~s	-0.2957*	-0.369*	-0.1576	0.1131	1.0000		
L4.dTBillR~e	0.0041	0.1637	0.4313*	0.1739	-0.4795*	1.0000	
L4.dGap16	0.0883	0.1795	0.5033*	0.1118	-0.7336*	0.7159*	1.0000

***p<0.01, **p<0.05,*p<0.1

Table 3: Correlation table for Austria

	dHICP	L.dHICP	dExpected lnflation	dLendingrates	dLaborcosts	dr	dFood
dHICP	1.0000						
L.dHICP	0.2873*	1.0000					
dExpectedI~l	0.2374	-0.2316	1.0000				
dLendingRa~s	0.2934*	0.0822	0.5017*	1.0000			
dLaborCosts	0.0802	0.0213	-0.3691*	-0.2965*	1.0000		
dr	0.2859*	0.0403	0.5829*	0.9086*	-0.3697*	1.0000	
dFood	0.6709*	0.1323	0.4444*	0.3783*	-0.1312	0.4293*	1.0000
dOutputGap	0.1202	-0.0746	0.2806*	0.4086*	-0.3439*	0.3404*	0.2120
dTBillRate	0.1044	-0.1766	0.3282*	0.1557	-0.1311	0.1578	0.2021
L4.dCPI	-0.3287*	-0.2035	-0.0634	-0.1031	0.0260	-0.1292	-0.1414
L4.dLaborCost	-0.2297	-0.1910	-0.0850	-0.1519	-0.0052	-0.1233	-0.1604
L4.dFood	-0.1372	-0.0070	0.0728	-0.0747	0.1266	-0.1404	-0.1526
L4.dTBillR~e	0.0140	0.0815	-0.0345	-0.0193	0.1030	-0.0402	-0.1313
L4.dOutputGap	0.1776	0.0537	0.0170	0.2115	0.0680	0.1289	0.1416

***p<0.01, **p<0.05, *p<0.1

	dOutputGap	dTBillRate	L4.dCPI	L4.dLaborCosts	L4.dFood	L4.dTBillRate	L4.dOutputGap
dOutputGap	1.0000						
dTBillRate	0.0144	1.0000					
L4.dCPI	0.0537	-0.0311	1.0000				
L4.dLaborCosts	-0.1331	0.0190	0.0902	1.0000			
L4.dFood	0.0527	0.0945	0.6737*	-0.1307	1.0000		
L4.dTBillR~e	-0.1383	-0.0164	0.0838	-0.1175	0.1909	1.0000	
L4.dOutputGap	0.8323*	-0.0383	0.1303	-0.3436*	0.2053	-0.0042	1.0000

***p<0.01, **p<0.05, *p<0.1

Table 4 Regression GMM with lending rates, excluding dummies

	α	β	γ	α_{π}	α_{y}	ρ	J-test
Euro-Area	.640***	.974***	.0002	1.23	-.132	3.72**	.68
	(.23)	(.25)	(.0005)	(.76)	(.32)	(1.64)	
Austria	.986***	.794***	-.00004	.131	.045	4.44**	.35
	(.32)	(.20)	(.0004)	(.47)	(.06)	(2.05)	
France	.409	.787	.0009	-1.31	-.028	5.85	.21
	(.33)	(.59)	(.0006)	(.89)	(.08)	(6.36)	
Germany	-.901	1.73**	-.002	-.410	.035	4.19	.96
	(.75)	(.83)	(.001)	(.51)	(.058)	(2.71)	

Italy	.797***	.240	- .0003	1.85***	.039	1.06	.42
	(.17)	(.24)	(.0003)	(.43)	(.03)	(.84)	
Luxembourg	.515	1.33*	.0009**	.122	-.022	2.31	.91
	(.35)	(.79)	(.0004)	(.24)	(.02)	(1.44)	
Netherlands	.324	.774***	-.0006	-1.04	.135	14.17*	.22
	(.39)	(.23)	(.0007)	(1.21)	(.14)	(7.31)	
Portugal	1.54	-.825	-.003	1.41**	-.005	-2.00	.56
	(1.44)	(.73)	(.002)	(.50)	(.04)	(3.55)	
Spain	1.13	-2.12	-.0006	-1.19	.109	3.17	.41
	(1.41)	(2.93)	(.002)	(6.23)	(.34)	(16.68)	

**** p<.01, ** p<.05, * p<.10. HAC robust standard errors are reported in parentheses.*

Table 5 Regression GMM without lending rates, excluding dummies

	α	β	γ	α_π	α_y	ρ	J-test
Euro-Area	.639*** (.22)	.974** (.18)	.0002 (.0005)	1.23 (.76)	-.132** (.32)	3.73** (1.63)	.68
Austria	.928*** (.32)	1.12*** (.39)	.00005 (.0005)	.215 (.44)	.036 (.06)	3.60* (1.92)	.35
France	.506 (.56)	2.11 (2.02)	.002 (.001)	-1.05 (.77)	-.021 (.08)	5.55 (5.99)	.42
Germany	-.886 (.76)	1.64** (.82)	- .002** (.001)	-.347 (.43)	.024 (.06)	3.71 (2.28)	.93
Italy	.829*** (.16)	.276 (.25)	- .0003 (.0003)	1.76*** (.49)	.044 (.04)	1.17 (.92)	.31
Luxembourg	.432 (.46)	2.44 (1.63)	.001* (.0008)	.064 (.30)	-.011 (.02)	3.19** (1.50)	.88
Netherlands	.351 (.41)	.784*** (.24)	-.0005 (.0007)	-1.18 (1.25)	.123 (.14)	14.01* (7.23)	.17
Portugal	1.62 (1.53)	-.865 (.74)	-.003 (.002)	1.40*** (.51)	-.005 (.04)	-2.06 (3.58)	.45
Spain	1.56 (2.79)	-4.21 (8.48)	-.001 (.006)	.85 (14.76)	-.012 (.76)	-.396 (38.06)	.72

**** p<.01, ** p<.05, * p<.10. HAC robust standard errors are reported in parentheses.*

Table6: Augmented Dickey-Fuller unit-root test

	Core CPI/HICP	Expected Inflation	Labor Costs	Lending Rates
Euro Area	-1.53	-1.71	-1.46	0.011
Austria	-2.80*	-1.71	1.84	-1.00
France	-1.24	-1.71	-2.06	-1.01
Germany	-2.99**	-1.71	1.42	-0.61
Italy	-0.66	-1.71	-1.96	-0.60
Luxembourg	-1.99	-1.71	-1.26	-0.66
Netherlands	-1.66	-1.71	-1.80	-0.76
Portugal	-1.00	-1.71	-3.14**	-0.74
Spain	-1.78	-1.71	-2.88**	-1.10

*** *p<.01,* ** *p<.05,* * *p<.10*

Table 7: Augmented Dickey-Fuller unit-root test

	Output Gap	Core Inflation incl. food prices	Money Market Rate	T-Bill Rate
Euro Area	-1.29	-1.60	-0.58	-0.61
Austria	-3.23**	-2.58*	-0.58	-0.25
France	-2.89**	-1.77	-0.58	-0.34
Germany	-2.90**	-3.46***	-0.58	-0.35
Italy	-1.97	-1.36	-0.58	-0.69
Luxembourg	-3.69***	-1.77	-0.58	-0.67
Netherlands	-2.69*	-1.42	-0.58	-0.27
Portugal	-2.10	-1.87	-0.58	-1.19
Spain	-1.62	-1.30	-0.58	-0.34

*** *p<.01,* ** *p<.05,* * *p<.10*

Table 8: Hausman test for equation (11) and (12)

(11)	chi2	(12)	chi2
Euro Area	5.23*	Euro Area	14.86***
Austria	22.75***	Austria	11.03***
France	7.35**	France	46.43***
Germany	6.15*	Germany	138.23***
Italy	5.04*	Italy	5.88**
Luxembourg	14.88***	Luxembourg	202.79***
Netherlands	31.54***	Netherlands	11.91***
Portugal	0.75	Portugal	11.03***
Spain	8.63**	Spain	24.80***

**** p<.01, ** p<.05, * p<.10*
H_0: differences in coefficients are not systematic

Table 9: Dummy variable coefficients

	With Lending Rates (1)		With Lending Rates (2)		Without Lending Rates (1)		Without Lending Rates (2)	
Countries	Structural Break Dummy (1)	Structural Break Dummy (2)	Crisis Dummy (1)	Crisis Dummy (2)	Structural Break Dummy (1)	Structural Break Dummy (2)	Crisis Dummy (1)	Crisis Dummy (2)
Euro Area	-	-	-.001	-.005**	-	-	-.001	-.005**
Austria	-	-	.007	-.007**	-	-	.008	-.007**
France	-.016	-.006	-.013	-.003	-.011	-.008	-.013	-.002
Germany	-	-	-.02	-.003	-	-	-.025	-.003
Italy	-	-	-.002	-.003	-	-	-.003	-.002
Luxembourg	-	-	-.01	-.002	-	-	-.005	-.002
Netherlands	-	-	.003	-.008	-	-	.004	-.008*
Portugal	-	-	-.018	-.005	-	-	-.018	-.005
Spain	-.07	.011	-.009	-.004	-.05	.014	.014	-.006

**** p<.01, ** p<.05, * p<.10*

Table 10: Supremum Wald test for structural break

Country	Test Statistic
Euro Area	7.92
Austria	6.44
France	16.31**
Germany	7.41
Italy	8.33
Luxembourg	7.68
Netherlands	6.71
Portugal	7.49
Spain	40.19***
*** $p<.01$, ** $p<.05$, * $p<.10$	
H_0: no structural break	

Table 11: Descriptive statistics for the Euro Area

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
NominaInterestRates	68	0.0181	0.0166	-0.00350	0.0484
ExpectedInflation	68	0.0164	0.00324	0.00800	0.0240
LendingRates	68	0.0504	0.0139	0.0248	0.0762
TbillRate	68	0.0204	0.0168	-0.00313	0.0502
LaborCostIndex	68	95.76	7.386	82.84	106.0
CoreHICP	68	0.0142	0.00473	0.00600	0.0250
OutputGap	68	-0.0167	0.0193	-0.0467	0.0255
CoreHICPfood[31]	68	0.0160	0.00606	0.00510	0.0287
LRLC[32]	68	95.81	7.373	82.91	106.1
dHICP	67	-2.99e-05	0.00192	-0.00400	0.00700
dExpectedInfl	67	-5.97e-05	0.00153	-0.00500	0.00300
dLendingRates	67	-0.000631	0.00237	-0.0123	0.00373
dLaborCosts	67	0.346	0.435	-0.440	2.160
dr[33]	67	-0.000542	0.00348	-0.0180	0.00700
dOutputGap	67	-0.000243	0.00568	-0.0313	0.00709
dTBillRate	67	-0.000575	0.00385	-0.0220	0.00720
dFood[34]	67	2.54e-05	0.00219	-0.00570	0.00560
dLRLC	67	0.345	0.435	-0.441	2.148

[31] Core inflation including food prices.
[32] Sum of lending rates and labor costs.
[33] Fist-differenced nominal interest rates.
[34] First-differenced core inflation including food prices.

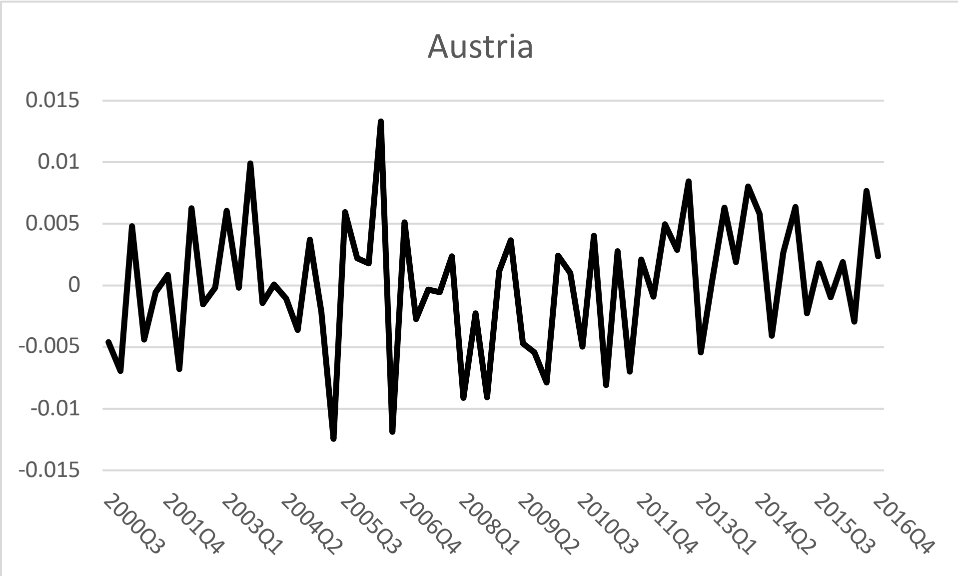

Figure 9: Residuals of first-differenced core inflation for Austria; Source: Author's Calculations

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