INTEREST POLICY IN THE EUROZONE ACCORDING TO THE TAYLOR RULE

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Index

1. Introduction

The European debt crisis was so disastrous that it almost caused the end of the euro. Due to the monetary intervention of the European Central Bank (ECB) in the summer of 2011, the euro still exists (Kennedy & Speciale, 2015). But the problems are thereby not over. In the years that followed, there was nearly no economic growth or inflation. In an ultimate attempt to counteract this, the ECB lowered the interbank interest rate to zero percent in 2016 (Beunder & Pijpker, 2016). This extraordinary policy leads to a heavy debate between members of the European Monetary Union (EMU)(Ten Bosch, 2016). The reason for this is the growing divergence in economic conditions between Eurozone members (ECB, 2015). The global crisis differed in duration and impact among especially northern and southern states (Gibson et al., 2013). After the bad year of 2009, Germany had no negative GDP (annual) growth rate. Spain achieved that considerably later in 2014 (OECD). There were also differences in inflation. In 2015, Austria had inflation of 0.9 percent, while Greece had deflation of 1.7 percent (OECD). The low interest rate generates resistance in Germany, where it can cause overheating of the economy (Jonker & Kooiman, 2016). More firms and consumers can borrow money to buy products. This will increase demand, resulting in an upward pressure on prices. On the other hand, decreasing prices can be bad for the economy (The Economist, 2015). Firms and consumers can delay purchases. That's why an inflation close but below 2 percent is healthy, the anchor of the ECB. There are several instruments that the ECB can use in order to manage this. One of them is controlling the total amount of money. An increasing or decreasing amount can determine the 'price' of money. The ECB buys for 80 billion euro's government securities each month. By increasing the amount of money the interest rate will fall, leading to a higher inflation (fd, 2016). But this indirect way of controlling the inflation rate takes time and is uncertain. Nowadays central banks, as also the ECB, set now directly the interbank interest rate where against commercial banks can borrow money (Croce & Khan, 2000). Those will in turn pass the rate on consumers and firms who want credit. It's a difficult task for the ECB to set this rate that fit somewhat for all his members. Given the mentioned divergence, the research question is:

Are the economic conditions and preferences between Euro members so different that one interbank interest rate that applies to all is still desirable?

Many economists developed theories about how interest rates must be set. One of them is John B. Taylor. He developed in 1993 a formula called the Taylor Rule (TR), which gain popularity due to its simplicity. It combines the country's economic conditions together with their preferences about monetary policy to compute the interbank interest rate. The economic conditions are the inflation gap and the output gap.

The inflation gap is calculated by subtracting the current inflation by some desired inflation level. The output gap is the difference between the GDP growth rate and the trend GDP growth rate. According to changes in those conditions, the central bank will respond by either increasing or decreasing the interbank interest rate. The magnitude of this altering depends on the preferences of the central bank. Some favor price stability. Those will react strongly when the inflation moves away from their target level. Others care more about economic growth and will mainly react when the GDP growth rate is lower than the trend GDP growth rate. Normally, central banks will only mention their interbank interest rate and not explicitly their preferences. Nevertheless, it can be estimated. The TR reflects the preferences by using the parameters on the inflation gap and the output gap, respectively α & β. A high α indicates a strict inflation policy. A high β indicates a policy more based on economic growth. Since the inflation gap, output gap and the interbank interest rate are known, the preference parameters can be estimated by an Ordinary Least Square (OLS) function. This study applies the OLS function on 11 EMU members: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal and Spain. Prior to the EMU, which started in 1999, those countries had their own central bank that was responsible for their domestic interest rate policy. With their interbank interest rate as input for the OLS function, together with their individual inflation gaps and output gaps, this paper estimates the preferences for each country, which they had prior to the EMU.

With the estimated preferences, we can calculate the TR implied interest rate (i_{TR}) for each member over the period 1999 to 2015. The i_{TR} is the rate that the national central bank in theory would have set. In reality, the ECB took control after 1999. They have the full autonomy to set the interbank interest rate that applies to all his members. The rate on the Main Refinancing Operations (MRO) is the most important one, since this is the main source of liquidity for commercial banks. To see if there is a difference between Euro members, this rate will be compared to the i_{TR} of each member. If one interbank interest rate policy is still desirable depends on the difference between the rates. If those are far away from each other, it can lead to serious problems. It's indeed shown that the rate of the Federal Reserve was too low in the period 2002 – 2005, according to the TR. This resulted in an overheated economy and the burst in 2007 (Lee, 2009). A same scenario for the Eurozone would be alarming, since there influence on the world economy.

However, this study shows that the differences between the i_{TR}'s and the rate of the ECB are reasonable. Only in the period after the financial crisis (2008-2012), the ECB rate seemed to be too expansionary. Nevertheless, it didn't lead to major inflation and output gaps. On the contrary, especially inflation started to decrease till the end of 2015, resulting in many i_{TR}'s below 0 percent. This indicates that the extraordinary policy of the ECB in the post-crisis period is justified.

This thesis has the following structure: After the introduction, section 2 contains the literature review. Section 3 introduces the data and the methodology. Section 4 shows the outcomes of the TR of all selected EMU members and section 5 discuss the results. Finally, the concluding remarks are in section 6.

2. Literature review

2.1 Interest rate

To get the basic idea of how the interest rate influences the economy, we look at the supply side and the demand side. At the supply side, let's assume the following cost function of a firm (Frank, 2010):

$$(2.1)\ C = wL + rK$$

The cost of production is the amount of labor L multiplied by wage w plus the amount of capital K multiplied by interest rate r. In order to make products, a firm faces the production function $F(K, L)$. In respect to capital, a firm has the most efficient production when equation 2.2 holds. It states that r must equal the marginal product of capital (MPK) times the value p (selling price) of the product. The MPK, described in equation 2.3, is the amount of extra products that one additional unit of capital can make.

$$(2.2)\ r = p * MPK$$

$$(2.3)\ MPK = {\Delta Q}/{\Delta K}$$

The relationship between capital K in the production function and output Q is illustrated in figure 2.1. Output Q is increasing in K ($F'_K(K, L) > 0$), whereas the MPK is decreasing in K ($F''_K(K, L) < 0$). Investing in the first amounts of K result in a high increase in Q. But when K is high, extra units will not cause a major increase in Q. When the interest rate increases, firms have to decrease their amount of capital to a level where the marginal product is high enough (because the MPK is decreasing in K). By reducing K, the MPK will go up. So, increasing r will reduce the demand for capital, resulting in a lower output. Another implication is the technology. When there are technical improvements, the MPK increases (red line in the figure). Firms want to invest in capital since it's more productive. More demand for capital will increase the interest rate. It also works backwards. Policy makers can lower the interest rate, making investing in projects with a lower MPK still advantageous. This will increase the output.

Figure 2.1: production function

Q

F(K,L)

F(K,L)

K
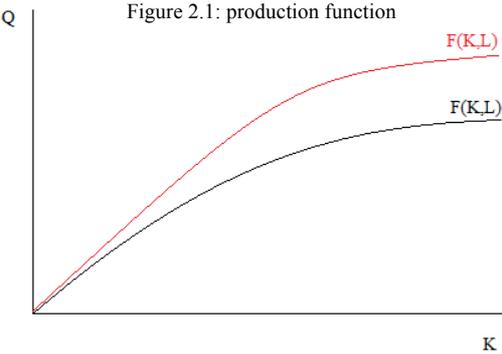
At the demand side: interest rates have impact on the amount of consumption. When central banks increase the interest rate, credit is more expensive and so is consumption. Also, if consumers decide to spend money instead of saving it for the future, they miss more interest income (opportunity cost).

In the economic theory, interest rate, inflation and output have all impact on each other. To begin with the interest rate: A low interest rate makes investment and consumption today cheaper. Firms increase production and investment, and consumers have a larger incentive to consume today (possibly by borrowing money) rather than saving. A higher demand for goods will have an upward pressure on prices (inflation). When this effect is strong or takes over a longer period of time, the economy can be overheating. A central bank wants to avoid this by increasing the interest rate. Capital is more expensive, so consumers and firms will spend less money. Less demand implicates a downward pressure on output and prices. But in reality there are lags between variables, which makes it harder for the central bank to control it (Svensson, 1996).

2.2 Trade-off

Economist William Phillips described in 1958 the trade-off between inflation and unemployment. In his Phillips curve (PC), those two are negatively correlated. High inflation indicates that unemployment is low and the same applies for the other way around. Equation 2.4 describes the PC.

$$(2.4)\ \pi_t = \gamma\ (U_t - U_{t-1})$$

The unemployment is described as U. If the unemployment goes up ($U_t - U_{t-1} > 0$), the inflation π_t will decrease by a magnitude U multiplied by a constant factor γ. For the PC to hold, we must have that $\gamma < 0$. Bhattarai (2016) found evidence for this relation between 1990 and 2014 for the first 11 EMU members, except for Austria and Germany. The magnitude γ ranges between $-0,133$ for Spain to $-0,879$ for Belgium. In contrast to Bhattarai, Del Boca et al. (2011) didn't find this relation in Italy in the post-WWII period. Nevertheless, he argues that the trade-off is visible in periods of low inflation and economic stability. Llaudes (2005) found a clear relation for all EMU members. He even made a distinction between short-term and long-term unemployment, where the latter one has less impact on inflation. Kanellopoulos and Koutrolis (2016) estimated a negative correlation between inflation and unemployment for the first 11 EMU members, except for Germany and Luxembourg [1997:2015]. Some researches argue that the PC became flatter over the years (lower γ in absolute terms). There is a strong indication that this is caused by globalization. Firms have fewer boundaries and can switch production to low-income countries easier than before. This increased openness led to higher productivity and lower prices. Foreign firms put pressure on profit margins of domestic firms, where after a while the least competitive ones have to shut down. Chen et al. (2004) showed that EU openness has negative effect on inflation, because firms have less space to markup their prices.

Kuttner and Robinson (2008) mention that better monetary policy lowered the trend inflation. Inflation around the world declined after the 1980s and became more stable (Borio & Filardo, 2004). Therefore, firms don't have to change their prices that frequently as they were used to in the past, which also contributes to the flattering of the PC. Bentolila et al. (2008) examined the PC for Spain [1982:2006], stated that immigration flattered the PC. With greater supply of workers, domestic employees have less bargaining power in setting their wages. A flatter PC has several implications for monetary policy. Bean (2006) stated at one hand that demand shocks and political errors don't lead to major inflation movements. At the other hand, with less impact of output on inflation, it's more difficult for policy makers to use that tool in order to keep their inflation at target. That is especially problematic when inflation is above target, since the central bank has to slow down the economy even more.

By introducing the Okun's law (equation 2.5), we can make the link with this trade-off to the TR. This law states that unemployment is negatively correlated with output. High unemployment is associated with low output and low unemployment automatically with high output.

$$(2.5)\ (y_t - y_{t-1}) = \beta_t(U_t - U_{t-1})$$

How much the output y responds to a change in the unemployment U depends on the constant variable β. Moosa (1997) showed that output is more responsive to a change in the unemployment rate in the US and Canada than in Europe. For example, the US had a coefficient of $-0,465$ compared to $-0,202$ for Italy. Reason for this is that workers are more protected in Europe, which makes the labor market more rigid. In the US and Canada, the labor market is more flexible, because employers can adjust their workforce easier and faster in regard to economic growth. Combining the PC and the Okun's law, we get the aggregate supply curve (equation 2.6).

$$(2.6)\ \pi = \rho(y - \bar{y})$$

Economic theory suggests that inflation π and the output y minus the trend rate $\bar{y}$ must move in the same direction ($\rho > 0$). A one-percentage point increase of output effects the inflation by a magnitude ρ. Bolt and Els (1998) confirmed indeed a positive effect. They found that ρ was 0,780 for Austria, 0,45 for Finland 0,45, 0,61 for France, 1,67 for Italy, 0,43 for the Netherlands, 0,39 for Spain, 0,53 for Germany and 0,84 for the Eurozone. For the most EMU members the data range was [1975:1996]. Some studies showed that a positive output gap increases the inflation more than a negative output gap with the same size would reduce it (Valadkhani, 2014). This suggest that in absolute terms: $\rho_{y-\bar{y}>0} > \rho_{y-\bar{y}<0}$

2.3 Taylor rule

John B. Taylor introduced in 1993 the TR:

$$i = r^* + \alpha(\pi - \bar{\pi}) + b(^{Y - \bar{Y}}/_{\bar{Y}})$$

It functions as a guide for central banks or policy makers to set the nominal interest rate[1] i, depending on the deviation of inflation π from the central bank's target $\bar{\pi}$, the output gap and the neutral real interest rate r^*. The output gap is described as $Y - \bar{Y}/\bar{Y}$, with Y as the GDP growth rate and $\bar{Y}$ as the trend GDP growth rate. The parameters α and b represents how strong the central bank reacts in adjusting their interest rate in response to deviations in inflation and output respectively. Taylor (1993) himself suggested 1,5 for α and 0,5 for b. This means that when inflation increases to 1 percent above target (=2 percent) and the output gap is zero or unchanged, the interest rate will follow with a 1,5 percentage point increase. But central banks are free in setting their own interest policy, although they never explicitly mention their distribution of α and b (De Sà & Portugal, 2015). Those have to be estimated to conclude in which extent the central banks cares about both inflation and output. Giving more 'weight' to one implicates directly a loss for the other. For example: setting the interest rate higher will give negative pressure on inflation, but this is at the cost of output. The stricter the inflation policy is, the more output it costs.

Most indicate that the TR is not linear, but asymmetric. Neuenkirch and Tillmann (2013) showed that policy makers set now higher interest rates when inflation passed their target. This is because inflation is harder to control, as explained by the PC. But in according to Neuenkirch and Tillmann, they do this also for their 'credibility' to the market. When the market believes that the central bank will really fight inflation, it's able to set a lower interest rate than the TR would suggest. Ikeda (2010) revealed that the ECB reacts asymmetric on output. There is a growing aversion for positive output gaps, which trigger positive inflation shocks. The ECB tries to prevent this, since it's more costly to bring inflation down. They are stricter in managing their inflation than the Federal Reserve in the US, which puts more weight on output (Belke & Klose, 2010). This became clear when the financial crisis started in 2007. The Federal Reserve started to cut the interest rate in August that year, while the ECB waited till October 2008.

Since March 2016, the ECB arrived at the zero lower bound. The most important rate was set on 0 percent. In a period of economic crisis, the central bank might change their policy. Additional variables must be added to the original TR to avoid omitted variable bias (Belke & Klose, 2013). This can be the money supply, which is another major tool in monetary policy. In March 2015, the ECB started to increase the money supply by buying securities for 60 billion euro each month. By increasing this amount of money, the ECB had lowered the interest rate and the value of the euro (De Grauwe, 2016; Blitz, 2016). This is positive for the export, since products form the Eurozone are cheaper for non-euro countries. That's the reason why some researches add currency value as a variable to the TR.

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[1] The real interest rate is the nominal interest rate minus the inflation rate

2.4 NRIR

Swedish economist Kurt Wicksell introduced the neutral real interest rate (NRIR) in 1898. It's the rate that equates saving and investment, which would equal the marginal product of capital in the long run. When the interbank rate is the same as the NRIR, there is no inflationary or deflationary pressure on prices. That's the case when inflation is exactly at target and economic growth follows the trend. The NRIR, Often called the 'equilibrium' or 'natural' rate, is a variable in the TR. When the sum of the preference weighted inflation gap and output gap is positive, the interbank rate must be higher than the NRIR (r^*). On the contrary, when the sum is negative, the interbank rate must be lower than the NRIR. As a benchmark for policy makers, they can estimate if their policy is expansionary ($i < r^*$) or contractionary ($i > r^*$). That implicates automatically that the interbank rate must equals r^* when there is no inflation gap and output gap. But unfortunately, it's not as straightforward as here assumed. The problematic aspect of the NRIR is that it can't be observed. A popular model to estimate it is introduced by Laubach and Williams in 2001. An important issue that that they mention is the time-varying aspect of r^*. It's dependent on variables that influence output, like population growth and technological improvements (Amato, 2005). If those rates are increasing, r^* will move in the same upward direction, since investing capital is more profitable. Their estimation of r^* is described in equation 2.7. The first variable is the trend output growth rate g_t, multiplied by a constant c. The second variable z_t captures all other temporary variables that have impact on r^*, like time preferences of consumption and the strictness of lending policies[2].

$$(2.7) \; r_t^* = c g_t + z_t$$

It's widely believed that the NRIR has a downward trend. Vargas (2016) showed by using the Laubach and William's model (LW) that the NRIR in the US was decreased from 1,898 percent [2000:2007] to only 0,55 percent [2008:2015]. Garnier and Wilhelsmsen (2005) estimated with the same LW model that in the Eurozone, the NRIR declined from 4 percent in the 1960s to less than 2 percent in 2004. One reason is the demographic change in the US, Japan and Western Europe (Carvalho et al., 2016). Japan has a downward pressure on the real interest rate, because of a declining ratio of working people to the total population (Ikeda & Saito, 2014). The same applies for Europe, where the natural population growth is already decreasing (Eurostat). But even between EMU members there are significant differences in the NRIR. Wintr et al. (2005) estimated that the NRIR of Luxembourg is twice as large as the average of the Eurozone. This can be explained by the population growth of Luxembourg, which has been remarkable since 1990 (Worldbank). It's also plausible that Luxembourg's technology is at a higher standard than the average EMU member. This difference in rates among EMU members can be a problem for the ECB. For members with a fast growing economy, the interest rate might be too low, which triggers the probability of high inflation.

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[2] Note that this explanation is very simplified. For full explanation, see 'Measuring the Natural Rate of Interest' by Thomas Laubach and John Williams (2001)

2.5 Differences within the EMU

For the ECB, monetary policy is more difficult, since there are currently 19 member states. Each member has equal voting power. Prior to the start of the ECB on the first of January 1999, there was already made effort to 'tune' the monetary policies to one another. In the Maastricht Treaty of 1992, the European Community had set some rules. One rule was that inflation wasn't allowed to be higher than 1,5 percent than the averaged one of the 3 members with the lowest inflation. But beside this fact, central banks of EMU members had (and still have) different opinions about monetary policy. The public opinion in the Netherlands suggests that there is mainly a conflict in monetary policy between northern members and southern members (Klamer, 2016; Teulings, 2014; Hofs, 2013). A lot of South-European banks have liquidity problems. The ECB wants to give them some flexibility by charging a low interest rate. This can be dangerous for countries like the Netherlands and Germany, where plenty of credit has to find a destination. This can cause high inflation and bubbles in for example the housing market. But already before the start of the ECB, some were concerned about the conflicts in interest. Martin Feldstein expected in 1997 that an equally vote system in the council of the ECB would lead to anger in Germany. Germany is the biggest economy in Europe and has a history of strong inflation aversion. But some members might care less about inflation. They want a more expansionary monetary policy when the unemployment is high, accepting the higher inflation in the future. Clausen and Hayo (2002) and Faust et al. (2001) examined the behavior of the Bundesbank prior to the euro. Their conclusion was that all the ECB rates were below the ones the Bundesbank would have chosen. This concludes that the Bundesbank had indeed a more strict policy to keep the inflation low than the majority of the EMU members.

Björkstén (2000) indicates that the economic variables between EMU members are diverging. This makes it more difficult for policy makers to set a proper interest rate. It's also problematic for the countries in the periphery, where it can cause a political crisis. In the Eurozone, output and inflation divergences are likely to remain significant (Angeloni & Ehrmann, 2004). In October 2016, inflation range from −0,1 percent for Italy to 1,9 percent for Belgium. When the inflation differentials increase, the ECB is less likely to increase the interest rate (Fendel & Frenkel, 2006). The ECB is scared that a stricter policy would lead to deflation in low-inflation countries. Hayo (2006) showed that every national central bank would set different interest rates than the ECB in the period 1999 to 2004. He estimated the TR and found that the weight for inflation was 1,87 for Italy and only 1,25 for Germany. That's not supporting the public opinion. Also Eleftheriou et al. (2006) estimated a high inflation weight for Italy (2,20) compared to Germany (0,74) [1993:1998]. It might be that the Bundesbank had greater credibility than the central bank of Italy. Overall, the weights on the output gap are less clear. Fendel et al. (2011) and Eleftheriou et al. (2006) found that they are less significant than the weights on inflation. Also, both researchers found negative weights. It's unlikely that a central bank would higher the interest rate in response to a reduction in output.

3. Data & Methodology

3.1 Introduction

This study will compute Taylor Rule implied interest rates (i_{TR}) for individual EMU countries over the period 1999 to 2015. Then compare these $i_{TR}'s$ to evaluate the claim that one unified monetary policy is appropriate for all EMU members. In order to compute the i_{TR}, the NRIR, output gaps, inflation gaps and the preference parameters are needed. The variables $\pi, \bar{\pi}$ & Y are observable and there are several available estimates for potential GDP ($\bar{Y}$). However, α, β and the NRIR are unobserved and have to be estimated. The Ordinary Least Squares (OLS) method based on pre-EMU data gives these estimations.

$$(3.1)\ y = C + \alpha(inflation\ gap) + \beta(output\ gap) + \varepsilon$$

Equation 3.1 is the TR in its original form. As input we have the interbank interest rate of a national central bank (y), the inflation gap and the output gap. Over the past, central banks have adjusted their interbank interest rate in respect to the inflation gap and the output gap. With OLS, the average of those adjustments will be calculated. From equation 3.1, we get the estimated weights on the inflation gap and output gap (α, β) and automatically the NRIR (C), which is the constant. With the given inflation gaps and output gaps of the period 1999 to 2015, the regression function gives the best prediction of the interest rate that the national central bank would have set. This paper researches simultaneously annual and quarterly outcomes in order to compare the i_{TR} with the ECB's policy rate. The sequence is as follows:

1. Estimate the members' NRIR and parameters (α and β) of the annual TR with annual data [1970-1999] and of the quarterly TR with quarterly data [1986:1-1998:4].

2. Annual inflation/output gaps and quarterly inflation/output gaps from 1999 till 2015 are used as input for respectively the annual TR and quarterly TR, which were computed in step 1.

3. The outcomes of step 2, which are the annual i_{TR} and quarterly i_{TR}, will be compared to the policy rate of the ECB.

3.2 Sample

This study will only focus on 11 EMU members: Austria, Belgium, Finland, France, Germany, Ireland, Italy, Netherlands, Portugal, Spain and Greece. Those are the first members of the Eurozone, which started at the first of January 1999. Thereafter, the ECB took control over the monetary policy. Greece entered the Eurozone 2 years later in 2001. Luxembourg, another member from the start, is excluded because of their small economy size. Countries that later entered the Eurozone are (in chronology order) Slovenia, Malta, Cyprus, Estonia, Latvia and Lithuania. These are also excluded for further research. One reason is that a few of those were former part of the Soviet Union and were not able to establish their own monetary policy before 1991.

The second reason is that their path inside the EMU is too short to make conclusions about their monetary policy in comparison to the one of the ECB.

3.3 Data

Data needed for this research are:

1. Interbank interest rate set by the individual central bank

The annual interest rates used are described in table 3.1. Most rates are year averages. Exceptions are Belgium, Greece, Ireland and Portugal. Those are all year-end because of missing average values. Interest rates of those members and also France come from the International Financial Statistics Yearbook of the IMF (2000). The rates of the Netherlands are from the Dutch Central Bank (DNB). The rest is from the Federal Reserve Bank of St. Louis. Note that the time range is shorter for Finland, Belgium and Greece, where the data start from respectively 1974, 1977 and 1980. For quarterly interbank interest rates, see table 3.2 which one are used. These interest rates are quarterly averages and obtained from the database of the Fed of St. Louis, with the exception of Greece (Central Bank of Greece).

Table 3.1: Annual data

Country	Time range	Interbank interest rate (till 1998)
1. Austria	[1970:2015]	Immediate rate: Less than 24 hours
2. Belgium	[1977:2015]	Discount rate (year-end)
3. Finland	[1974:2015]	Immediate rate: Less than 24 hours
4. France	[1970:2015]	Immediate rate: Less than 24 hours
5. Germany	[1970:2015]	Discount rate
6. Greece	[1980:2015]	Discount rate (year-end)
7. Ireland	[1970:2015]	Discount rate (year-end)
8. Italy	[1970:2015]	Discount rate
9. Netherlands	[1970:2015]	Fixed rate DNB
10. Portugal	[1970:2015]	Banco de Portugal rate (year-end)
11. Spain	[1970:2015]	Discount rate

Table 3.2: Quarterly data

Country	Time range	Interbank interest rate (till 1998)
1. Austria	[1986:1-1998:4]	Immediate rate: Less than 24 hours
2. Belgium	"	3-Month or 90-day rates and yields
3. Finland	"	Immediate rate: Less than 24 hours
4. France	"	Immediate rate: Less than 24 hours
5. Germany	"	Discount rate
6. Greece	"	Overnight interbank market rate
7. Ireland	"	3-Month or 90-day rates and yields
8. Italy	"	Discount rate
9. Netherlands	"	3-Month or 90-day rates and yields
10. Portugal	"	3-Month or 90-day rates and yields
11. Spain	"	Discount rate

The $i_{TR}'s$ will be compared with the ECB's policy rate on the Main Refinancing Operations (displayed in figure 3.1), which is the rate charged on loans borrowed by commercial banks. The Governing Council of the ECB, which consists of 6 executive members, including President Mario Draghi, sets this rate. Also the 19 central bank governors from each EMU member take part in the council, which also set 2 other main interest rates:

1. Deposit facility rate: where banks can stall money, has a negative interest rate since June 2014.
2. The marginal lending facility: the rate on overnight credit for commercial banks, when they have not enough credit to meet their reserve requirements.

Figure 3.1: marginal lending policy rate of the ECB

2. Output

Annual output gaps from 1970 to 1980 are from the April 2002 report of the International Monetary Fund (IMF). Data for Belgium, Finland and Greece started somewhere later. For their time range and the others, see table 1. Data from 1980 to 2015 are from the IMF report of October 2016. Output gaps are described as percent of potential GDP. The quarterly growth rates are from the databank of the OECD and measured by the expenditure approach. Products and services are summed up by their purchase price by final use. The growth rates are compared to the same quarter of the previous year and are seasonally adjusted.

3. Inflation

Annual and quarterly inflation numbers of the individual Eurozone members are from the database of the OECD and include all goods. Note that inflation is not one uniform number. There is lack of consensus which calculation method must be used. Some researches exclude energy prices, others exclude food prices and some exclude both. Reason for this is that mainly the prices of energy can be highly volatile. We have seen this with the oil crisis in 1973 and 1979. The index that includes energy and all other goods is the Consumer Price Index (CPI). There are some measurement complications. This inflation index is based on price developments of a basket of goods. Each year, researches must estimate which goods the average person buys and in which extent. This change each year, but the substitution effect[3] is hard to measure. This also relates to improvements of technical products. For example: Laptops nowadays are much better than 10 years ago (Hinrichs, 2016).

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[3] Consumers decide to choose cheaper products when the price of their usual product is rising

To solve this problem, Taylor himself suggested using the GDP deflator. It's calculated by first dividing the nominal GDP by the real GDP, then multiplied by 100. The nominal GDP is calculated with current prices, the real GDP is calculated with a base year. Nevertheless, the ECB uses an index that is harmonized across the EU members (HICP), which includes also all goods. That is the reason why this research will uses a similar index.

3.4 Methodology

Input for the TR is the inflation gap and output gap. To obtain the inflation gap, actual inflation has to be subtracted by a certain desired inflation level, the target. Here the target inflation is 2 percent, the same as the target of the ECB. This target is also used to calculate the inflation gaps of individual countries prior to the EMU-period. So the inflation gap is the actual inflation minus 2 percent, both for annual data and quarterly data.

The annual TR uses output gaps obtained from the databank of the IMF. Data of quarterly output gaps is usually nowhere to find. To estimate the quarterly output gap, quarterly growth rates of real GDP are used from 1970:1 till 2015:4. Those growth rates are from the databank of the OECD and measured by the expenditure approach. In order to calculate the output gap, a potential GDP rate or trend rate is needed. Here, the trend growth rate is estimated with a regression function with growth (Δy) as dependent variable and time (t in quarters) as independent variable. Looking at the results of each country, the cubic trend has the highest R squared: The proportion of variance in the dependent variable (growth) caused by the independent variable (time). A linear trend and a quadratic trend have both less prediction value. In figure 3.2, the quarterly (cubic) trend growth rate of each country is presented. Those are based on the regression function 3.2, where $\beta_1, \beta_2, \beta_3$ are the estimated coefficients from the regression model.

$$(3.2) \; \Delta y_t = \alpha_t + \beta_1 t + \beta_2 t^2 + \beta_3 t^3 + \varepsilon_t$$

Figure 3.2: Trend GDP growth rates (Quarterly)
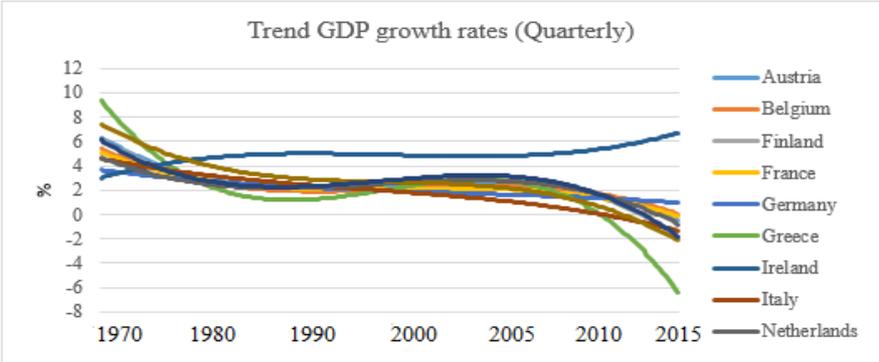
In figure 2, the trend rates are presented. With the known trend, we are able to calculate the gap with formula 3.3.

$$(3.3) \; output \; gap = actual \; growth \; rate - trend \; growth \; rate$$

3.4.1 Annual TR

To estimate the parameters of the annual TR of each member, formula 3.4 is used.

$$(3.4)\ i_t = \bar{\imath}_t + \alpha(inflation\ gap_t) + \beta(output\ gap_t) + \varphi * DUMMYCRISIS_t + \rho(i_{t-1}) + \varepsilon_t$$

Where i_t is the annual averaged interbank interest rate of the country's national bank, $\bar{\imath}_t$ the NRIR, α the weight on the inflation gap and β the weight on the output gap. In addition to the TR, this research uses a crisis dummy φ and a lag variable ρ. The crisis dummy is 1 when the negative output gap is 2 percent or larger and 0 for all other values. The minus 2 percent is chosen as threshold, because during a severe recession, GDP growth rate will usually fall 2 percentage point below the trend rate (Filardo, 1998; Taylor, 2000). This dummy is used because during a crisis, the original TR would give many times negative interest rates. In reality, the central bank can't set the interest rate much lower than 0. That is why some parameters of the crisis dummy are positive, to (somewhat) offset the negative interest rates. The lag variable is the interest rate in the previous period. It was necessary to use this lag in order to solve autocorrelation problems. That is: the error terms ε are correlated with each other. In addition to including the lagged dependent variable, heteroscedasticity and autocorrelation consistent standard errors (HAC se) are used. After the estimation of all parameters, the next step is to compute the i_{TR} for the 11 members. The $i_{TR}'s$ will be compared with the annual averaged ECB policy rate.

3.4.2 Quarterly TR

To estimate the parameters of the quarterly TR of each member, formula 3.5 is used:

$$(3.5)\ i_t = \bar{\imath}_t + \alpha(inflation\ gap_t) + \beta(output\ gap_t) + \theta(exchange_t) + \varphi * DUMMYCRISIS_t + \varepsilon_t$$

In addition to the quarterly data, the variable 'exchange rate' is added to the TR. Prior to the Eurozone, nations had a third instrument to control the economy. Next to monetary supply and the interest rate, currency value can also work expansionary or contractionary to the economy. High value makes it more expansive for foreigners to buy domestic goods. This will have a negative effect on output. Low value implicates the other way around. Currency value is always relative to the value of another currency. Here it's the local currency compared in value to the value of the German Mark. As the biggest economy in Europe, the German Mark was very stable. The exchange rates of the individual currencies prior to the Euro are from the database of the Fed. After the estimation of the parameters with using HAC se, the computed i_{TR} will be compared with the quarterly averaged ECB policy rate.

3.4.3 Classic TR

Also a third TR is used in this research. This one is the same as described by John B. Taylor and is labeled as 'classic' TR (3.6). The NRIR is set on 2 percent, α is 1,5 and β is 0,5.

$$(3.6) \; i_t = 2 + 1,5(inflation \; gap_t) + 0,5(output \; gap_t) + \varepsilon_t$$

The reason for using the classic TR is due to the presence of autocorrelation in the quarterly TR. Even the lagged dependent variable could not solve that.

3.4.4 NRIR

The estimation of the parameters with OLS functions 3.4 and 3.5 is based on data from the pre-EMU period. Then the estimated parameters are used to compute the i_{TR} over the period 1999 to 2015. The i_{TR} gives only a meaningful prediction when we assume that the parameters remain 'fixed'. For the preference parameters α and β, this assumption is more or less satisfied. It's obvious when a country had a history of price stability; their central bank keeps this vision also after they lost their right to set the interest rate. For the NRIR, the assumption that it remains fixed is less certain. Most researches show that the NRIR of the Eurozone has a downward trend, as can be seen in table 3.3.

Table 3.3: NRIR estimations

Researchers	Time horizon	NRIR range	Latest estimate
Cour-Thimann, Pilegaard, Stracca (2006)	[1960:2005]	[-1,5%; 6%]	[1%; 2%]
Gerdesmeier, Roffia (2003)	[1985:2002]	[0%; 10%]	[0%, 1%]
Garnier, Wilhelmsen (2005)	[1965:2004]	[1%; 4,5%]	[1%; 2%]
Benati, Vitale (2007)	[1990:2005]	[2%; 4%]	2%
Holsten, Laubach, Williams (2016)	[1990:2015]	[-0,5%; 2,4%]	-0,5%
Mésonnier, Renne (2004)	[1979:2002]	[1%; 7%]	1%

In table 3.3, the estimations of the NRIR of the Eurozone are between 1 and 2 percent for the mid-2000s. The study of Holstein, Laubach and Williams shows even a negative estimation in 2015. So it's unlikely that the estimated NRIR, which is based on data from the pre-EMU period, is the same as the NRIR during the EMU-period. With the downward trend in mind, we can conclude that the estimations of the NRIR from the functions 3.4 and 3.5 are too high. If we keep using the same estimations for computing the i_{TR}, the i_{TR} will be overestimated. In order to prevent this, this study will use a fixed NRIR of 2 percent. This means that the constant in the functions 3.4 and 3.5, which is the NRIR ($\bar{\iota}_t$), is set on 2 percent by computing the i_{TR}. The use of 2 percent is based on the findings by John B. Taylor himself and therefor the same as by the classic TR. It will be applied to all the 11 EMU members, although there might be differences in the NRIR between them. Earlier studies found only small differences between EMU members (Fries et al., 2016).

3.5 Graphs

Next, graphs based on quarterly data are shown. Section A contains of every member the growth rate and trend growth rate, which was calculated by 3.2. Note that the output gap is the difference between the 2 rates. This output gap, together with the inflation gap, is shown in section B.

In 2008, the global crisis started. It was most severe in year 2009, where every member suffered a decline in both output and inflation. The most recovered soon afterwards till 2010/2011. Thereafter, a second dip can be seen. In 2013 and afterwards, the most growth rates are positive, while the inflation remains low. Note that a positive output gap is achieved more easily in later years, since 10 of the 11 growth rates are negative. The only one with a positive trend is Ireland. This is mainly due to the extraordinary growth rates in 2015, which are above 20 percent.
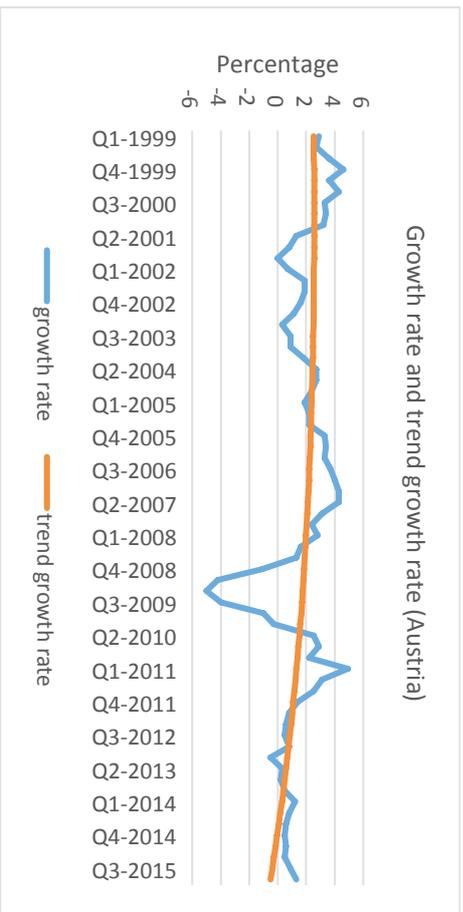
Figure 3.5.1a: growth rate and trend growth rate of Austria

Growth rate and trend growth rate (Austria)

growth rate

trend growth rate

Percentage
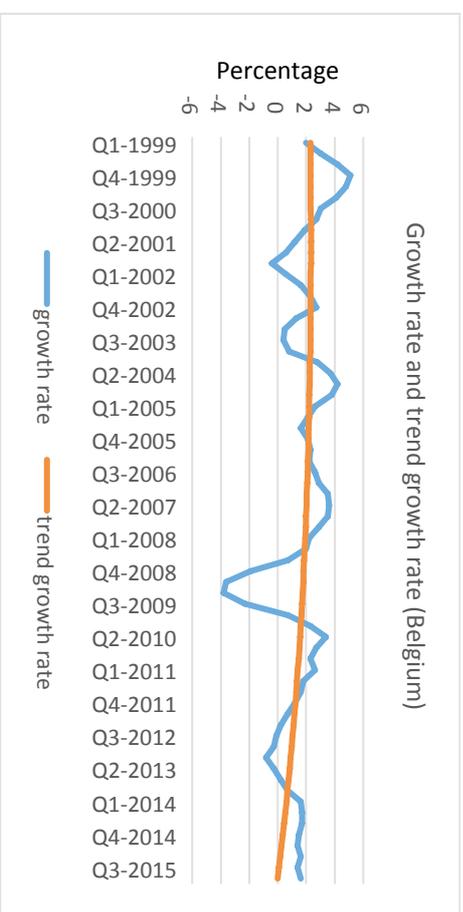
Figure 3.5.2a: growth rate and trend growth rate of Belgium

Growth rate and trend growth rate (Belgium)

growth rate

trend growth rate

Percentage
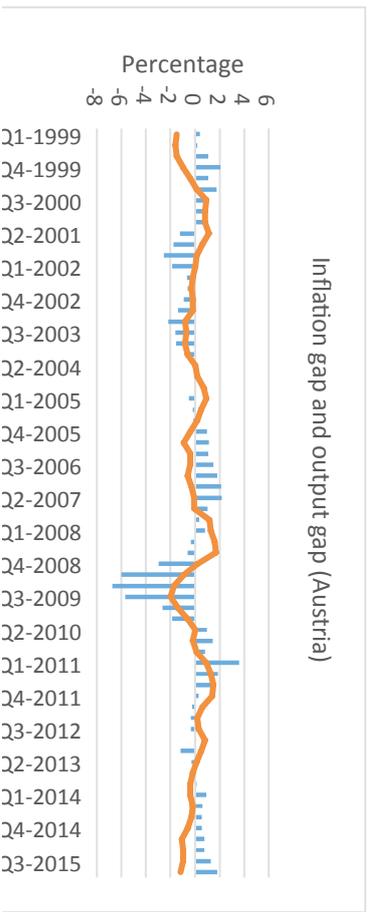
Figure 3.5.1b: inflation gap and output gap of Austria

Inflation gap and output gap (Austria)

Percentage
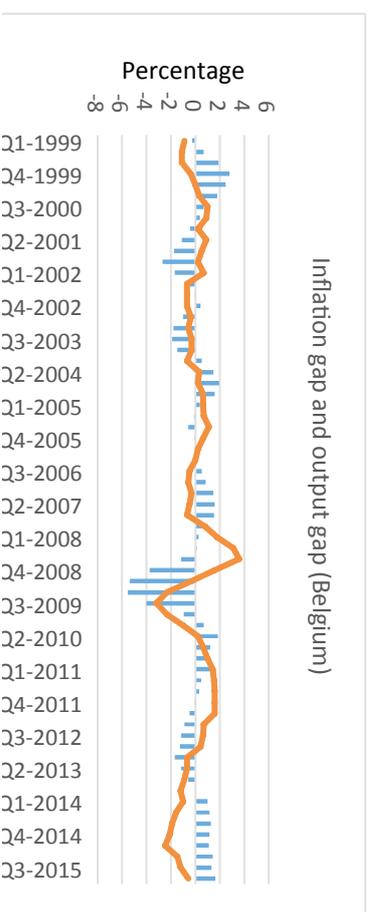
Figure 3.5.2b: inflation gap and output gap of Belgium

Inflation gap and output gap (Belgium)

Percentage

Figure 3.5.3a: growth rate and trend growth rate of Finland

Growth rate and trend growth rate (Finland)

Figure 3.5.3b: inflation gap and output gap of Finland

Inflation gap and output gap (Finland)

Figure 3.5.4a: growth rate and trend growth rate of France

Growth rate and trend growth rate (France)
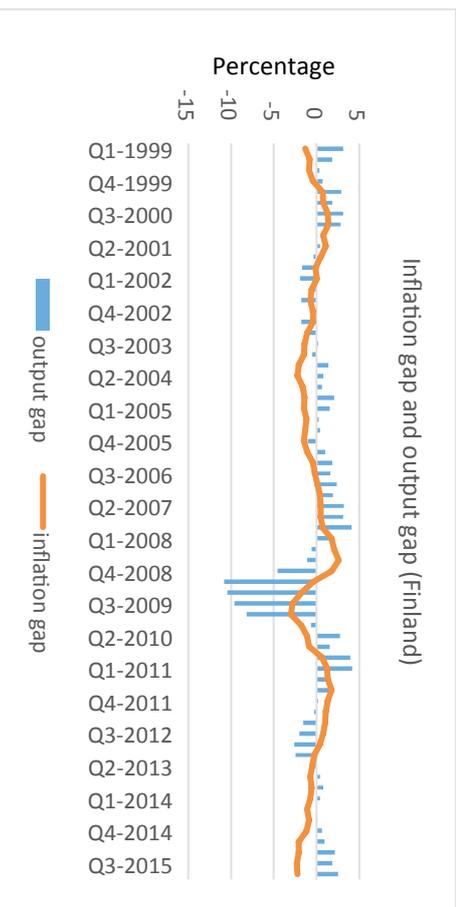
Figure 3.5.4b: inflation gap and output gap of France

Inflation gap and output gap (France)
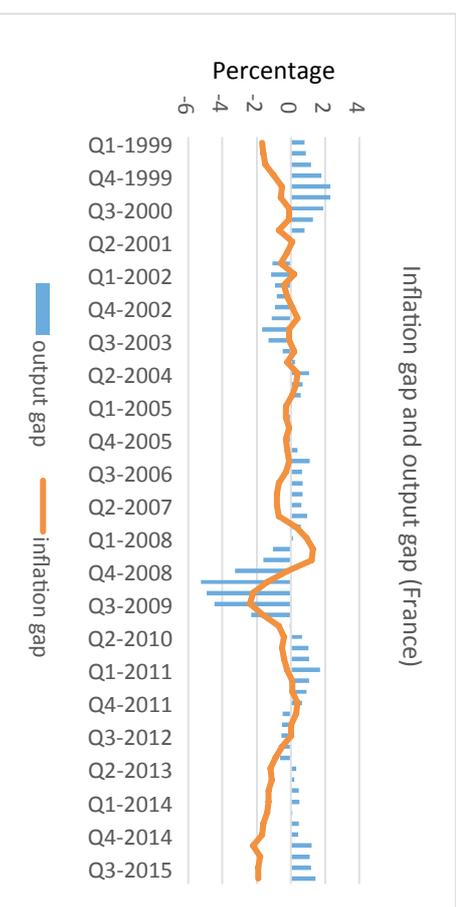
Figure 3.5.5a: growth rate and trend growth rate of Germany

Growth rate and trend growth rate (Germany)

Percentage

— growth rate   — trend growth rate

Figure 3.5.6a: growth rate and trend growth rate of Greece

Growth rate and trend growth rate (Greece)

Percentage

— growth rate   — trend growth rate

Figure 3.5.6b: inflation gap and output gap of Germany

Inflation gap and output gap (Germany)

Percentage

output gap   — inflation gap

Figure 3.5.6b: inflation gap and output gap of Greece

Inflation gap and output gap (Greece)

Percentage
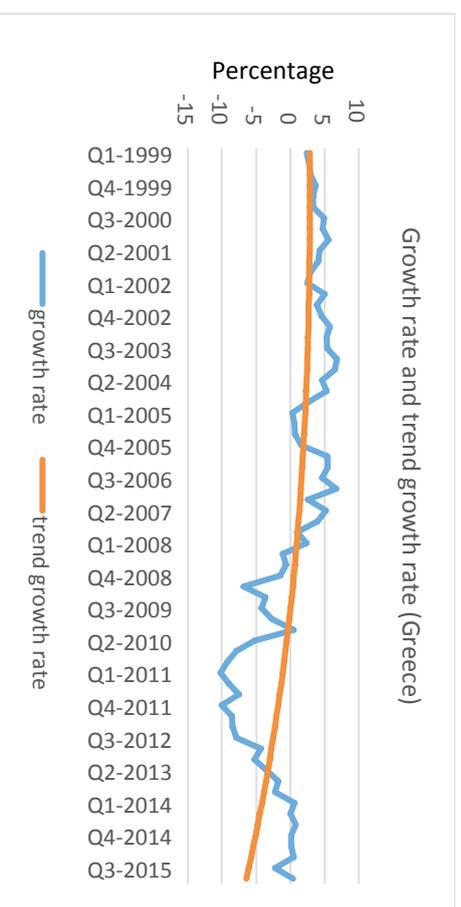
output gap   — inflation gap
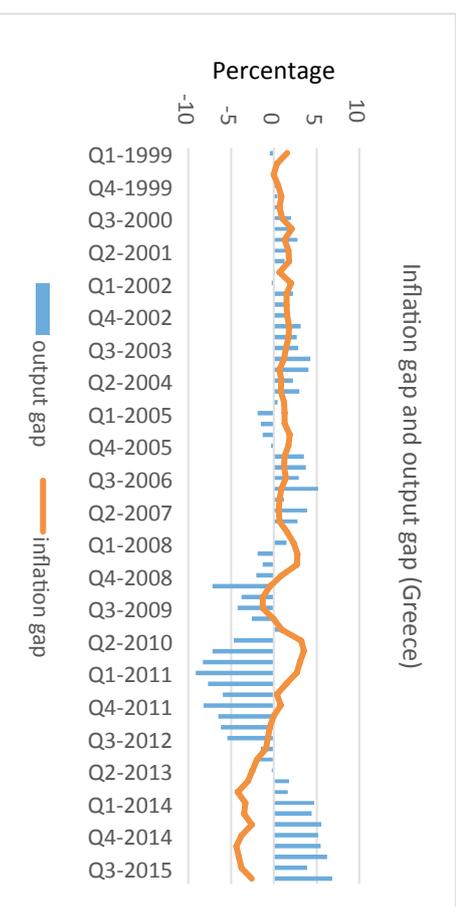
Figure 3.5.7a: growth rate and trend growth rate of Ireland

Growth rate and trend growth rate (Ireland)

Percentage

growth rate   trend growth rate
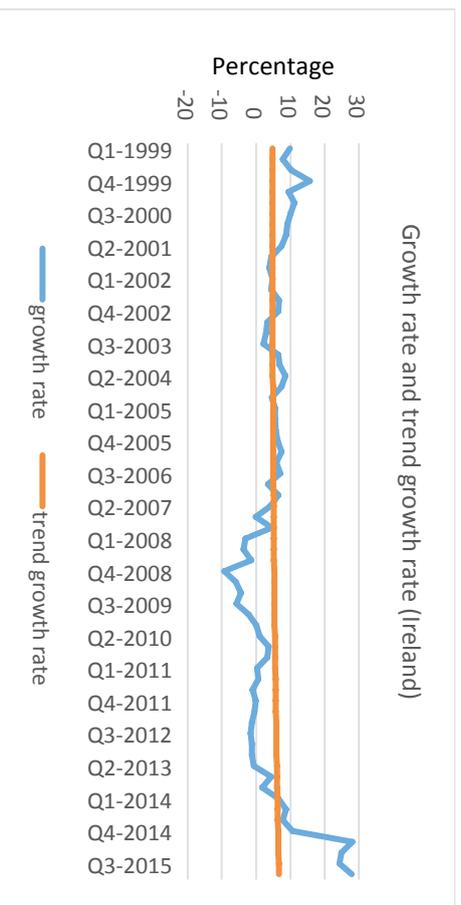
Figure 3.5.7b: inflation gap and output gap of Ireland

Inflation gap and output gap (Ireland)

Percentage

output gap   inflation gap
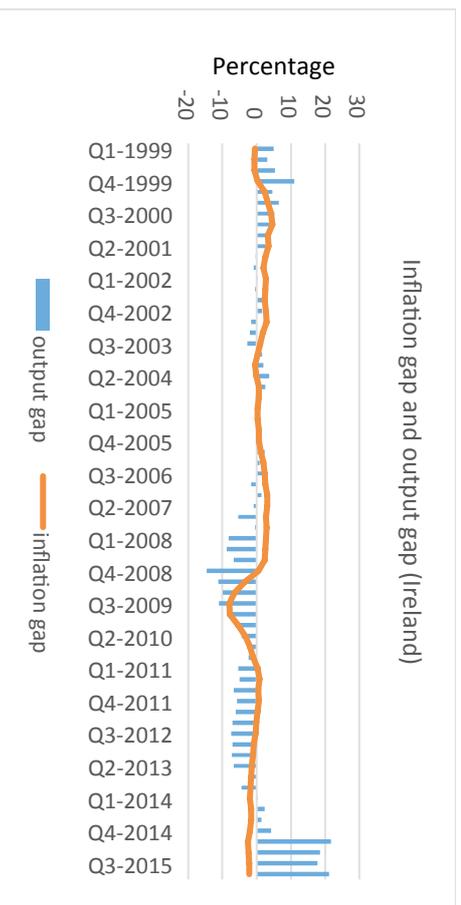
Figure 3.5.8a: growth rate and trend growth rate of Italy

Growth rate and trend growth rate (Italy)

Percentage

growth rate   trend growth rate
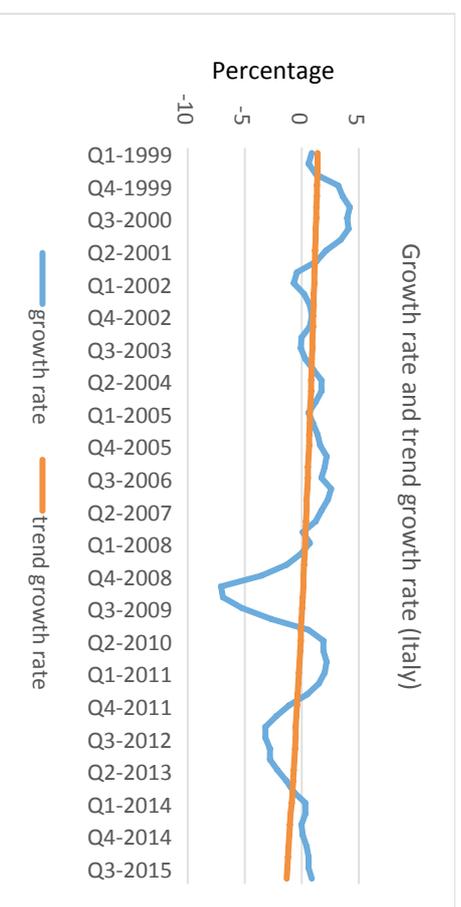
Figure 3.5.8b: inflation gap and output gap of Italy

Inflation gap and output gap (Italy)

Percentage

output gap   inflation gap
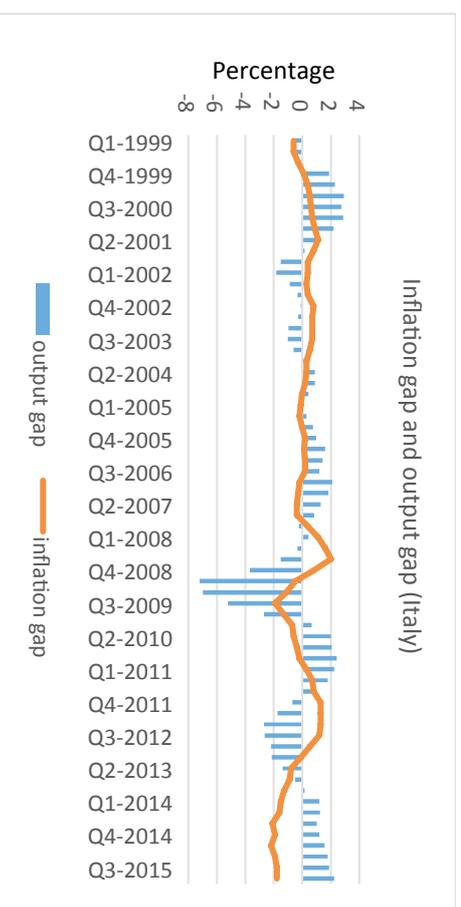
Figure 3.5.9a: growth rate and trend growth rate of the Netherlands

Growth rate and trend growth rate (Netherlands)

Percentage

growth rate — trend growth rate

Figure 3.5.9b: inflation gap and output gap of the Netherlands

Inflation gap and output gap (Netherlands)

Percentage

output gap — inflation gap

Figure 3.5.10a: growth rate and trend growth rate of Portugal

Growth rate and trend growth rate (Portugal)

Percentage

growth rate — trend growth rate
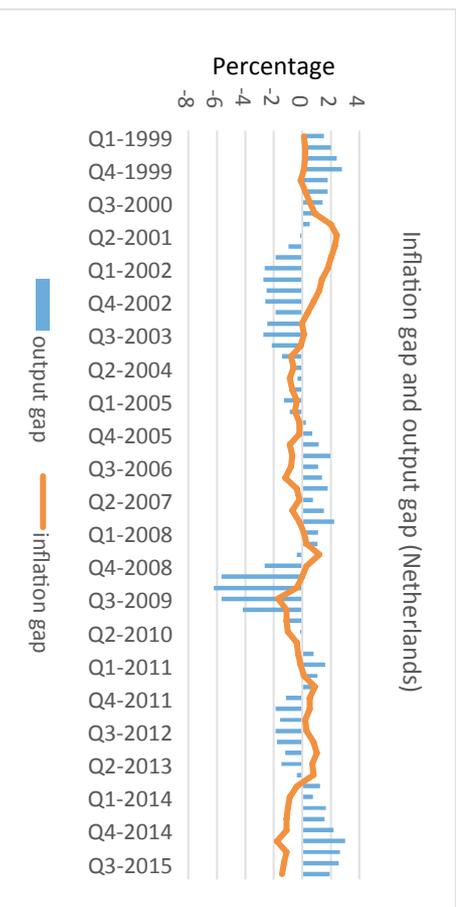
Figure 3.5.10b: inflation gap and output gap of Portugal

Inflation gap and output gap (Portugal)

Percentage

output gap — inflation gap
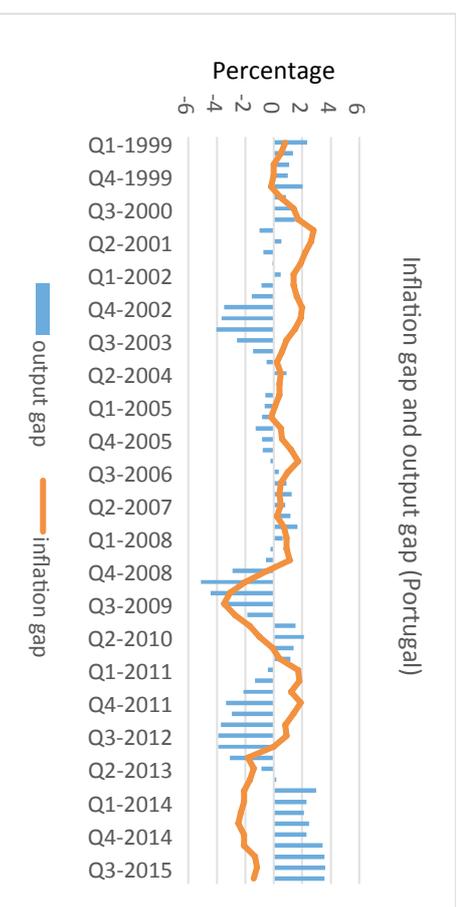
Figure 3.5.11a: growth rate and trend growth rate of Spain

Growth rate and trend growth rate (Spain)

Percentage

growth rate
trend growth rate
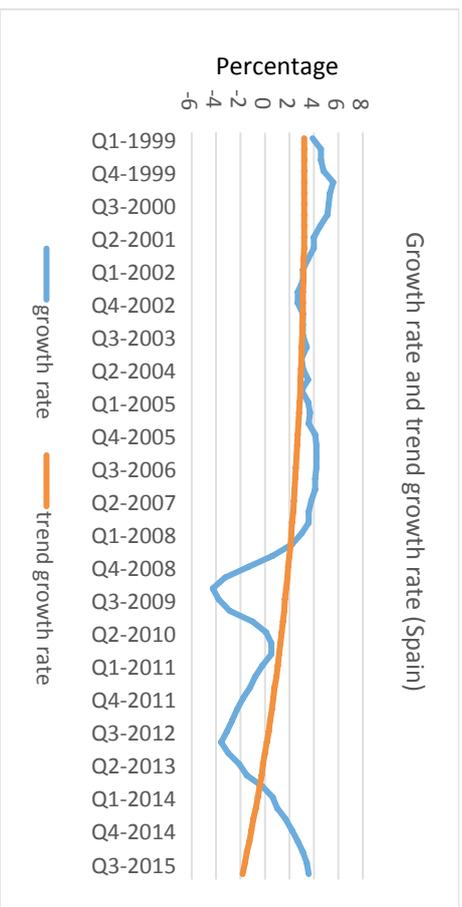
Figure 2.5.11b: inflation gap and output gap of Spain

Inflation gap and output gap (Spain)

Percentage

output gap
inflation gap

23
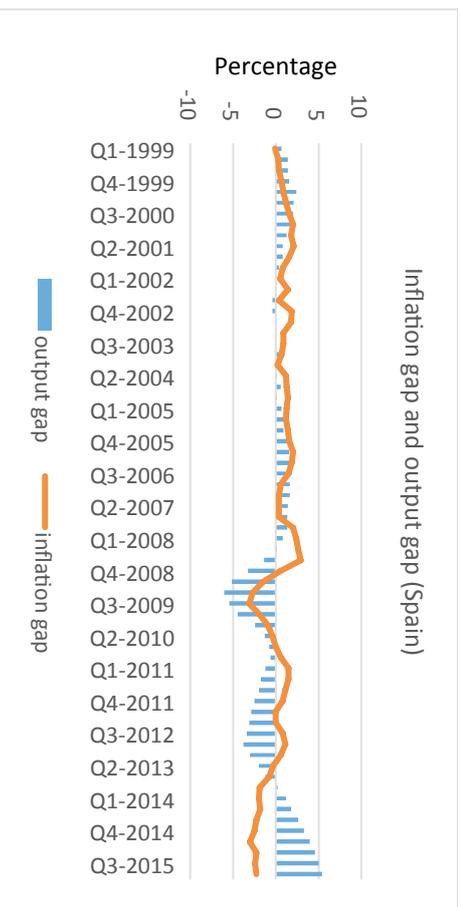
4. Results

4.1 Results from estimations α and β

The results from the estimations of the preference parameters (α and β) are presented in tables. Table 4.1a contains the estimations based on annual data, table 4.2 on quarterly data. Concerning the annual results, only the Netherlands has autocorrelation. Regarding quarterly results, all countries have autocorrelation. Nevertheless, it's possible to make some (cautious) conclusions.

4.1.2 Annual results

$$(3.4)\ i_t = \bar{\iota}_t + \alpha(\text{inflation gap}_t) + \beta(\text{output gap}_t) + \varphi * DUMMYCRISIS_t + \rho(i_{t-1}) + \varepsilon_t$$

Table 4.1a: TR estimations (annual)

	$\bar{\iota}$	α	β	φ	ρ
Austria	1.929002*	0.250064*	0.488538*	1.422845*	0.43627*
	(0.408916)	(0.091194)	(0.161047)	(0.528226)	(0.084743)
Belgium	1.670984	0.319908	0.292075	-0.704368	0.7054*
	(1.102066)	(0.219606)	(0.233004)	(0.532367)	(0.158661)
Finland	1.122991	0.08771	0.04073	-0.29694	0.796036*
	(0.951967)	(0.052123)	(0.058187)	(0.450012)	(0.141958)
France	2.527364*	0.256544*	-0.078377	-1.588702	0.621703*
	(0.883091)	(0.109437)	(0.20133)	(0.844484)	(0.114312)
Germany	2.071396*	0.205455*	0.415264*	0.080677	0.529546*
	(0.658879)	(0.094618)	(0.102008)	(0.566802)	(0.105969)
Greece	3.243368	0.172027*	0.187479*	1.418058	0.675236*
	(2.408178)	(0.045184)	(0.067635)	(0.747616)	(0.155723)
Ireland	7.727745*	0.201347*	-0.020797	-3.09849	0.188496
	(2.686274)	(0.091506)	(0.096427)	(1.538892)	(0.232658)
Italy	0.483609	0.186374*	0.140542	-1.011836	0.880355*
	(0.716225)	(0.035073)	(0.19115)	(0.649974)	(0.072017)
Netherlands	0.642309	-0.063553	0.458426*	1.843633*	0.856478*
	(0.458517)	(0.087748)	(0.148058)	(0.693267)	(0.130425)
Portugal	0.328051	0.288484*	0.52719	1.584807	0.70798*
	(0.835126)	(0.051898)	(0.257717)	(1.660364)	(0.083185)
Spain	1.317124	0.18139*	-0.044037	-0.484204	0.754917*
	(1.530007)	(0.071035)	(0.239688)	(1.465028)	(0.1421)

*=significant (a=5 percent). Numbers in (..) are Heteroscedasticity and Autocorrelation Consistent (HAC) standard errors.

These results are parameters in the short-term. By dividing the estimations with $(1 - \rho)$, we get the parameters for the long term, shown in table 4.1b.

Table 4.1b: long-term parameters

	$\bar{\iota}$	α	β	φ
Austria	**3.42**	**0.44**	**0.87**	**2.52**
Belgium	5.67	1.09	0.99	-2.39
Finland	5.51	0.43	0.20	-1.46
France	**6.68**	**0.68**	-0.21	-4.20
Germany	**4.40**	**0.44**	**0.88**	0.17
Greece	9.99	**0.53**	**0.58**	4.37
Ireland	**9.52**	**0.25**	-0.03	-3.82
Italy	4.04	**1.56**	1.17	-8.46
Netherlands	4.48	-0.44	**3.19**	**12.85**
Portugal	1.12	**0.99**	1.81	5.43
Spain	5.37	**0.74**	-0.18	-1.98

*Numbers in **bold** are significant (a=5 percent).*

The weight on inflation (α) is positive for all countries except the Netherlands. It's significant in 8 of the 11 cases. Overall, α is not close to the described 1,5 by John B. Taylor, except for Italy. The weight on output (β) is less significant and some are even negative. This is unrealistic, because it's unlikely that a central bank would higher the interest rate when the output gap is negative. For those countries, the weight on the output gap will be fixed at 0. The crisis dummy is only significant for Austria and the Netherlands, although the parameter of the latter one is very high.

4.1.3 Quarterly results

$$(3.5)\ i_t = \bar{\imath}_t + \alpha(inflation\ gap_t) + \beta(output\ gap_t) + \theta(exchange_t) + \varphi * DUMMYCRISIS_t + \varepsilon_t$$

Table 4.2: TR estimations (quarterly)

	$\bar{\imath}$	α	β	θ	ϕ
Austria	3,965*	1,595*	0,112	0,367	0,647
	(0,278)	(0,222)	(0,161)	(0,615)	(0,751)
Belgium	6,322*	1,624*	0,221	0,056	1,715
	(0,661)	(0,405)	(0,335)	(0,146)	(1,719)
Finland	5,760*	0,626*	-0,217*	-0,033	0,111
	(0,178)	(0,061)	(0,072)	(0,023)	(0,674)
France	6,378*	2,250*	-0,160	0,010	2,332
	(0,501)	(0,245)	(0,278)	(0,016)	(1,201)
Germany	4,151*	0,968*	0,121		0,677
	(0,307)	(0,175)	(0,143)		(0,721)
Greece	13,514*	0,444*	-0,470	-0,128	-3,055
	(1,797)	(0,118)	(0,305)	(0,097)	(2,660)
Ireland	8,286*	1,804*	-0,399	0,092	-1,123
	(1,215)	(0,402)	(0,262)	(0,062)	(2,095)
Italy	5,531*	1,634*	0,264	-0,066	1,688*
	(0,488)	(0,124)	(0,233)	(0,082)	(0,653)
Netherlands	6,115*	0,579	-0,281	0,073	1,354
	(0,589)	(0,343)	(0,390)	(0,121)	(1,108)
Portugal	6,908*	1,019*	-0,558*	0,150	0,014
	(0,540)	(0,081)	(0,196)	(0,108)	(1,05)
Spain	5,321*	1,503*	0,645*	0,288*	5,434*
	(0,661)	(0,248)	(0,270)	(0,138)	(1,573)

*=significant (a=5 percent). Numbers in (..) are Heteroscedasticity and Autocorrelation Consistent (HAC) standard errors.

Here, α is significant for all countries except for the Netherlands. They seem to be also more closely to the by Taylor assumed 1,5. France has the highest weight (2,25), whereas Greece has the lowest weight (0,44). The weight on output is only significant for Spain, Finland and Portugal, although the weights for Finland and Portugal are negative. Therefore, their weights on output will be fixed at 0. This applies also for France, Greece, Ireland and the Netherlands. In this study, the impact from the exchange rates in the TR is small. A possible reason is because prior to the euro, most members worked with the European Currency Unit (ECU)[4] in order to minimize fluctuations between their currencies. Only Spain has a significant parameter, where it means that if the peseta increases 1% in value relatively to the German mark, the interest rate set by their central bank would be 0,288% higher.

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[4] A basket of the member's currencies values, based on their economy size.

*4.2 Results from TR calculations*

The computed i_{TR} of each member are presented in separate graphs. Section A contains the quarterly i_{TR}. The estimated parameters from table 4.2, which are used for computing the i_{TR}, are put in a formula and are shown above every graph. The currency variable is not used, because every member uses the euro since 2001. Section B contains the annual i_{TR}, computed with the estimated parameters from table 4.1b. Those are also put in a formula, shown above the graphs in section B. Note that in both formulas the NRIR is set at 2 percent, as discussed in 3.4.4. By computing the i_{TR}, negative parameters on either the inflation gap or output gap are not used. That is the case when variables are missing in some formulas. Next to the computed i_{TR}, also the implied interest rate from the classic TR (3.6) is presented in every graph. The classic TR means that α is 1,5, β is 0,5 and the NRIR is 2 percent. The rates of the TR are compared to the rate of the ECB. In section A is the rate on MRO quarterly averaged. In section B is the rate an annual average.

4.2.1 Austria

In the years 2010 and 2011, Austria had a strong recovery from the global crisis in 2009. According to the TR, the rate of the ECB was too low for all periods after 2010. The difference between the ECB rate and i_{TR} seems to get smaller after 2011.

$$i\_TR_{Quarterly\ t} = 2 + 1.595(inflation\ gap_t) + 0.112(output\ gap_t) + 0.647DUMMYCRISIS_t$$

Figure 4.2.1a: quarterly i_{TR} of Austria
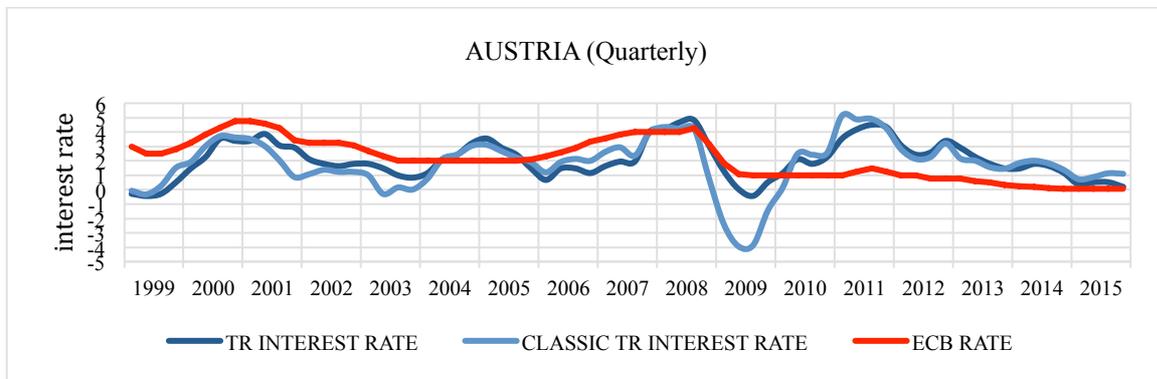
$$i\_TR_{Annual\ t} = 2 + 0.44(inflation\ gap_t) + 0.87(output\ gap_t) + 2.52DUMMYCRISIS_t$$

Figure 4.2.1b: annual i_{TR} of Austria
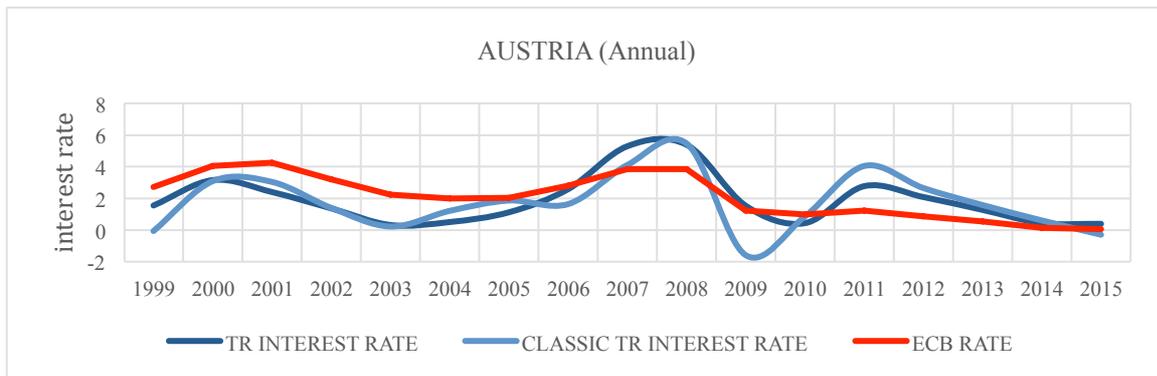
4.2.2 Belgium

The ECB rate was too low in the years 2008 and 2011. Due to the negative inflation gap in 2014 and 2015, the i_{TR} of Belgium decreased in those years.
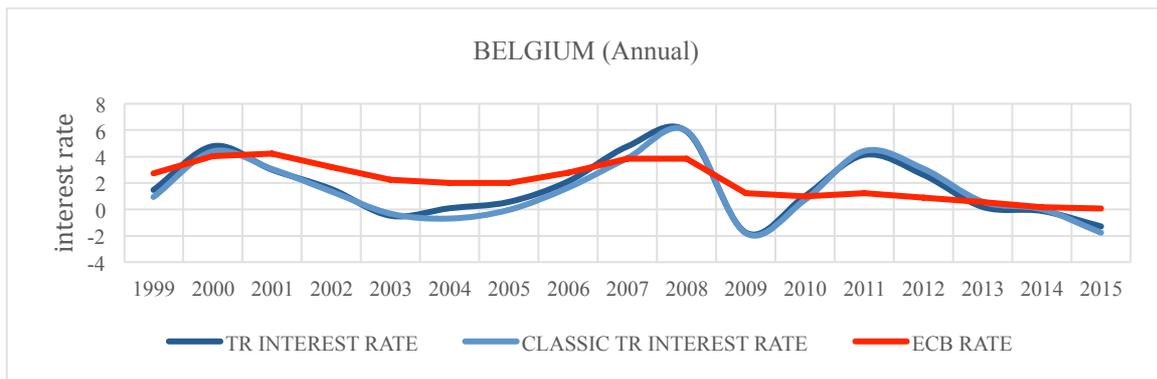
$$i\_TR_{Quarterly\ t} = 2 + 1.624(inflation\ gap_t) + 0.221(output\ gap_t) + 1.715 DUMMYCRISIS_t$$

Figure 4.2.2a: quarterly i_{TR} of Belgium
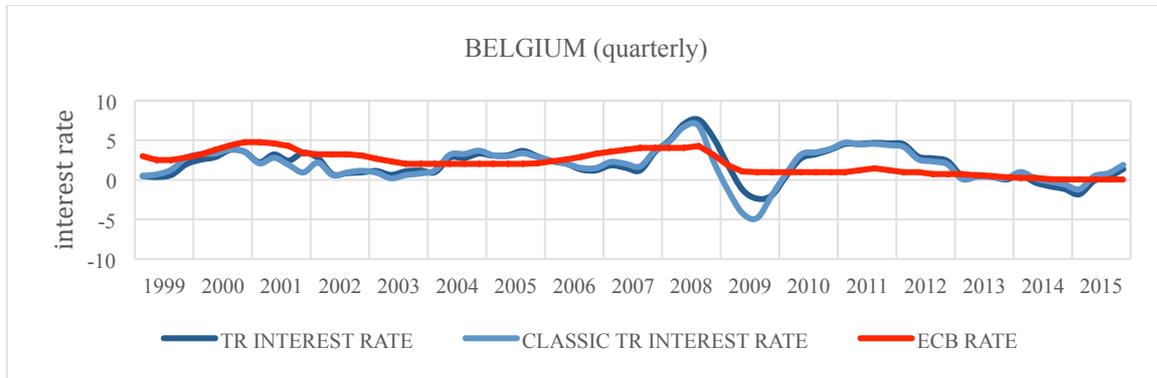
$$i\_TR_{Annual\ t} = 2 + 1.09(inflation\ gap_t) + 0.99(output\ gap_t) - 2.39 DUMMYCRISIS_t$$

Figure 4.2.2b: annual i_{TR} of Belgium

4.2.3 Finland

The global crisis had very large impact on Finland. The output gap was –9 in the first quarter of 2009. The fast recovery resulted in a higher i_{TR} than the one of the ECB. But with the decreasing inflation, the two rates are very similar in 2015.

$$i\_TR_{Quarterly\ t} = 2 + 0.626(inflation\ gap_t) + 0.111 DUMMYCRISIS_t$$

Figure 4.2.3a: quarterly i_{TR} of Finland
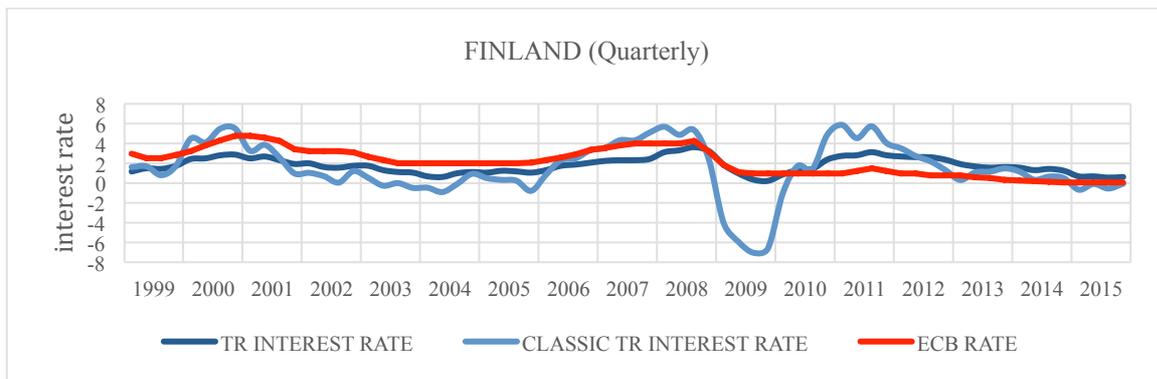
$$i\_TR_{Annual\ t} = 2 + 0.43(inflation\ gap_t) + 0.20(output\ gap_t) - 1.46DUMMYCRISIS_t$$

Figure 4.2.3b: annual i_{TR} of Finland
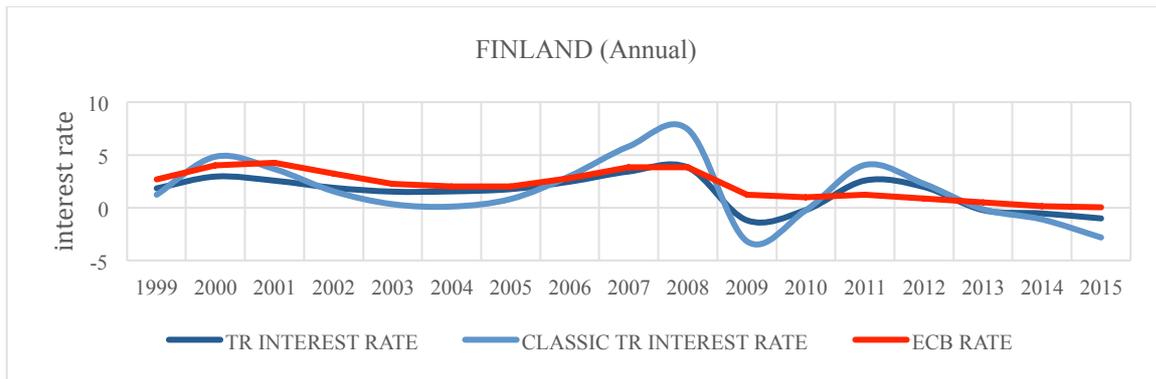
4.2.4 France

In the beginning of the EMU, the ECB rate seemed to be too high for France till 2003. The same occurs in the years 2006 and 2007. At the end of 2012, the ECB rate and the i_{TR} seem to be converging.
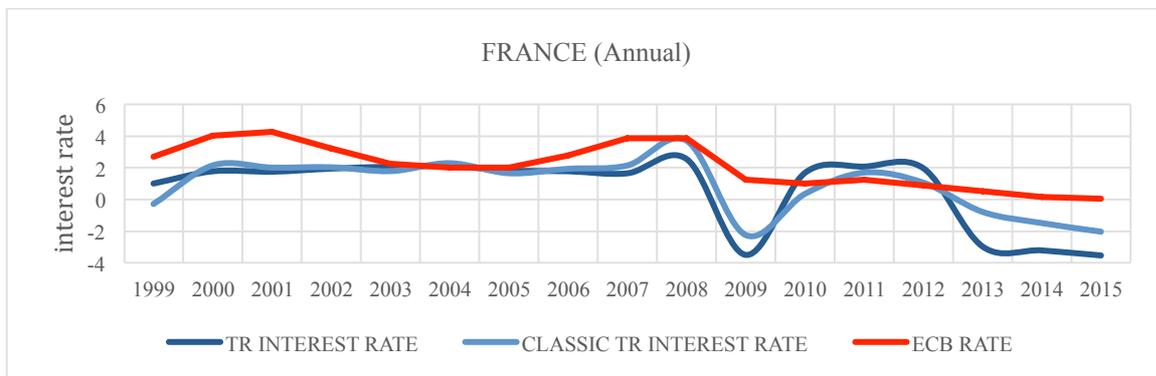
$$i\_TR_{Quarterly\ t} = 2 + 2.250(inflation\ gap_t) + 0.2.332DUMMYCRISIS_t$$

Figure 4.2.4a: quarterly i_{TR} of France
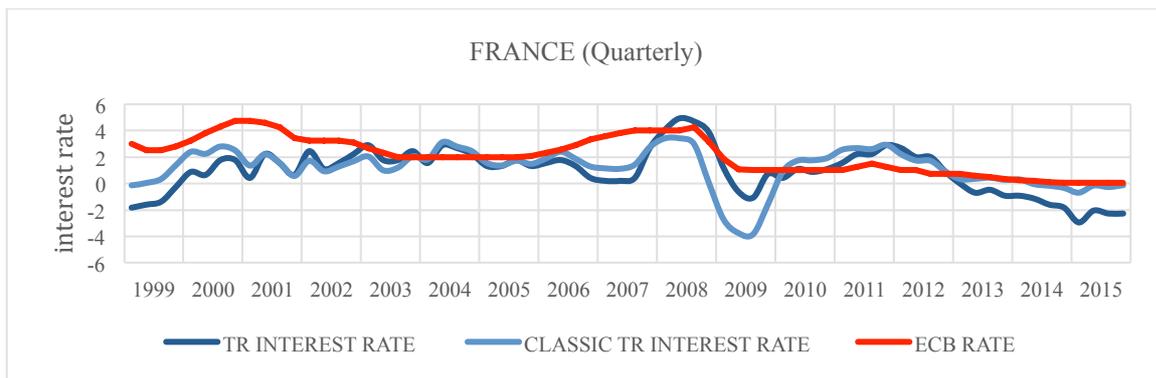
$$i\_TR_{Annual\ t} = 2 + 0.68(inflation\ gap_t) - 4.20DUMMYCRISIS_t$$

Figure 4.2.4b: annual i_{TR} of France

4.2.5 Germany

Germany had two output booms: In 2006-2007 and in 2011. During the first one, the ECB adjust their interest rate upwards in the same way as the German i_{TR}. During the second one, the rate is too expansionary, but didn't result in a major increase in inflation.
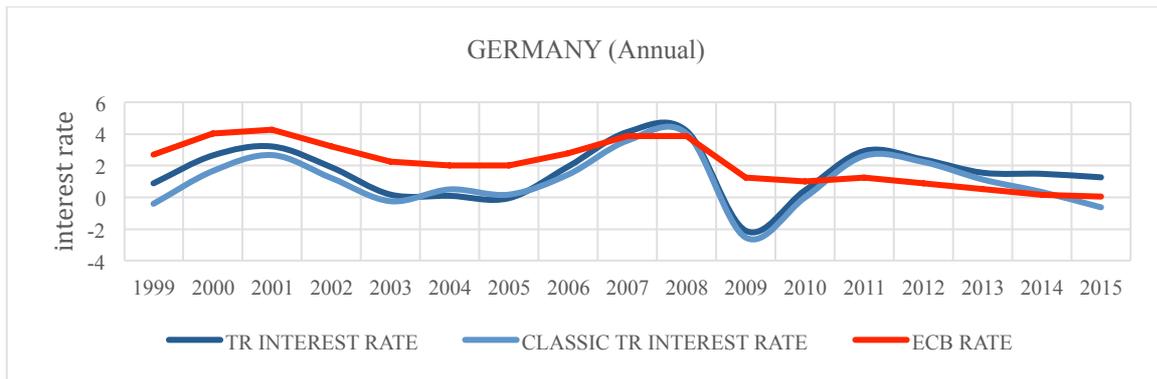
$$i\_TR_{Quarterly\,t} = 2 + 0.968(inflation\,gap_t) + 0.121(output\,gap_t) + 0.677DUMMYCRISIS_t$$

Figure 4.2.5a: quarterly i_{TR} of Germany
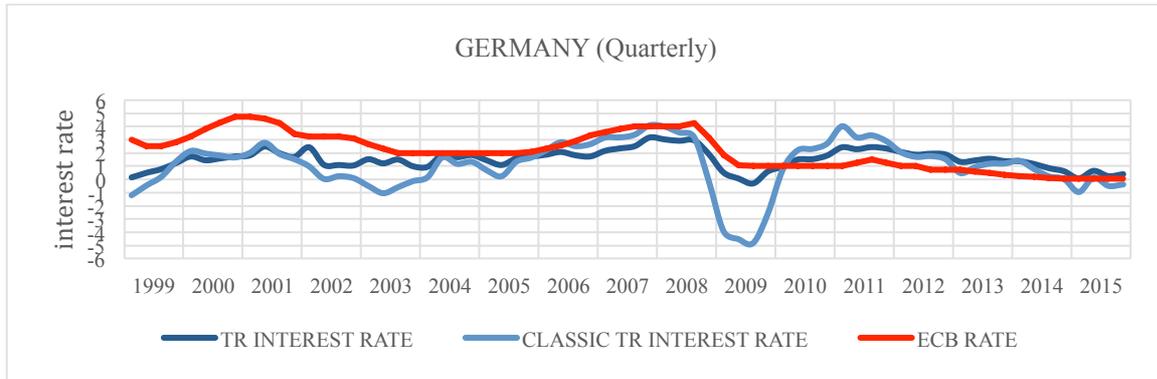
$$i\_TR_{Annual\,t} = 2 + 0.44(inflation\,gap_t) + 0.88(output\,gap_t) + 0.17DUMMYCRISIS_t$$

Figure 4.2.5b: annual i_{TR} of Germany

4.2.6 Greece

Making conclusions about Greece is difficult, because of the extraordinary quarterly trend rate. The actually growth rate did not exceed 0 after 2010. Also the inflation gap is negative in the last years. The zero lower bound of the ECB is the best option for Greece after 2012.
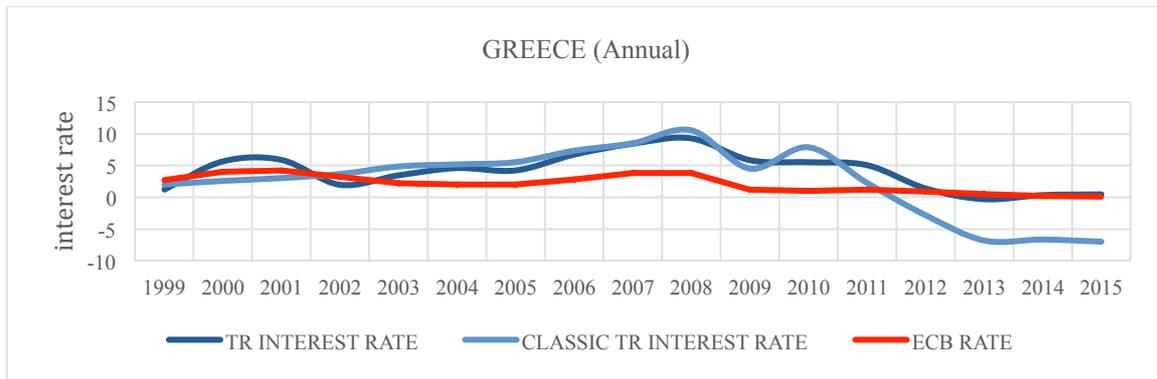
$$i\_TR_{Quarterly\,t} = 2 + 0.444(inflation\,gap_t) - 3.055DUMMYCRISIS_t$$

Figure 4.2.6a: quarterly i_{TR} of Greece
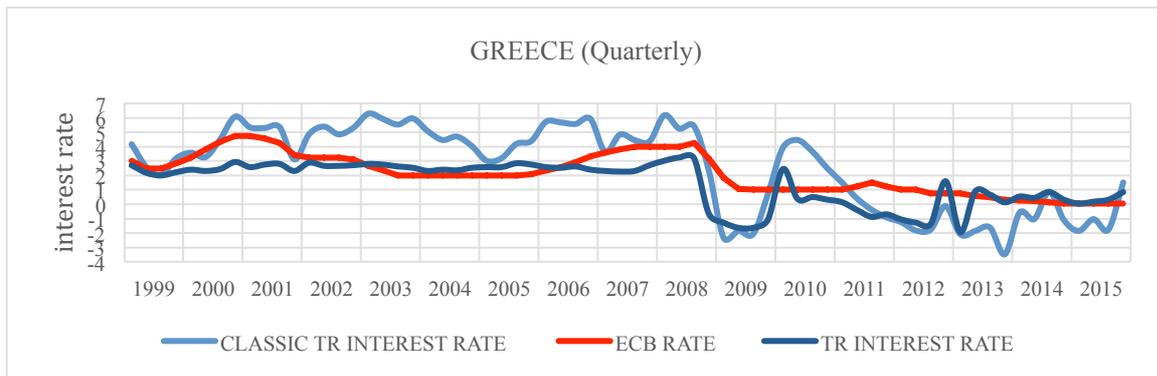
$$i\_TR_{Annual\ t} = 2 + 0.53(inflation\ gap_t) + 0.58(output\ gap_t) + 4.37DUMMYCRISIS_t$$

Figure 4.2.6b: annual i_{TR} of Greece

$$i\_TR_{Quarterly\ t} = 2 + 1.804(inflation\ gap_t) - 1.123DUMMYCRISIS_t$$

4.2.7 Ireland

Year 2015 is remarkable for Ireland, with a growth rate of more than 25 percent. Due to the massive positive output gap, the implied interest rate from the classic TR increased to 8 percent in 2015. The estimated parameter for the output gap is negative. That's the reason why the quarterly i_{TR} is lower than the one from the classic TR, because the output boom of 2015 has no impact in computing the i_{TR}. The annual classic TR uses output gaps estimated by the IMF. Their output gap in 2015 is not as high as the estimated one calculated by formulas 3.2 and 3.3. That results in a lower annual i_{TR} in comparison to the quarterly i_{TR}.
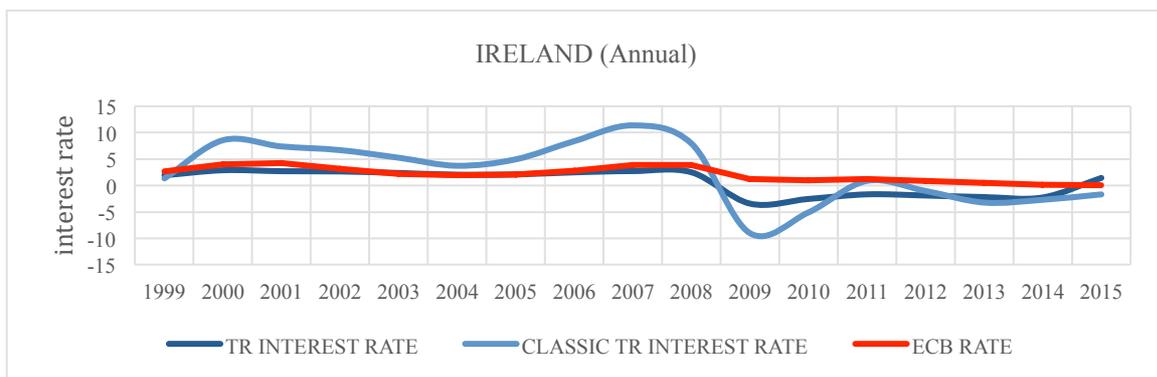
$$i\_TR_{Quarterly\ t} = 2 + 1.804(inflation\ gap_t) - 1.123DUMMYCRISIS_t$$

Figure 4.2.7a: quarterly i_{TR} of Ireland
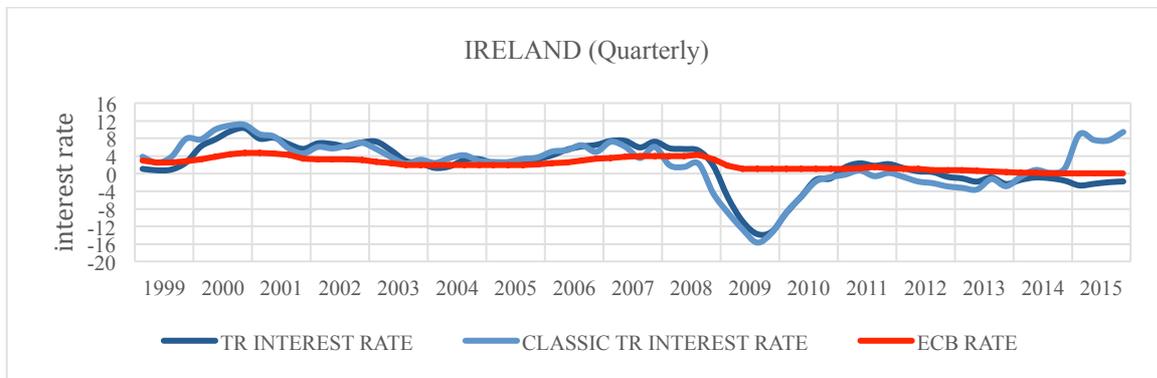
$$i\_TR_{Annual\ t} = 2 + 0.25(inflation\ gap_t) - 3.28DUMMYCRISIS_t$$

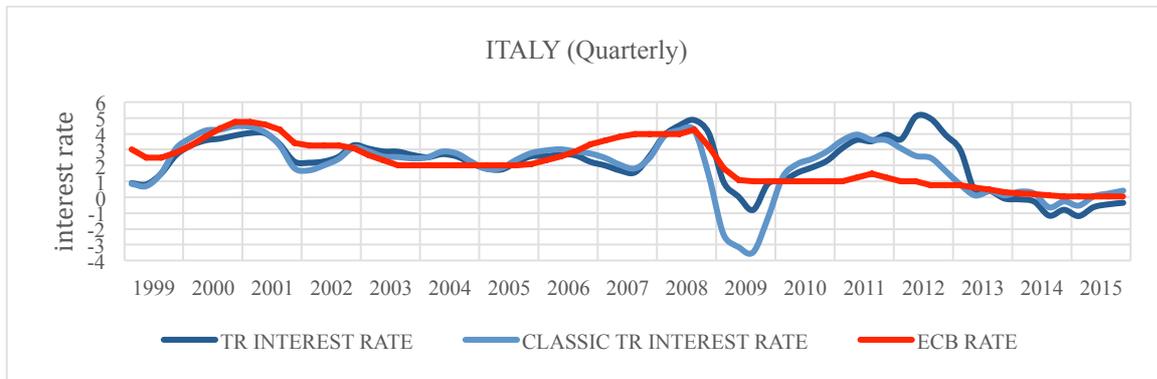Figure 4.2.7b: annual i_{TR} of Ireland

4.2.8 Italy

The rate of the ECB was too low during 2010 till 2013. In 2014 and 2015, the rates are very similar. The annual output gap is very low. Combined with a high weight on output (1.17) and an extreme crisis dummy, it results in a negative annual i_{TR} of -15 percent in 2014.
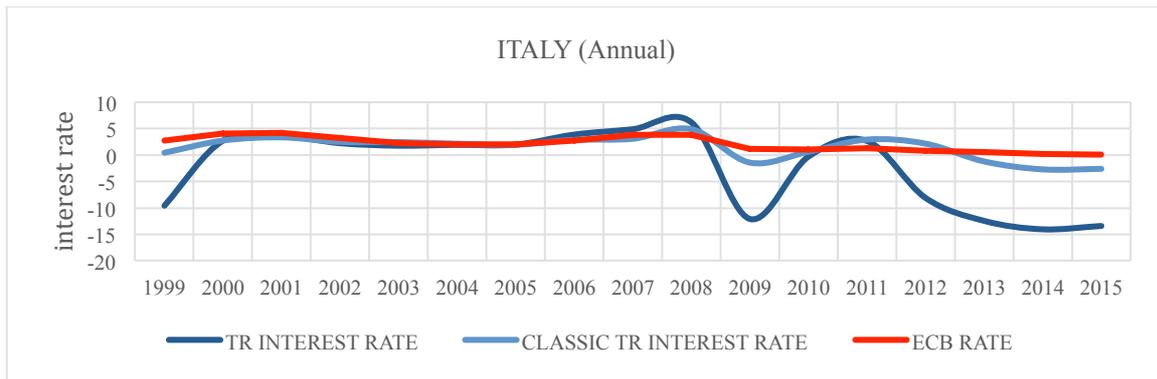
$$i\_TR_{Quarterly\ t} = 2 + 1.634(inflation\ gap_t) + 0.264(output\ gap_t) + 1.688DUMMYCRISIS_t$$

Figure 4.2.8a: quarterly i_{TR} of Italy

$$i\_TR_{Annual\ t} = 2 + 1.56(inflation\ gap_t) + 1.17(output\ gap_t) - 8.46DUMMYCRISIS_t$$
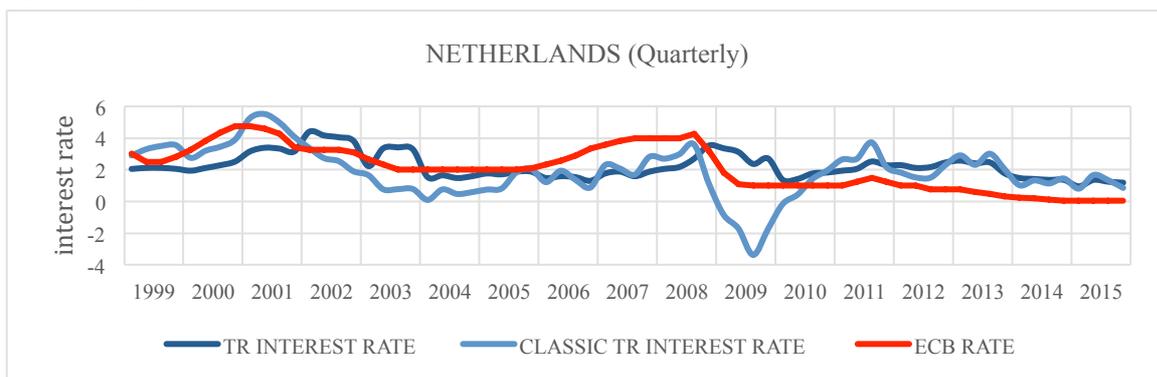
Figure 4.2.8b: annual i_{TR} of Italy

4.2.9 Netherlands

Both the quarterly TR and the annual TR have autocorrelation. Making conclusion about the Netherlands is very difficult. Thereby, the weight on inflation in the annual TR is negative. That's unlikely, so it's excluded in the TR. The annual crisis dummy seems to be too high.
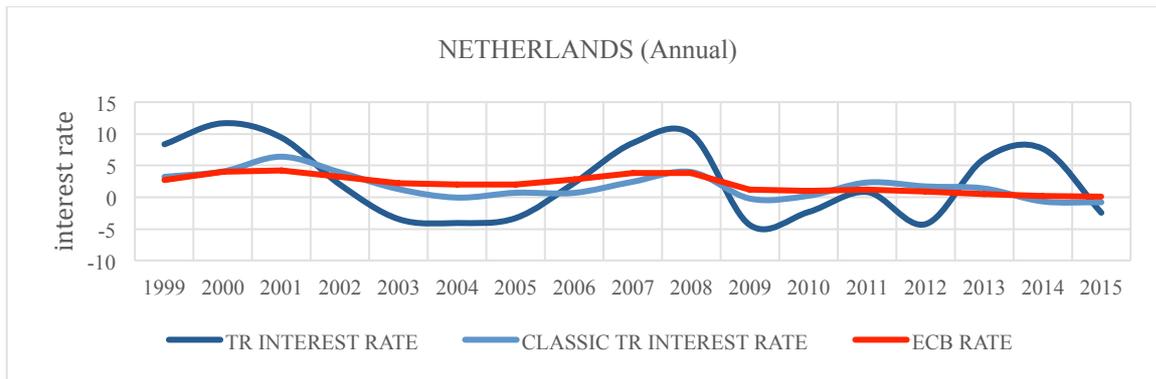
$$i\_TR_{Quarterly\ t} = 2 + 0.579(inflation\ gap_t) + 1.354DUMMYCRISIS_t$$

Figure 4.2.9a: quarterly i_{TR} of the Netherlands

$$i\_TR_{Annual\ t} = 2 + 3.19(output\ gap_t) + 12.85DUMMYCRISIS_t$$

Figure 4.2.9b: annual i_{TR} of the Netherlands

$$i\_TR_{Quarterly\ t} = 2 + 1.019(inflation\ gap_t) + 0.014DUMMYCRISIS_t$$

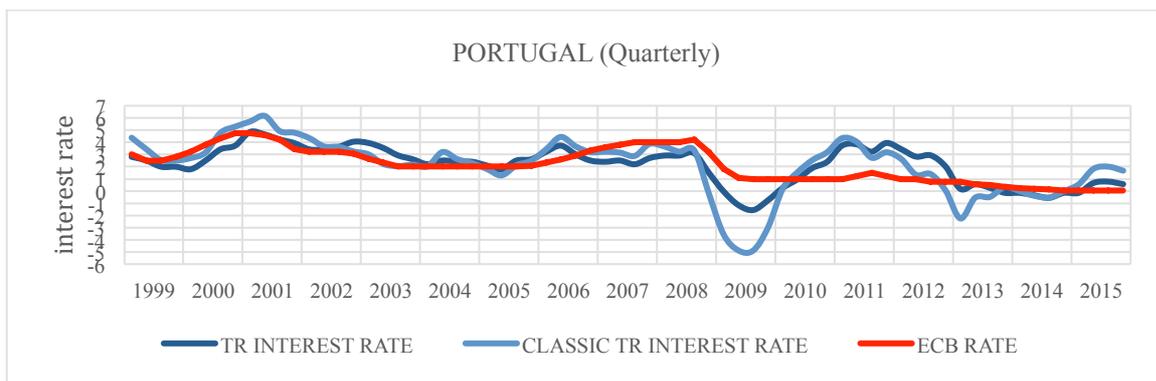Figure 4.2.10a: quarterly i_{TR} of Portugal

4.2.10 Portugal

Prior to the crisis, the policy of the ECB seemed to fit for Portugal. In 2011, the ECB rate was higher than the i_{TR}. After 2012, the zero lower bound is the best option.

$$i\_TR_{Annual\ t} = 2 + 0.99(inflation\ gap_t) + 1.81(output\ gap_t) + 5.43DUMMYCRISIS_t$$

Figure 4.2.10b: annual i_{TR} of Portugal
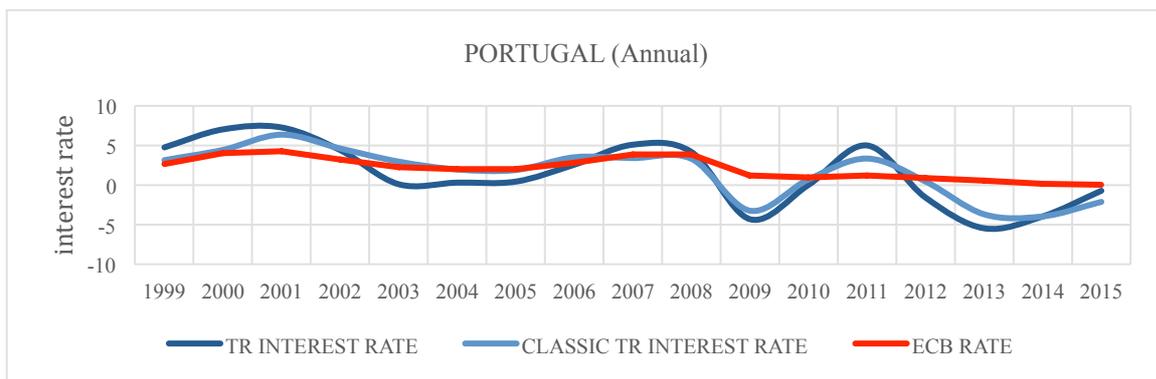
4.2.11 Spain

From 2002 till 2006, the rate of the ECB was too low for Spain. This is also the case in 2010 and 2011. In 2012, the quarterly crisis dummy of Spain (5,434) applies, because the negative output gap was greater than 2 percent. That's why the i_{TR} is high in 2012.
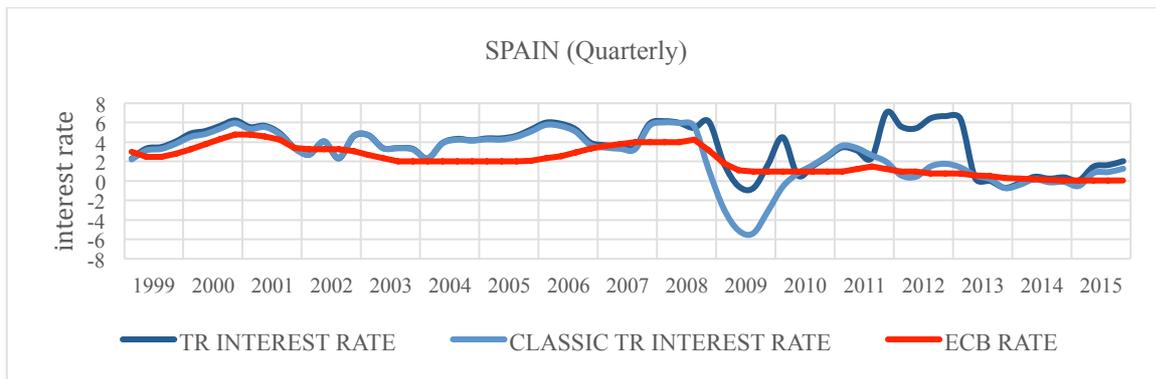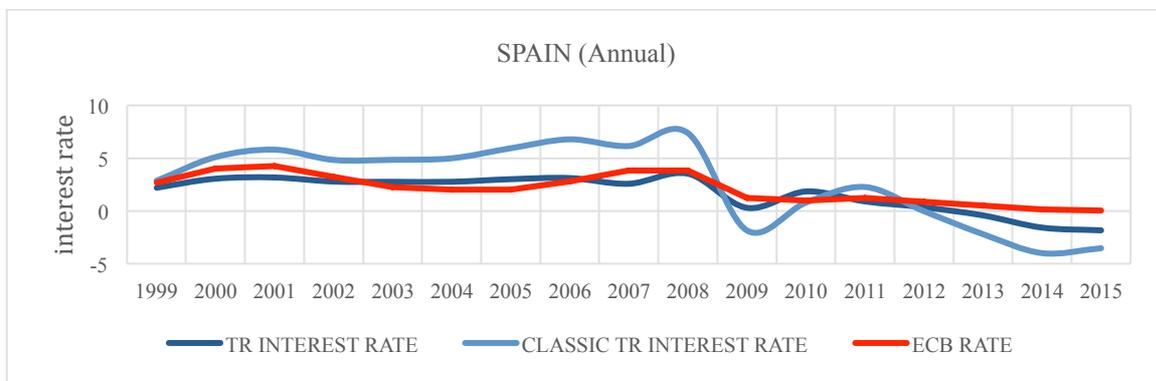
$$i\_TR_{Quarterly\ t} = 2 + 1.503(inflation\ gap_t) + 0.645(output\ gap_t) + 5.434DUMMYCRISIS_t$$

Figure 4.2.11a: quarterly i_{TR} of Spain

$$i\_TR_{Annual\ t} = 2 + 0.74(inflation\ gap_t) - 1.98DUMMYCRISIS_t$$

Figure 4.2.11b: annual i_{TR} of Spain

5. Discussion

In the previous section, all the computed i_{TR}, the implied interest rate from the classic TR and the rate of the ECB are plotted individually for each EU member. To answer the research question, we have to compare them with each other. In order to do so, the rates are plotted together in graphs entirely. There are 4 graphs in total. Figures 5.1a and 5.1b contains the quarterly results. Figures 5.2a and 5.2b contains the annual results. Further, figures 5.1a and 5.2a plot the i_{TR}, computed with the estimated preference parameters. Figures 5.1b and 5.2b contains the interest rates implied by the classic TR, with 'standardized' parameters as described by John B. Taylor (α is 1,5, β is 0,5 and the NRIR is 2 percent). Some members are excluded and their rates are not plotted in the graphs. For example, in section 5.1, Ireland is excluded. The reason for this is that the implied interest rates of Ireland are too high in comparison to the other members. This enlarges the y-axis, making it harder to see the differences between the other rates. The Netherlands and Italy are excluded in figure 5.2a for the same reason.

33

Figure 5.1a: i_{TR} (Quarterly). Excluded: Ireland.

TR interest rates (Quarterly)
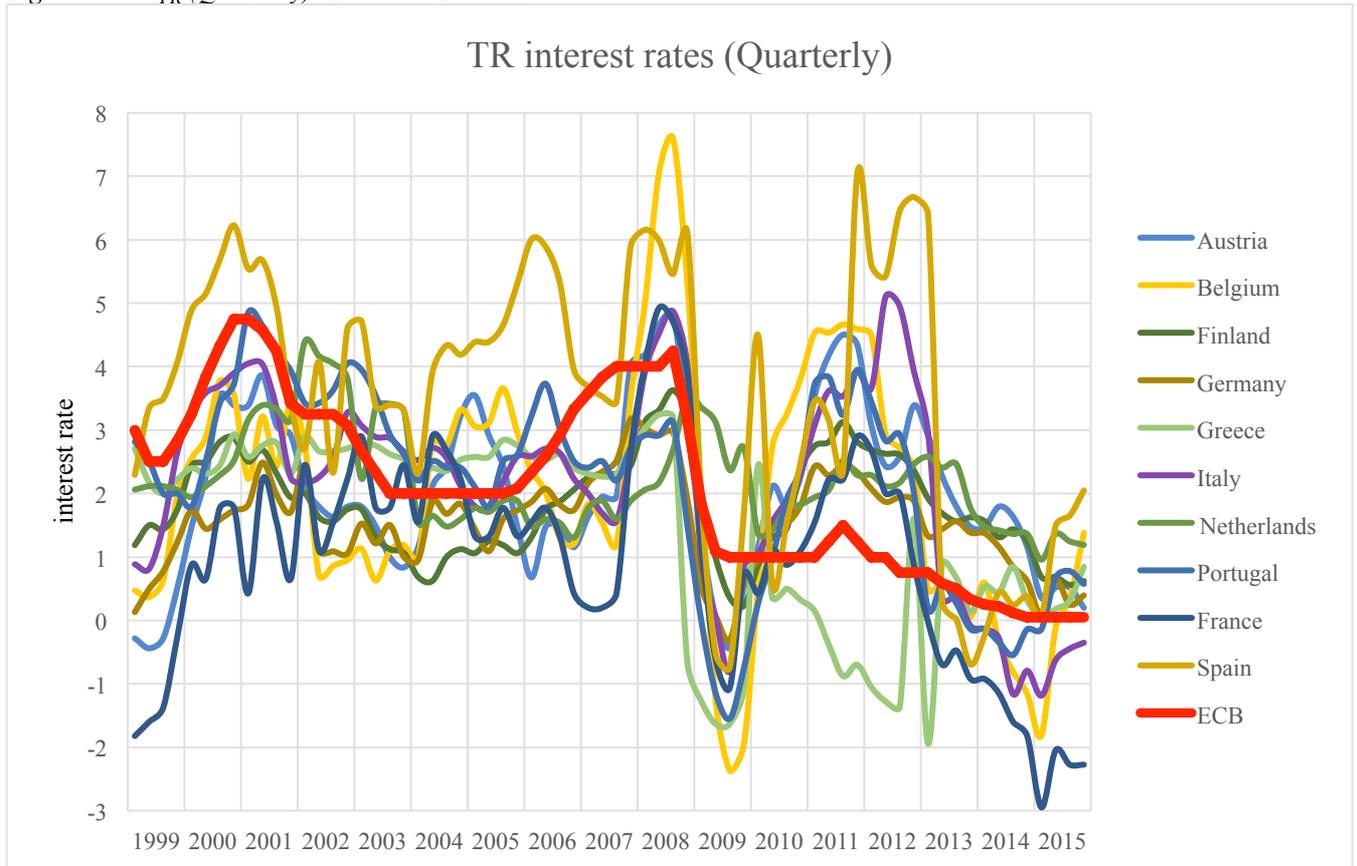
Figure 5.1b: Classic TR interest rates (Quarterly). Excluded: Ireland.

Classic TR interest rates (Quarterly)
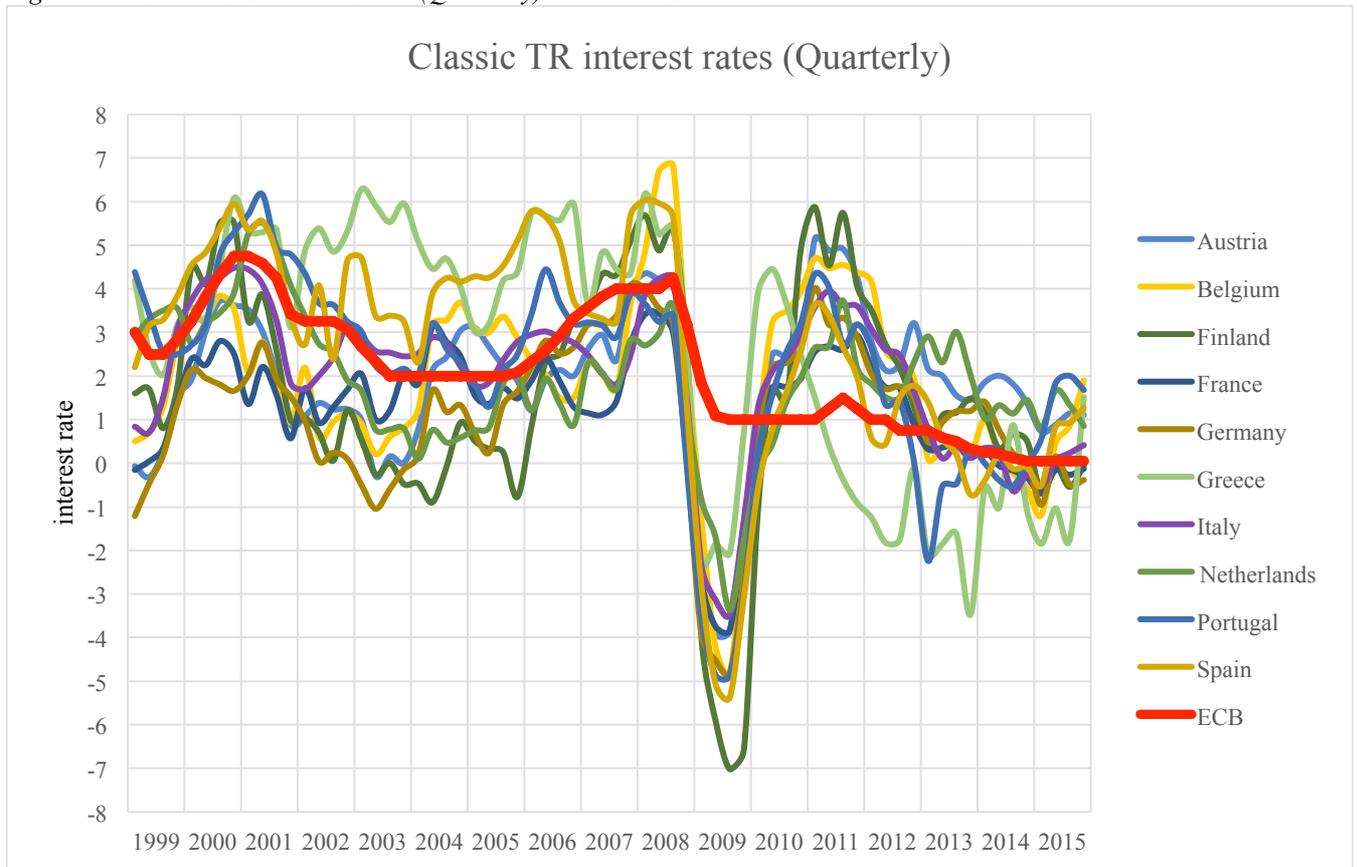
Figure 5.2a: i$_{TR}$ (Annual). Excluded: Netherlands and Italy

TR interest rates (Annual)

Figure 5.2b: Classic TR interest rates (Annual)
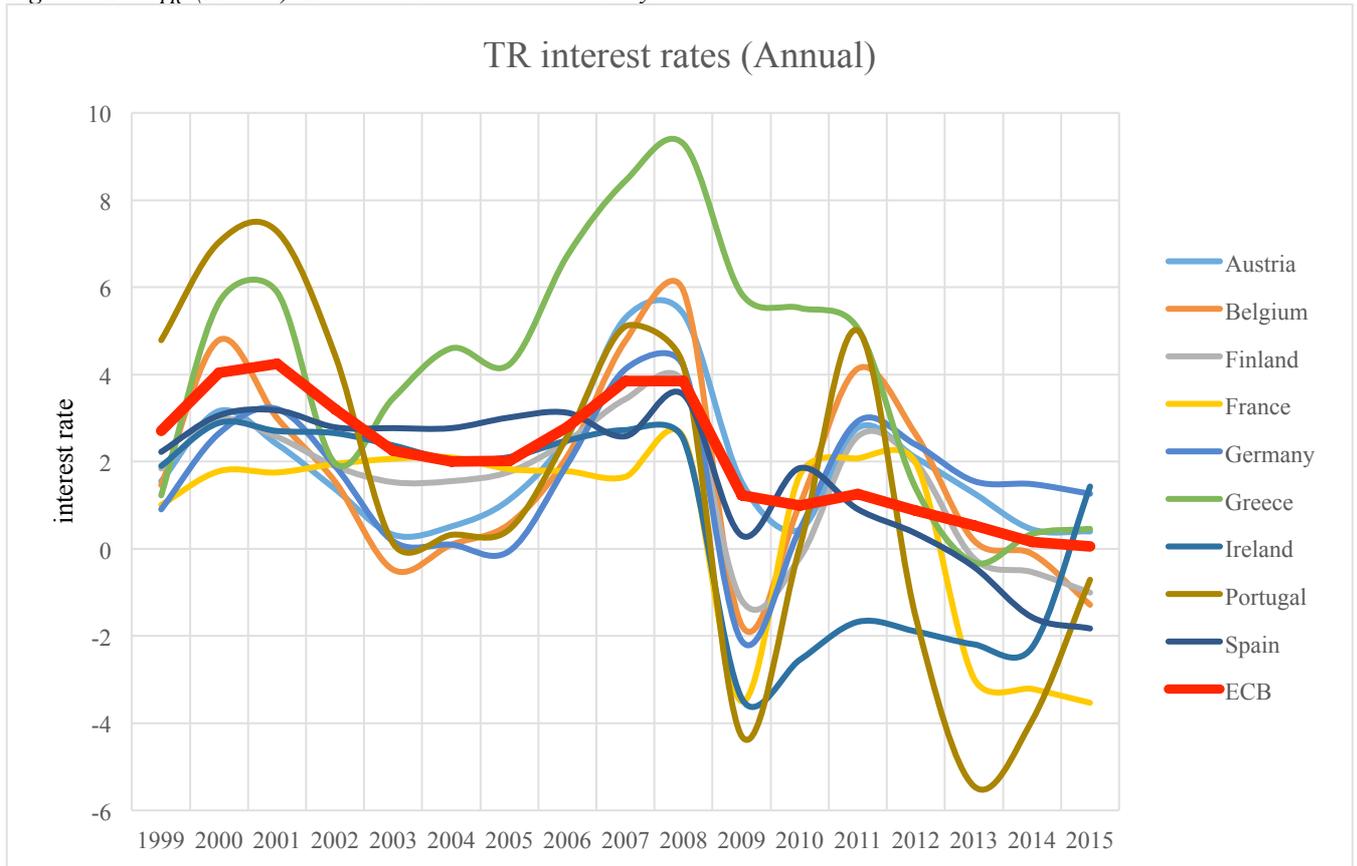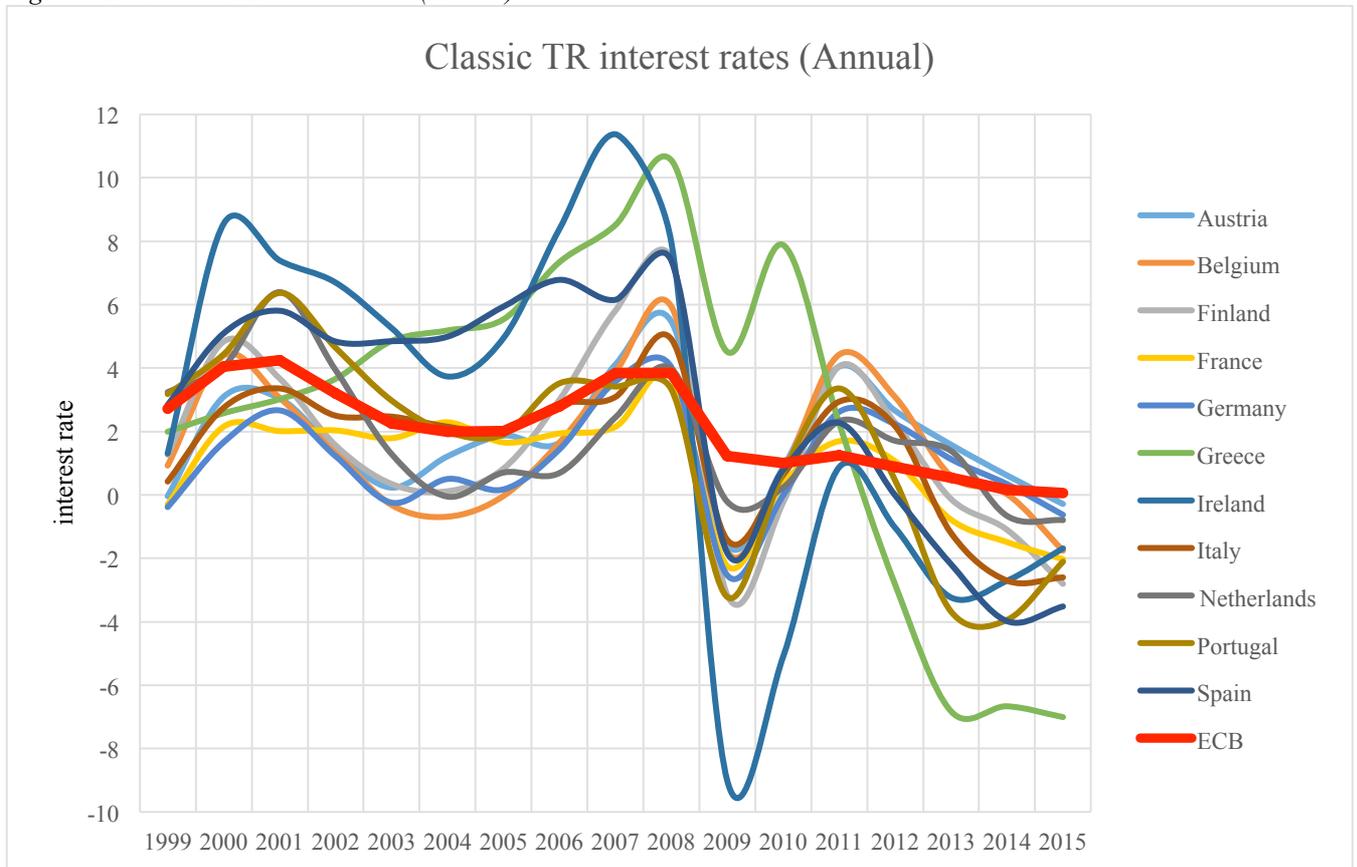

Classic TR interest rates (Annual)

First, we compare the quarterly i_{TR} (figure 5.1a) with the quarterly implied interest rate by the classic TR (figure 5.1b). The main difference between them can be seen in crisis year 2009. In this year, the implied interest rate by the classic TR (5.1b) is much lower than the i_{TR} (5.1a) of all members. This is because all the estimated preference parameters on output β are lower than 0,5, the parameter used in the classic TR. Some estimated parameters are even negative and therefor fixed at 0. This is the case for Finland, France, Ireland, Netherlands and Portugal. This makes that the major negative output gap in 2009 has no or little impact on the i_{TR}, in contrast to the implied interest rate of the classic TR.

Between the quarterly results (section 5.1) and the annual results (section 5.2), later years show a difference. Especially between the quarterly classic TR (figure 5.1b) and the annual classic TR (figure 5.2b) there is a difference in the computed interest rate. Where the annual computed interest rates are all below 0 in 2015, the quarterly computed interest rates are almost all above 0 in 2015. This is mainly due to how the quarterly output gap is estimated. By estimating the trend rate with 3.2, most trend rates turn out to be negative after 2010, as can be seen in figure 3.2. That means that by calculating the output gap (3.3), the GDP growth rate is subtracted by a negative trend rate. As a result, most output gaps are (very) positive. The annual TR uses output gaps estimated by the IMF in computing the interest rate. They estimate positive trend rates, making it harder to achieve a positive output gap. Therefor, most output gaps are negative in 2014 and 2015, making those interest rates lower than their quarterly counterparts.

Overall, we can conclude that the policy rate of the ECB seems to be an average of all the computed TR rates. Especially till 2008. When the financial crisis started in 2009, the ECB adjusted their policy rate to 1 percent. According to the TR, most interest rates had to be very negative in 2009. The ECB could go to the zero lower bound. Despite that, most members recovered well after the start of 2009. The computed TR interest rates of almost every member exceeded the policy rate in the years 2010, 2011, and 2012. The expansionary policy didn't lead to major economic growth and inflation. In fact, the inflation started to decrease in 2013. In 2014 and 2015, inflation and economic growth remained low. That resulted in many negative TR rates, in particular in the annual part (figure 5.2a and figure 5.2b). The ECB's policy rate of almost zero percent 2015 seemed therefor justified. In addition, as the TR suggests negative interest rates in 2014 and 2015, the ECB tried to loosen the monetary policy even more by buying securities (QE).

6. Conclusion

In March 2016, the ECB decided to set the most important interbank interest rate at 0 percent. Some Eurozone-members were anxious that the lower rate would cause overheating of their economy. To see if they were right, this research used the Taylor Rule (TR), invented in 1993 by John B. Taylor, to

compare the TR implied policy rate with the ECB's interest rate. The TR describes how the interbank interest rate can be set by the central bank according to the levels of inflation and output. If those are not at the desired level, the central bank adjusts their interest rate according to their preferences. Some are more inflation strictly and react stronger to increasing or decreasing price levels. Others care more about output and take the more volatile inflation for granted. Because the preferences of central banks are not explicitly mentioned, they have to be estimated. The central bank of each EU-member had prior to the EMU the autonomy to set their own interest rates. First step was to use those interest rates as independent variable and their inflation gap and output gap prior to the EMU as dependent variable in an Ordinary Least Square (OLS) function. This function estimates the parameter of the inflation gap (α) and output gap (β), the preferences of the individual central banks. Secondly, by using those parameters, together with their inflation gap and output gap during the EMU period, it's possible to compute the TR implied interest rate. This is the rate that the individual central banks in theory would have set in the period after 1999, the year when the ECB took over the interest rate policy. The most important rate that is set by the ECB is the rate on Main Refinancing Operations (MRO), the main source of liquidity for commercial banks. This rate is compared to the TR implied interest rates from 1999 to 2015 of the first 11 EMU members: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal and Spain.

This study found that the rate of the ECB fitted very well for most EMU members from 1999 to 2008. Only for Greece, Spain and Ireland, the ECB rate was too low in this period. The rest of computed TR rates were close to the ECB rate or just below. In the post-crisis years (2011, 2012 and 2013), the rate of the ECB was too low for all members. But in the later years (2014 and 2015), mainly caused by negative inflation, the rates of each member are converging to the zero lower bound. It's even possible that the rates are actually lower than here assumed, but that depends on the neutral real interest rate (NRIR), which is the constant in the TR function. In this research, it's fixed at 2 percent, but recent findings state that the NRIR is close to zero. Keeping that in mind, together with the low inflation in the euro area, this study concludes that the unconventional policy of the ECB in 2015 is justified.

This study concludes that the economic conditions and the preferences of the EMU members are not too different between 1999 and 2015. The one interbank interest rate of the ECB functioned well enough for all members in this time period. Sure, there are differences between individual TR interest rates and the rate of the ECB, but it's not large enough to break up with the ECB. A change in the policy, like different interest rates for northern and southern members, is difficult due to the open money market. It's better to keep the differences small between the member's TR rates. That will highly depend on the ability of southern members to achieve the same growth rates as their northern neighbors. If this is not the case, the support for the ECB will decreasing, making the policy in his current form very difficult to maintain.

The main shortcoming of this research is the neutral real interest rate (NRIR). Because it has a lot of influence in determining the TR rate, it's recommended to estimate the NRIR exactly and individually for each member.

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8. Appendix

Quarterly results with formula:

$$i = \bar{\imath} + \alpha(inflation\ gap) + \beta(output\ gap) + \theta(exchange) + \varphi * DUMMY_{crisis} + \rho(i_{t-1}) + \varepsilon$$

Numbers in (..) are Heteroscedasticity-consistent standard errors (HAC)

	$\bar{\imath}$	α	β	θ	φ	ρ
Austria	-0,233542	-0,031961	0,159234	-0,090078	-0,38861	1,03413
	(0,205259)	(0,066322)	(0,044873)	(0,155223)	(-0,187269)	(0,044383)
Belgium	0,297452	0,267729	0,098896	-0,242365	-0,030646	0,929364
	(0,266561)	(0,118805)	(0,078914)	(0,068783)	(0,378211)	(0,042091)
Finland	0,968521	0,167202	-0,043352	0,004465	-0,134647	0,817445
	(0,488549)	(0,060229)	(0,037943)	(0,013598)	(0,348239)	(0,083102)
France	0,320614	0,258134	0,138179	-0,007316	0,08281	0,924558
	(0,481422)	(0,175573)	(0,068233)	(0,012706)	(0,468303)	(0,078358)
Germany	0,277559	0,135301	0,070739		-0,48334	0,926552
	(0,179307)	(0,050332)	(0,027221)		(0,147608)	(0,040014)
Greece	8,09098	0,295572	-0,403583	-0,135068	-3,820437	0,392186
	(2,702456)	(0,104499)	(0,273129)	(0,095353)	(2,023414)	(0,160404)
Ireland	3,083046	1,175627	-0,129226	0,061955	-0,961321	0,588271
	(1,232768)	(0,437153)	(0,157113)	(0,055512)	(1,430489)	(0,114944)
Italy	0,064502	0,219138	0,16189	-0,03382	-0,518194	0,916342
	(0,456359)	(0,083217)	(0,068703)	(0,036769)	(0,381836)	(0,069443)
Netherlands	-0,357355	-0,038183	0,146564	0,006467	-0,512416	1,040374
	(0,191366)	(0,050677)	(0,067077)	(0,010259)	(0,199232)	(0,02609)
Portugal	0,94299	0,260963	-0,089131	0,127842	-0,188684	0,796747
	(0,453299)	(0,058031)	(0,055594)	(0,063485)	(0,504768)	(0,056866)
Spain	0,436455	0,422646	-0,01855	0,084385	0,167417	0,832075
	(0,361651)	(0,140311)	(0,102322)	(0,059644)	(0,637831)	(0,070752)

(TABLE A)

Long-term estimates. Dividing the estimations with $(1 - \rho)$:

	$\bar{\imath}$	α	β	φ
Austria	6,842719016	0,936448872	-4,66551421	11,38617052
Belgium	4,211053854	3,790262756	1,40007928	-0,433858089
Finland	5,305365506	0,915899318	-0,237473638	-0,7375695
France	4,249807799	3,421621908	1,831592482	1,097664431
Germany	3,778986494	1,84213321	0,963116763	-6,580710162
Greece	13,3116052	0,486286923	-0,663990958	-6,285536365
Ireland	7,488046749	2,855341742	-0,313861788	0,150475191
Italy	0,771020106	2,61945062	1,935140692	-6,194195415
Netherlands	8,851117056	0,945732402	-3,630158022	12,6917323
Portugal	1,146243	0,464216	0,114122	-0,928320861
Spain	2,599106744	2,516873604	-0,110465982	4,955039452