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A Taylor Rule for the Euro Area?

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Abstract

The purpose of this paper is to examine whether the original Taylor rule can be used to describe the monetary policy set by the European Central Bank (ECB), when using aggregated inputs for inflation and output gap from the whole euro area as well as for specific regions. If the original Taylor rule is not applicable to the monetary policy of the ECB, we aim to develop a new Taylor rule equation specially adapted for the euro area and the ECB, based on their monetary policy set 1999–2016. The methodology used is to compute the interest rate implied by the original Taylor rule and regress it on the actual interest rate set by the ECB. The conclusion is that the monetary policy of the ECB does not follow the original Taylor rule. The original Taylor rule is not applicable to the monetary policy of the ECB when breaking down the euro area into different regions either. Therefore a new Taylor rule better suitable for the euro area is developed. The new formula puts more weight on the output gap than the deviation from the inflation target, as opposed to the original Taylor rule where there are equal weights on the two variables. The new Taylor rule is shown to be applicable for almost all regions in the euro area.

Keywords: Monetary policy, Taylor rule, European Central Bank, Euro area

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TABLE OF CONTENTS

1. Introduction

Since the financial crisis in 2007–2008, many countries have struggled to keep the inflation at target levels (European Central Bank, 2018d). In its endeavours to keep the inflation at 2%, the European Central Bank (ECB) has for the past couple of years used negative deposit facility interest rates. The negative deposit rates have spurred a discussion about whether the ECB should adopt alternative monetary policy measures. One of the suggestions has been to use a mechanical formula such as the Taylor rule, instead of the flexible inflation targeting strategy currently used (Constancio, 2017). There are even those who argue that it is time for the ECB to normalise its monetary policy, an argument based on the Taylor rule (Alcidi, Busse and Gros, 2017). The Taylor rule was originally designed for the Federal Reserve, the central bank in the United States, offering a formula for the Fed funds rate. Comparing the actual Fed funds rate and the Taylor rule predictions, one can conclude that the rates align relatively well (Jones, 2014, p. 389). The ECB has not formally adopted a similar mechanical formula (ECB, 2018h).

However, the modern macroeconomics is clear on the fact that policy rules have significant advantages over a monetary policy without a pre-defined contingency plan in improving economic performance. Hence, it should be important to preserve the concept of a policy rule even in an environment where it is practically impossible to mechanically follow the algebraic formulas developed by economists to describe their preferred policy rules (Taylor, 1993). Therefore we find it relevant to examine whether the Taylor rule can be applied to the euro area and the ECB or if a similar mechanical rule could be adapted for the ECB. Thus, in this paper, we research whether the interest rate predictions, given by the Taylor rule historically coincide with the actual ECB interest rates. If the analysis shows that the interest rate set by the ECB follows the Taylor rule, this could provide some predictability to the monetary policy carried out by the ECB. It would also be possible to further analyse whether the Taylor rule could be formally adopted as a policy rule that is part of the monetary policy strategy of the ECB.

However, the ECB differs from the Fed, since the ECB sets a monetary policy for a range of different countries, each with different economic preconditions. The differing economic conditions provide further challenges for the ECB when conducting their monetary policy. Even if our results would indicate that the ECB as a whole does not follow the Taylor rule when conducting its monetary policy, it might still be possible that the ECB does follow the Taylor rule to some extent. In other words, they might consider only a few countries in the European Union (EU) when setting interest rates. For example, either the ECB might consider solely the bigger economies such as Germany and France or the financially struggling countries such as Portugal, Ireland, Italy, Greece and Spain. The applicability of the Taylor rule will therefore also be analysed with regards to different regions in the euro area separately.

If the Taylor rule is shown not to be explanatory of the actual interest rates, an alternative Taylor rule, specifically adapted for the euro area, will be suggested. We determine there might be a need for such adjustment to the original Taylor rule since this original formula was created based on the monetary policy conducted by the Fed (in particular 1987–1992) (Taylor, 1993). If it is possible to suggest such a formula that is suitable for the euro area, this new formula could perhaps serve as a monetary policy rule not currently in use by the ECB. It would provide predictability and might even prevent future challenges with low inflation. For example, in Taylor (2009), empirical evidence showed that government actions had worsened the financial crisis by deviating from historical principles. Therefore Taylor urged central banks to return to interest setting principles such as the Taylor rule.

The purpose of this paper is to examine whether the original Taylor rule can be used to describe the monetary policy set by the ECB, when using aggregated inputs for inflation and output gap from the whole euro area as well as for specific regions. If the original Taylor rule is shown to not be applicable to the monetary policy of the ECB, we aim to develop a "new" Taylor rule equation specially adapted for the euro area and the ECB, based on their monetary policy setting 1999–2016 (except July 2012–June 2014). The research questions are thus the following:

- How well does the original Taylor rule describe the actual interest rates set by the ECB?
- Could the ECB be said to follow the original Taylor rule when using inflation and output gap values from a specific region?
- How could the Taylor rule be adjusted to better explain the interest rate set by the ECB from 1999–2016 (except July 2012–June 2014)?

The remaining parts of the paper are divided into the following. Section 2 provides a background of the monetary policy conducted by the ECB. Section 3 gives an overview of the current state of research. In Section 4 the research design is presented and Section 5 contains the results. In Section 6 the results are discussed and in Section 7 the conclusion is presented.

2. Background

This section gives a background to the structure and monetary policy of the ECB. This background information aims to give a context to the subsequent analysis to facilitate the understanding of the thesis.

2.1 The structure of the ECB

The ECB is a central bank for the EU member states having the euro as their currency, hereafter called the euro area (European Union, 2012). The Governing Council of the ECB is the highest decision-making body and is conducting the ECB's monetary policy. The Governing Council consists of six Executive Board members and the central bank Governors of the euro area countries. The Executive Board members have permanent voting rights. In addition to this, there are 15 voting rights. The five countries that have the greatest economies and financial sectors (Germany, France, Italy, Spain and the Netherlands) share four voting rights and the remaining countries share 11 voting rights. The voting rights rotate between the Governors (ECB, 2014a). The ECB is independent of any political influence, whether it is from EU institutions or national governments (European Union, 2012). One of the aims of the ECB being independent is to ensure it acts in the best interest of the euro area as a whole instead of favouring certain national interests (ECB, 2017).

2.2 ECB's monetary policy

2.2.1 Standard monetary policy measures

The primary objective of the ECB's monetary policy is to maintain price stability. To reach this objective, the ECB has adopted a monetary policy strategy comprising of a quantitative definition of price stability, and a two-pillar approach to the analysis of the risks to price stability. The quantitative definition of price stability does, more specifically; mean keeping inflation rates below, but close to 2% (ECB, 2018e). Inflation is defined as the increase in consumer prices and is measured by an index for the EU member states, called the Harmonized Index of Consumer Prices (HCIP) (ECB, 2018c). The two-pillar approach is the ECB's approach to analyse economic developments and to assess the risks to price stability. These two pillars are economic analysis and monetary analysis. The economic analysis is concerned with short and medium-term price developments and the factors influencing price development. On the other hand, the monetary analysis assesses the long-run link between money and prices (ECB, 2018e).

The main measure used to achieve this monetary policy objective is the setting of interest rates. There are three key interest rates set by the ECB; the interest rate on the main refinancing operations (MROs), the rate on the deposit facility and the marginal lending facility. The deposit facility rate is fixed at a spread below the MRO rate (Coeure, 2015). In this paper, the interest rate on the MROs will be used as it determines the bulk of liquidity to the banking system. Hence, the MRO rate determines the price at which banks can borrow money from the ECB, and as a consequence, it also determines at which rate the banks can lend out to the end consumer. Thus, if the ECB wishes to stimulate the economy they lower the MRO, which stimulates investment, which in turn increases the inflation level. This rate can be either variable or fixed. Since the ECB began its monetary policy measures the 1 January 1999 the interest rate has mostly been fixed, however between 28 June 2000 and 9 July 2008, the interest rate was variable (ECB, 2018b). A high-interest rate makes it more expensive to borrow money from the bank, resulting in lower investment and consumption, which in turn keeps the price level, that is inflation, low. On the other hand, when investment and consumption are low, the ECB can lower the interest rate to encourage more borrowing, investment and consumption. In turn, more investment and consumption typically raises the inflation. In order to keep inflation at a steady level, the ECB consequently needs to adjust the interest rate on a regular basis (Jones, 2014, pp. 306–324).

2.2.2 The zero lower bound

Traditionally the perception has been that interest rates cannot go below zero (or slightly above zero). This concept is called the zero lower bound. The reasoning underlying the assumption of the zero lower bound is that investors would never hold a fixed-income instrument with a risk-free negative return, since holding cash (with a zero nominal return) would always be the superior alternative. Likewise, central banks were expected to be constrained by the zero lower bound when setting monetary policy rates to stimulate the economy. Before the financial crisis, the zero lower bound had not been a topic of discussion since the ECB had not been close to this lower bound. However, in July 2012 the ECB set the deposit facility rate to zero and in June 2014 the ECB decided to decrease the deposit facility rate to a negative rate of -0.10. A new negative lower bound was thus established (Lemke and Vladu, 2017). After this first decrease, three more rate cuts followed. In September 2014 the ECB lowered the deposit facility rate to -0.20, in December 2015 to -0.30 and in March 2016 to -0.40 percent (ECB, 2018b). While investors considered negative interest rates inconceivable in the euro area for a long time, investors seemed to adapt their view of the lower bound when the ECB decreased policy rates to negative levels (Lemke and Vladu, 2017). Coeure (2015) states that the lower bound should not be seen as a strict bound on interest rates, but it is rather the combination of standard as well as non-standard monetary policy measures that constrain the lower bound.

2.2.3 Non-standard monetary policy measures

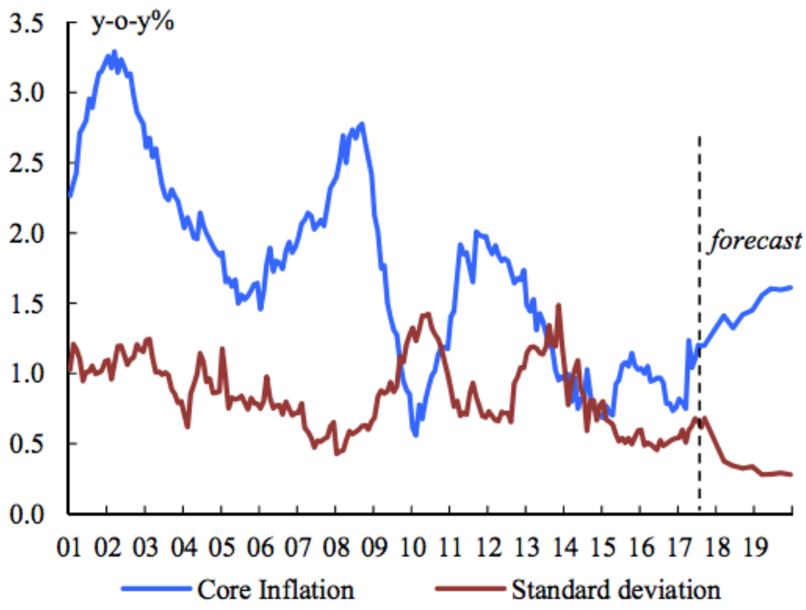
Before the financial crisis, the standard monetary policy measures fully explained the monetary policy conducted by the ECB. However, after the financial crisis, adjusting interest rates have been insufficient in controlling inflation and stimulating the economy, especially when the ECB treated the zero lower bound as binding. As a consequence, the ECB has started to set negative interest rates, as well as introduced non-standard monetary policy measures (ECB, 2014b). One such non-standard measure is quantitative easing which was introduced in March 2015. Quantitative easing means that the ECB buys bonds from commercial and public banks, which increases the price of these bonds. As a result, interest rates fall, and people are able to borrow more money. When people can borrow more they can consume and invest more, which leads to a higher inflation level (ECB, 2018a). Thus, quantitative easing helps with reaching the inflation target of 2% when low interest rates are insufficient. According to Lhuissier (2016), the impact of quantitative easing results in a monetary condition comparable to an interest rate below -3%.

The ECB has also targeted longer-term refinancing operations (TILTROs) that provide long-term financing to credit institutions at attractive conditions to stimulate bank lending to the real economy (ECB, 2018f). Under the TILTRO-II program, borrowing banks can borrow up to 30% of their outstanding loans from the ECB at a lower interest rate and with a maturity of four years. Usually, the amount and cost of borrowing depend on how much loans the banks provide the real economy, and the maturity of the loans are usually within one week or three months. By instead providing the attractive conditions for borrowing under the TILTRO-II program, the ECB enables borrowing banks to lend money to business and consumers in the euro area. This, in turn, stimulates the real economy. Thus the TILTROs are also non-standard monetary policies helping the ECB to reach its main objective (ECB, 2016).

In conclusion, the ECB monetary policy is determined by the interaction of a range of instruments including the level of interest rates, the pace of quantitative easing and other non-standard monetary policy tools. The different tools complement each other to generate sustainable inflation convergence (Draghi, 2017).

2.3 The euro area challenge

The ECB is different from domestic banks in Europe because the ECB has to manage countries with such differing economies. Instead, inflation and output growth differentials in the euro area are more comparable with other large currency areas such as the United States. The differentials in inflation and output growth may be due to differences in demographic trends, long-term catching-up processes or on-going adjustments leading to a more efficient allocation of resources. As long as the inflation and output growth differentials are moderate, there is no problem for the ECB to conduct its monetary policy for the euro area. However, if there is a persistence of inflation and growth differentials, induced by structural inefficiencies or misaligned national policies, of individual euro area countries over a longer period it needs to be addressed by national policy adjustments (ECB, 2011, pp. 52–53).



*Graph 1: Euro area core inflation and dispersion (*The European Commission 2017)

Since the late 1990s, the inflation dispersion in the euro area has been moderate, up until the financial crisis in 2008, when the dispersion spiked. At the same time, the core inflation level plunged. The increase in inflation dispersion and the decrease in core inflation level in 2008–2009 reflect the differences across countries in the extent and timing of their impact of the economic recession and recovery as well as fiscal policy response. The rise in inflation dispersion highlighted the need for domestic economic policy adjustments to tackle previously accumulated imbalances at a national level, which started to be implemented in 2009–2010. In the second half of 2010 inflation dispersion in the euro area declined and normalised and the core inflation rose again (ECB, 2011, pp. 52–54). However, the rebound that took place from 2009 to 2011 was derailed by the onset of the sovereign debt crisis. There was a nascent recovery in mid-2013, but it lost steam in mid-2014 as the external environment became more uncertain. The severity of the crisis had contributed to high debt levels in European countries, which made the euro area highly vulnerable to new shocks. The euro area economy was consistently struggling to gain momentum (Draghi, 2017).

Even though the EU adopted a range of measures that should have regulated the indebtedness of individual member states, many countries gave up their implementation and did not apply them. Some countries, in particular, Portugal, Italy and Greece, have run a substantially large deficit and their indebtedness have depressed further development and growth, not just in these countries but the whole Eurozone (Latjtkepová, 2016). The euro area has one currency and one interest rate but lacks a fiscal union to stand alongside the monetary union. This limits the ECB capabilities to stabilise the Eurozone and reduces differentials in inflation and output growth across countries as they cannot recycle taxes raised in those parts of the Eurozone that recovered well into higher spending for those parts of the Eurozone that are performing poorly (Elliott, 2015). Apergis and Cooray (2014) point out that neither for the EU nor the Eurozone itself is there one single recommendation for crisis measures. Instead, they recommend that each country proceed in accordance with its specific conditions.

However, in recent years the euro area recovery has evolved from being fragile and uneven into a firming, broad-based upswing. According to Mario Draghi (2017), there are only two "exogenous" factors that can realistically explain the resilience of the recovery: the collapse in oil prices in 2014–2015 and the ECB monetary policy. But even though there have been signs of progress such as growth and employment rates converging upwards across the euro area, significant gaps remain in terms of levels, reflecting the ECB challenge of managing such differing economies and their inability to use fiscal policy. In large parts of the euro area, there are still substantial under-utilised resources, reflected in a negative output gap and high unemployment rates (Draghi, 2017).

3. Current State of Knowledge

This section gives an overview of previous research conducted in the area relating to our research questions. The original Taylor rule is presented followed by previous research concerning the Taylor rule in relation to the ECB and to the countries in the euro area.

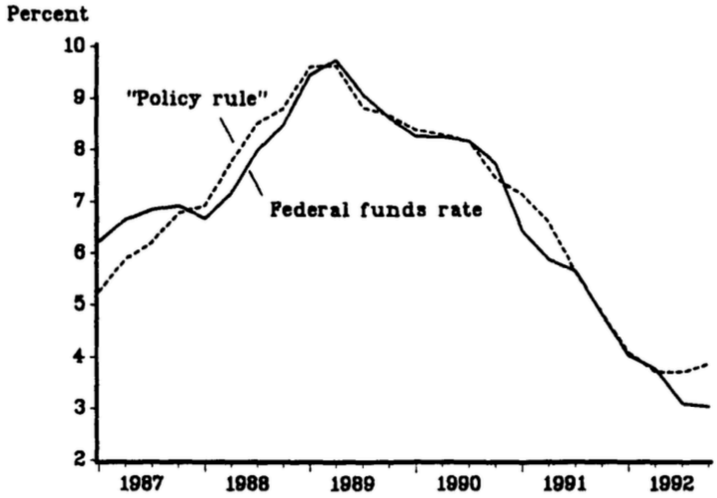
3.1 The Taylor rule – a policy rule

In Taylor (1993), John B. Taylor examines how econometric policy evaluation research on monetary policy rules can be applied in a practical policy-making environment. According to this paper, which is based on Taylor's research, a good policy rule typically calls for changes in the federal funds rate in response to changes in the price level or changes in real income. A policy rule is here defined as "a contingency plan that lasts forever unless there is an explicit cancellation clause*"*. The opposite of a policy rule is pure discretion, where the setting for the instruments of policy is determined from scratch each period without attempting to follow a predefined contingency plan. As previously mentioned in the introduction, most macroeconomists argue that policy rules have major advantages over discretion in improving economic performance (Taylor, 1993).

Taylor's research has resulted in one of the most well-known instrument rules to determine the nominal short-term interest rate. Taylor finds that it is preferable for a country to set interest rates based on their own economic conditions, and to pay little attention to exchange rates (which preferably should be flexible). Also, placing a positive weight on the real output and price-level is preferable in most countries. However, there is no consensus on the size of the coefficients (Taylor, 1993). The rule he suggests describes how the nominal short-term interest rate responds to inflation and the short-run output gap. The policy rule, which captures the result of his research, is stated below.

The Taylor rule equation: $i_t = \bar{r} + \pi_t + \bar{m}(\pi_t - \bar{\pi}) + \bar{n}\tilde{Y}_t$
Where $\bar{m} = \bar{n} = 0.5$ (Taylor, 1993)

In the equation above i_t is the nominal interest rate set at time t, π_t is the inflation at time t and $\tilde{Y}_t$ is the GDP output gap at time t. The inflation target is $\bar{\pi}$ and the real interest rate target is $\bar{r}$ (Jones, 2014, p. 359). The 2% equilibrium real rate is close to the assumed steady-state growth of 2.2% (Taylor, 1993). The policy rule has the feature that the federal funds rate raises if inflation rises above the target of 2% and decreases if it is below target. A positive output gap results in an increase in the Fed funds rate and a negative output gap results in a decrease. The rule was found to describe the monetary policy setting for the early years of Alan Greenspan's chairmanship of the Board of Governors of the U.S Federal Reserve system "the Fed" (1987–1992) extremely well (Carare and Tchaidze, 2005).



Graph 2: Federal funds rate and the Taylor rate 1987–1992 (Taylor, 1993)

Although the Taylor rule is widely recognised, there is research criticising the rule. Österholm (2003) investigates the econometric properties of the Taylor (1993) rule applied to U.S., Australian and Swedish central banks to evaluate its empirical relevance. He concludes that little attention has been paid to the time series properties of the data that underlie the calculations when using interest rate rules. Using unit root tests, he shows that the variables in the Taylor rule are likely to be integrated of order one or near integrated. Given this, Österholm argues, that cointegration should be a necessary condition for consistent estimation of the parameters in the model. Since this condition cannot be shown to be satisfied, Österholm concludes that the Taylor rule generally cannot be a reasonable description of how monetary policy is conducted. Gerlach-Kristen (2003) argues that previous work has disregarded the factor of non-stationarity of variables when computing the Taylor rule on the euro area. In this paper, Gerlach-Kristen estimates interest rate reaction functions under the hypothesis that the variables of the Taylor rule have a unit root. In order to account for the non-stationarity, a cointegration approach is taken. The results show that the interest rate reaction functions using the cointegration approach are, in contrast to traditional Taylor rules, stable in sample and forecast better out of sample. Based on this research we will in this paper also test for unit roots and cointegration.

There are those who argue that the Taylor rule should not be followed strictly but rather as a guidepost. Carlstrom and Fuerst (2003) suggest that the exact form of the Taylor rule probably is not that important but instead that monetary policy rules should satisfy the Taylor principle. The Taylor principle says that the nominal interest rate must increase more than for each unit of increase in inflation. Such a monetary policy rule, they argue, can be used as a guidepost for monetary policy conducted by central banks. Guideposts provide the credibility of strict rules but make it possible to deviate from the principle to respond to unforeseen events temporarily. This idea of having a Taylor rule as a guidepost rather than, as a strict rule is further elaborated on in Section 6 of this paper.

3.2 The Taylor rule and the ECB

Much research has been carried out regarding the Taylor rule in relation to the Fed. However, there is also some previous research relating the Taylor rule to the ECB. Sauer and Sturm (2003) research how Taylor rules can be used to understand the ECB monetary policy. They begin by concluding that a form of the Taylor rule does apply to the ECB based on the ECB's two-pillar approach. Taylor rules are thus determined applicable and their results show that the ECB has put a higher weight on the output gap relative to inflation. These results by Sauer and Sturm confirm the conclusion drawn by Faust et al. (2001) who argue that the ECB has put a too high weight on the output gap relative to the inflation when they compare the monetary policy of the ECB and the Bundesbank (the central bank of Germany). These research papers are examples of papers where Taylor rules are determined applicable to the monetary policy conducted by the ECB. However, these research papers do not claim that the ECB follows the standard formula where equal weights of 0,5 are put on the inflation and the output gap respectively. This is because the notion of “Taylor rules” here merely is defined as a mechanical formula where the nominal interest rate is related to the output gap and the deviation from the inflation target.

Belke and Pelleit (2006) further analyse the weights put on the deviation from the inflation target and the output gap respectively and conclude that Taylor rules generally describe the Fed's policy better than the ECB's policy. In this study, the monetary policies of the ECB and the Fed are measured in the period 1999 to 2005. The results for the ECB show that the weight on the deviation from the inflation target is smaller than the weight on the output gap as opposed to the equal weights postulated by the original Taylor rule. Moreover, the ECB appears to have considered money growth as an important factor in the monetary policy strategy. The estimation results for the Fed, however, show that the weights on the deviation from the inflation target and the output gap respectively are not too different. The authors conclude that both the ECB and the Fed seem to follow some form of Taylor rule, but the standard Taylor rule appears to describe the behaviour much better for the Fed. However, the inflation in the euro area was low during the sample period, which they mean, might explain why the ECB assigned such a low weight to inflation.

In conclusion, there are research papers showing that the ECB is following some kind of Taylor rule although not the original standard formula from 1993. However, these research papers were produced many years ago, which means there were only a few years of ECB monetary policy included in the samples studied. Furthermore, these papers were produced before the financial crisis, which means they are not descriptive for the more recent years. This is because the ECB, after the financial crisis, has faced challenges previously not encountered. Therefore we see the need for a more recent study in this area, which our research paper is aiming to provide.

3.3 The Taylor rule and the euro area countries

Our second research question is aiming to answer the question of whether the ECB can be said to follow the Taylor rule when dividing the euro area into different regions. There is no previous research on this exact research question. However, there are papers analysing the monetary policy of the ECB in relation to the specific countries constituting the euro area. Ullrich (2006) aims to answer the question of how much the economic situation of the member states influences the interest rate decision of the council. The background to this research question is the following. In the Statute of the ECB, the monetary policy decisions shall be made given the situation of the euro area as a whole. However, the decision-making body of the ECB (the Governing Council) consists of representatives of national central banks. These representatives might consider the national economic situations over the euro area as a whole. To investigate this question, the researcher estimates Taylor type functions for the period 1999 to 2005 where country-specific variables for the Eurozone member states are included. These variables include inflation rates as well as economic sentiment indicators. The result from this research paper is that a dominant influence from specific countries cannot be detected; meaning the decisions of the ECB do indeed take the whole euro area into account.

However, there are research papers showing that there are notable differences in how the single monetary policy affects each member country. Sturm and Wollmershäuser (2008) analyse this issue by using Taylor rule functions. They show that the degree of adequacy of the monetary policy of the ECB for each member country depends on the underlying weighting scheme in the decision process. By attaching the actual policy weights that the ECB has implicitly attached to each member country, they show that developments in small member countries have received more than proportional weights in actual monetary policy decisions of the ECB. Their reasoning concerns stress levels, defined as the difference between the ECB main refinancing rate and the optimal monetary policy of a country. From a country perspective, their results show for example that the interest rates should have been 2.8 percentage points higher in Ireland on average whereas they should have been 0.6 percentage points lower in Germany. Moons and van Poeck (2007) reach similar results in their research paper where they aim to show whether the interest rate setting of the ECB is in accordance with the needs of the individual member countries. In this paper, they assume that the standard Taylor equation is applicable to the ECB's monetary policy. Their result shows that the ECB's interest rate setting does not suit all European Monetary Union (EMU) members equally well. For example, the interest rate is too high for Germany and too low for Ireland. In a research paper by Hayo (2006) the question is whether interest rates would have been different for the EMU countries if their national central banks had not given up control over monetary policy to the ECB. The study period is from the year 1999 to 2004, and the estimates of the monetary policy reaction functions are derived using Taylor rules. The results are that most countries would have set higher national interest rates than the ECB interest rates. The country gaining higher credibility when becoming a member of the ECB can explain these lower interest rates. The only exception is Germany that would have set lower national interest rates than the ECB interest rates.

In conclusion, there are research papers relating Taylor rules to the specific countries in the euro area. However, there are no research papers that research the Taylor rule's applicability to regions, rather than countries. Furthermore, the results from previous papers are contradictory, which confirms the need for more research and clarity in this area, which our thesis is aiming to provide.

4. Research Design

In this section we present the research design, which constitutes of the specification of our detailed research focus, the methodology and the data sources used.

4.1 Specification of detailed research focus

In order to keep the research topic focused, a number of specifications to the research questions are made. We analyse the time period from January 1999 until December 2016, excluding the period July 2012–June 2014. We want as large of a sample as possible to be able to draw relevant conclusions and therefore we decide to use all the data available. January 1999 is when the ECB introduced their monetary policy measures and after December 2016 we lack the necessary data for the output gap. The reason we exclude the years July 2012–June 2014 is that before July 2012 the zero lower bound was, as mentioned, for the most part, seen as a purely theoretical problem whereas between July 2012 and June 2014 the zero lower bound became a concrete problem as further actions were required to stimulate the economy. The Taylor formula would not have been applicable in the presence of a zero lower bound. This is because, during the years with the zero lower bound, the ECB would not set an interest rate below 0% even though the Taylor rule would recommend it. However, after the replacement of the zero lower bound to a negative lower bound in June 2014, the lower bound does not appear to have been very binding since the lower bound has decreased several times since mid-2014. As the ECB has relaxed the assumption of the "zero lower bound" four times one could expect this to happen again if the ECB finds it necessary. Therefore, the periods after June 2014 are included in the analysis.

In this thesis, we choose to focus on regional analysis as we find it more interesting than a country-specific analysis. This is because we determine a regional analysis to be able to show trends more clearly as it gives aggregate outputs. The EU countries analysed, comprising the regions, are the countries having the euro as its currency and that joined the EU before the year 1999. The reason for this is that the ECB is the central bank for the euro area. Hence it makes sense to analyse the Eurozone. Furthermore the regional Taylor rate comparison to the actual ECB rate would not be possible for all the years in our sample if we include member states that joined after 1999.

An additional specification to the research focus is that the Taylor formula used is the original equation presented by Taylor in 1993. The rule has undergone many modifications as researchers have tried to make it a better fit for current monetary policy. However, in this research paper, we only seek to investigate whether the ECB follows the original Taylor formula (93) and thus this is the only one we will consider.

4.2 Methodology

4.2.1 Testing for stationarity and cointegration

As mentioned, there are some previous research papers criticising the fact that the Taylor rule has been used without taking time series properties of the data into account. When analysing regressions using time series, the time series must be stationary. Time series that are not stationary have a unit root. Therefore, we test whether the variables have a unit root or not. The first order difference of non-stationary variables can be included in the regression analysis under the condition that they are cointegrated. Cointegration means that the variables have long run associations. If the variables are non-stationary but not cointegrated the regression can be spurious with inconsistent estimated parameter vectors and diverging t- and F-statistics. The augmented Dickey-Fuller (ADF) test is used to test for unit root and the Johansen test is used to test for cointegration. Since the Johansen test is sensitive for the number of lags we test for the recommended number of lags with lag-order statistics for VAR and VEC (Sjö, 2008). The results of these tests can be seen in Appendix A.

4.2.2 Regressing the original Taylor rate on the ECB rate

In order to answer the proposed research questions, we compute the nominal interest rate implied by the Taylor rule (93) for the entire euro area. The idea is to compare and see if these predicted rates could be used to explain the interest rates set by the ECB from 1999–2016 (except July 2012 to June 2014). To make the predictions on the interest rates we use panel data on all the inputs in the Taylor equation, including GDP output gap, inflation rate, inflation target and the real interest rate target. With regards to our research question to investigate if the original Taylor rule can be used to describe the monetary policy in the euro area and due to limited and contradictory information on what input to use for the real interest rate target in the euro area, the original value of 2% proposed by the Taylor rule (93) is used as the real interest rate target in our equation. Data sources for the other inputs used can be found in the data sources section. The rate implied by the Taylor rule is calculated for the period 1 January 1999 to 31 December 2016 (except July 2012–June 2014). Quarterly observations are used to increase the number of observations and also to make sure that we capture all changes in the interest rate. To analyse if the Taylor rule can describe the ECB interest rate, the implied nominal interest rates are regressed on the actual interest rate set by the ECB.

4.2.3 Regressing the regional original Taylor rates on the actual ECB rate

The procedure described in the above section is then repeated, but by using region-specific inflation and output gap numbers. The point is to see how well the Taylor rule can describe the ECB interest rate setting, when using values for inflation and output gap from specific regions in the euro area, instead of using the inflation and output gap numbers for the whole euro area.

FG	BeNeLuxA	PIIGS
France	Belgium	Portugal
Germany	Netherlands	Ireland
	Luxembourg	Italy
	Austria	Greece
		Spain

Table 1: The regional split of the Eurozone countries that joined the EU before 1999

Splitting the countries in the Eurozone into different regions is done based on economic similarities between countries. Countries with similar characteristics are placed into the same "region". There are several factors we take into consideration; how the countries performed during and after the financial crisis, the geographic location of the countries, their inflation development and the output gap of the countries. The regions can be found in Table 1. When all countries from the Eurozone included in our sample are put in a region, the input data (inflation, output gap) for all the countries within a region are aggregated. The aggregation of the predictive values for a region is performed by weighting the input from each country within that region based on the total GDP for a country from 1999–2016 (except July 2012–June 2014). Hence, a country with a higher GDP gets a bigger weight within their region. The calculations are demonstrated with the below example for Greece and the PIIGS region.

Greece total GDP for all the years 1999–2016 are added together:

$$\sum_{i=1999}^{2016} Y_i = Y_{TOTAL\ GREECE}$$

The total GDP for all countries within the same region are summed together (example PIIGS (Portugal, Ireland, Italy, Greece, Spain):

$$Y_{TOTAL\ GREECE} + Y_{TOTAL\ SPAIN} + Y_{TOTAL\ ITALY} + Y_{TOTAL\ IRELAND} + Y_{TOTAL\ PORTUGAL} = Y_{PIIGS}$$

The countries are given weights by dividing their own total GDP with the total GDP of that particular region:

$$\frac{Y_{TOTAL\ GREECE}}{Y_{PIIGS}} = Weight_{greece}$$

The "region-specific" inflation levels are then calculated by taking the weight for each country times the inflation for that country in that particular year (for each year). The weighted inflation for each country within that region is then summed together (The sum of the weights for all the countries within a region should be 1).

$$\begin{aligned}(Weight_{greece} \times inflation_{greece}) + (Weight_{italy} \times inflation_{italy}) + (Weight_{spain} \times inflation_{spain}) \\ + (Weight_{ireland} \times inflation_{ireland}) + \left(Weight_{portugal} \times inflation_{portugal}\right) \\ = Aggregated\ inflation_{PIIGS} \text{ for year X}\end{aligned}$$

The process is repeated for the output gap but by using the same weights as previously calculated.

$$\begin{aligned}(Weight_{greece} \times Output\ gap_{greece}) + (Weight_{italy} \times Output\ gap_{italy}) \\ + (Weight_{spain} \times Output\ gap_{spain}) + (Weight_{ireland} \times Output\ gap_{ireland}) \\ + \left(Weight_{portugal} \times Output\ gap_{portugal}\right) \\ = Aggregated\ Output\ gap_{PIIGS} \text{ for year X}\end{aligned}$$

The calculations are made in excel.

When the inputs for inflation and output gap are calculated, the implied Taylor rates for each region are computed and regressed on the actual ECB rate.

4.2.4 The modified Taylor equation for the euro area

In order to answer the third research question "*How could the Taylor rule be adjusted to better explain the interest rates set by the ECB from 1999–2016 (except July 2012–June 2014)?*" we develop our own regression by using the inputs from the original Taylor equation as our independent variables and the actual interest rate set by the ECB as our dependent variable. However, due to multicollinearity between variables, we cannot include both the inflation variable and the deviation from the inflation target variable. Multicollinearity refers to when there is a perfect relationship between two independent variables. Hence one independent variable could be described as a linear combination of another independent variable. As a result when regressing all the variables from the Taylor equation on the ECB interest rate the deviation from the inflation target automatically becomes omitted (Wooldridge, 2012, p. 95). Therefore we choose to only keep the deviation from the inflation target as a variable, as it is the deviation from the target that determines the ECB monetary policy setting (ECB, 2018g). Furthermore, the real interest rate target variable is uncertain and not possible to observe directly (Taylor, 1999) and therefore we decide to instead include it as part of the intercept of the model. Since the relationship between the variables in the original Taylor equation is linear, we choose to use a linear multiple regression as a starting point. However, before performing the regression, we need to conduct a series of tests on our data to ensure that the linear regression is, in fact, an appropriate regression model. We use Stata to check how well our data meet the assumptions of a multiple regression (Laerd Statistics, 2018). These conducted pre-tests can be found in the Appendix B. The following assumptions are considered and tested for:

1) Dependent and independent variables are measured at a continuous level: The variables have to be continuous for both the predictors and the response, which is true for our dataset (Laerd Statistics, 2018).

2) Linearity and *no significant outliers*: The relationship between the predictor variables and the outcome should be linear and there should be no significant outliers. To examine the linear relationship between the predictors and the outcome, scatter plot diagrams are used. Each independent variable is regressed on the dependent variable and a fitted line is added to easier spot potential outliers in the data (Laerd Statistics, 2018).

3) *Independence of observations:* No serial correlation on data (Laerd Statistics, 2018). The Breusch-Godfrey test is used to test for serial correlation (independence of variables). There are two main reasons we choose Breusch-Godfrey, rather than the classical Durbin-Watson statistic. First, the classical Durbin-Watson test relies heavily on the assumption of normally distributed residuals, while the Breusch-Godfrey test is less sensitive to that assumption. Second, the Breusch-Godfrey allows us to test for serial correlation through a number of lags, as opposed to just one lag as in the Durbin-Watson test (Wooldridge, 2012, p. 422).

4) *Homoskedasticity:* The error variance should be constant. We begin to test the homoscedasticity assumption using the Breusch-Pagan test. The idea behind this test is to regress the squared residuals *(e2)* from the original model on all of the explanatory variables *(statadiff* and *outputgap),* and test for the overall significance on this second regression. If there is joint significance we conclude that the explanatory variables have an effect on the variance of the error term and therefore there is heteroskedasticity. The null hypothesis is that there is *no* joint significance (and homoskedasticity) (Wooldridge, 2012, p. 477). We also conduct two versions of the White test. The White test is different from the Breusch-Pagan test since it also allows for the independent variables to have a non-linear and interactive effect on the error variance (Williams, 2015).

5) *No multicollinearity:* The two independent variables are not allowed to be perfectly correlated. A VIF test is used to test for multicollinearity (Laerd Statistics, 2018).

6) Normally distributed errors: Residuals of the regression should follow a normal distribution. To test the assumption of normally distributed errors in our regressions, we plot a histogram of the residuals as well as conduct a Jarque-Bera test. The Jarque-Bera test has a null hypothesis of a normal distribution, so if the null hypothesis can be rejected, then the errors are not normally distributed (Ciuiu, 2008).

After having considered and tested for all the assumptions that must hold for unbiased multiple regression, the ECB rate is regressed on the deviation from the inflation target and the output gap.

4.2.5 Regional regressions on the ECB rate using the new Taylor equation

As described in the above section we create a new Taylor equation that is adjusted for the euro area. After that, a new implied Taylor rate for each quarter within our time period is calculated. This is done by generating a new variable in Stata that corresponds to the implied Taylor rate given by our adjusted Taylor equation. Then, we regress the new implied Taylor rates on the ECB rates in order to see which regions the ECB seems to take most into consideration when setting interest rates. The process is the same as previously described.

4.3 Data

For the nominal interest rate we use data directly from the ECB, where they publish the interest rate set for each quarter. The data on the output gap and the inflation data are gathered from the IMF. The reason these data sources are used is because they are well established and known for producing quality data, which consequently gives them credibility. Furthermore the IMF covers data on inflation and output gap for many countries, which is important for us in order to make accurate predictions and draw conclusions when performing the regional regressions. The same data sources have been used for all countries for comparability reasons.

5. Results

In this section we present the results from our tests and regressions conducted as described in the methodology. First, the regression of the implied Taylor rates on the original ECB rates is shown followed by the regressions of regional Taylor rates on the actual ECB rates. Then our own Taylor formula adapted for the euro area is presented. Lastly, new regional Taylor rates are calculated and regressed on the actual ECB rates.

5.1 Regression of the original Taylor rate on the ECB interest rate

The first regression aims to answer whether the ECB can be said to follow the Taylor rule when setting the interest rate. As previously explained (in the methodology section), this is done by regressing the Taylor rule interest rates with observations from each quarter on the actual ECB interest rates. The summary table from the regression in Stata can be seen in Table 2. *Statataylor* is the variable representing the calculated Taylor rates for the euro area.

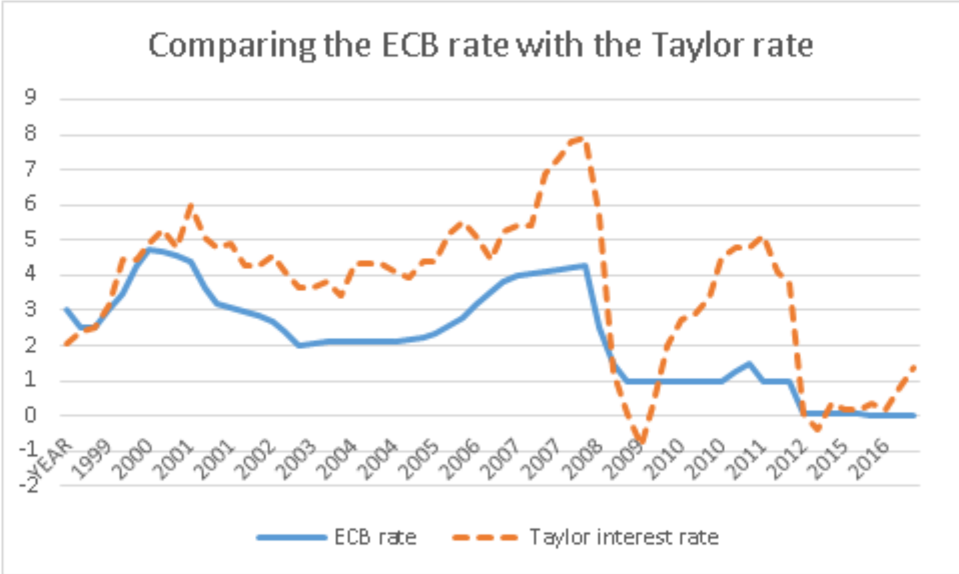
	(1) ECB_RATE
statataylor	**0.542*** **
	(10.43)
_cons	**0.234**
	(1.08)
N	**64**

t statistics in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Table 2: The regression of the quarterly Taylor rates on the actual quarterly ECB rates

The p-value tells us at which level we can reject the null hypothesis that the regression coefficient is equal to 0. We usually look at 0.1, 0.05 or 0.01 level significance and our results indicate that we can reject the null hypothesis for the *statataylor* coefficient at all these significance levels. Thus, the model has explanatory power. However the constant appears to be non-significant, but since *statataylor* is more relevant in explaining how well the Taylor rate corresponds to the actual ECB rate we will not discuss the constant further.

Thus the coefficient of 0.542 indicates that an increase of 1 in the *statataylor* rate transforms to a 0.542 increase in the actual interest rate set by the ECB. However, this implies that changes in one of the inputs in the Taylor equation leads to more aggressive changes in the interest rate calculated by the Taylor rule, than in the actual ECB interest rate. Therefore, the Taylor rule can be said to have some explanatory power on the actual ECB interest rate, but the rule is far from perfect in describing the actual rate. If the Taylor rule explained the monetary policy of the ECB exactly, our *statataylor* coefficient should be one and the constant should be zero. A comparison between the ECB rate and the implied Taylor rate for the euro area can be illustrated in a graph. Graph 3 shows that the interest rate predicted by the Taylor rule is for the most part higher than the ECB rate.



Graph 3: Comparison between the actual interest rates set by the ECB and the interest rates implied by the Taylor rule

5.2 Regression of the regional original Taylor interest rates on the ECB rate

As a second step, the Taylor rates are computed for each region using regional inflation and output gap numbers. The calculated Taylor interest rate for the different regions are then regressed on the actual ECB interest rates. The results for all of these regressions are demonstrated in the below table. All coefficients appear to be significant, which demonstrates that they all have explanatory power for describing the ECB rate. As before, a coefficient close to one indicates that the regional Taylor rate is in line with the actual ECB rate.

	(1) ECB_RATE	(2) ECB_RATE	(3) ECB_RATE	(4) ECB_RATE
statatay~r	0.542***			
	(10.43)			
BENELUXA~R		0.583***		
		(9.65)		
FGTAYLOR			0.571***	
			(7.28)	
PIIGSTAY~R				0.374***
				(12.77)
_cons	0.234	-0.0487	0.426	0.554***
	(1.08)	(-0.19)	(1.54)	(3.48)
N	64	64	64	64

t statistics in parentheses
* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table 3: The regressions of the quarterly regional Taylor rates on the actual quarterly ECB rates

The regional regressions (Table 3) provide similar results as the regression for the whole euro area, except for the *PIIGS Taylor* coefficient, which is significantly lower. The coefficient for the variable Taylor rate with inputs from *BeNeLuxA* and the coefficient for Taylor rate with inputs from *FG* are both slightly higher than the Taylor coefficient with inputs from the whole euro area and are thus more in line with the original Taylor rate. However, the difference is marginal. For the PIIGS countries the coefficient was significantly lower (0.374). These are the countries in the euro area that struggled the most after the financial crisis (2008–2009) as they have suffered from poor inflation numbers and periodically negative output gaps (IMF, 2018).

From these regressions, we conclude that it doesn't seem like the ECB follows the original Taylor rule when setting their interest rates. Even when computing Taylor rates using inputs from specific regions the ECB does not seem to follow the original rule. Furthermore, since the ECB does not appear to follow the original Taylor rule, it is not possible for us to draw any conclusions regarding how well the different regional regressions correspond to the actual ECB rates at this stage.

5.3 The new Taylor regression for the euro area

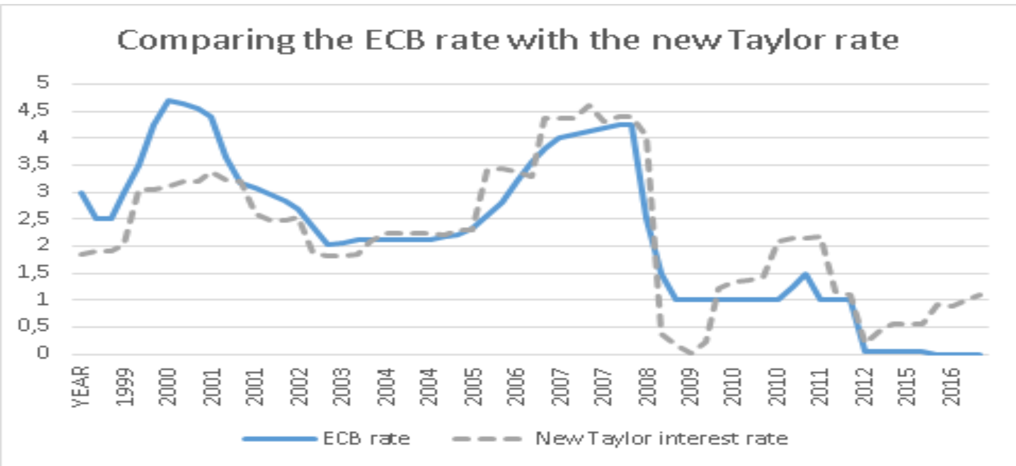
After having tested for how well the original Taylor rule fits the ECB monetary policy in previous regressions, we conclude that it does not describe the ECB interest rate setting especially well. Therefore a new regression adapted for the euro area is carried out. The new regression can be seen in Table 4 and the equation is stated below. The results are in line with previous research (as discussed in the "Current State of Knowledge" section), where the *outputgap* is given a higher weight and the *deviation from inflation target (statadiff)* a lower weight than in the original formula. The deviation from inflation target is slightly less significant but still significant at the 5% level.

	(1)
	ECB_RATE
statadiff	**0.243***
	(2.05)
Outputgap	**0.676*****
	(9.16)
_cons	**2.294*****
	(25.00)
N	**64**

t statistics in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Table 4: The new Taylor regression for the euro area

The new Taylor rule equation: $i_t = 2.294 + 0.243(\pi_t - \bar{\pi}) + 0.676\tilde{Y}_t$



Graph 4: Comparison between the actual interest rates set by the ECB and the interest rates implied by the new Taylor rule

5.4 Regional regressions with the new Taylor rates on the ECB rate

The implied Taylor rates for each region are calculated again but this time by using the new Taylor equation adapted for the euro area. The new regional Taylor rates are regressed on the actual ECB rates. The results can be seen in the below table.

	(1) ECB_RATE	(2) ECB_RATE	(3) ECB_RATE	(4) ECB_RATE
EUnewTAY~R	0.999***			
	(14.16)			
BE~wTAYLOR		1.015***		
		(11.10)		
FGnewTAY~R			0.954***	
			(7.88)	
PIIGSnew~R				0.465***
				(11.49)
_cons	0.00149	-0.0892	0.294	1.014***
	(0.01)	(-0.39)	(1.08)	(7.02)
N	64	64	64	64

t statistics in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Table 5: The regression of the quarterly regional new Taylor rates on the actual quarterly ECB rates

The *BeNeLuxA* coefficient is the one that corresponds the best to the actual ECB rate when comparing across all regions. The coefficient of 1.015 is very close to 1, which means that the new regression is almost perfectly applicable to these countries' economies. For *FG* the coefficient is also close to 1. Thus the new Taylor formula is also well suited for their economic situations. However, the coefficient of 0.465 for the *PIIGS* countries is the one that corresponds the worst to the euro area coefficient of 1. As mentioned, these are the countries that were worst affected by the financial crisis. Even though there are some correlation between the new Taylor rates and the ECB rates, they have not been able to lower the interest rates as much as the new Taylor rule would require. Thus, it is not unexpected that the PIIGS Taylor rates are not in line with the actual ECB rates.

From this section, we conclude that the implied Taylor rates from the new equation give a correlation closer to 1 between the regional Taylor rates and the actual ECB rates than the original Taylor rule rates did. The new Taylor equation is thus better suited for the ECB overall than the original Taylor equation is. Furthermore, the results seem to match fairly well for all different regions (except for the PIIGS region for reasons mentioned), meaning that the ECB considers all regions in the euro area when conducting their monetary policy.

6. Discussion

This section presents a discussion of the results obtained above. We discuss our results and connect them back to the purpose and research questions of our thesis, previous research and the current economic situation in the euro area.

As mentioned in the introduction, the purpose of this thesis is to examine whether the Taylor rule could be applied to the euro area, either when looking at the euro area as a whole or when comparing across different regions in the euro area. The results of our study showed that a form of Taylor rule can be applied to the euro area, although the coefficients in the Taylor rule regression must be adjusted to better fit the ECB monetary policy.

The new Taylor rule regression confirms the results of previous research by Faust et al. (2001), Sauer and Sturm (2003) and Belke and Pelleit (2006), who all conclude that a larger weight is placed on the output gap and that a smaller weight is placed on the deviation from the inflation target. Thus, despite the fact that the ECB introduced unconventional monetary policy tools after the financial crisis in 2008, our findings confirm that the merits on which the ECB bases its interest rate setting have not changed significantly since before the crisis. In other words, the ECB still places a bigger weight on the output gap and a smaller weight on the deviation from the inflation target. Thus the conclusions drawn by authors who have conducted previous studies remain accurate in this regard. As our findings show, the original Taylor rule cannot be said to be particularly applicable to any of the regions in the euro area. However, when specifying our own formula, the Taylor rates implied by our new regression correspond best to the actual ECB rates for the France-Germany region and the BeNeLuxA region. Perhaps the rotating voting system of the ECB can be thought to give an advantage to the greater economies Germany, France and the Netherlands. However, Italy and Spain are also among the five greater economies and the new implied Taylor rates for the PIIGS countries correspond the least to the actual ECB rates. A possible explanation can be that the PIIGS countries have had inflation and output gap levels that differ significantly from the other euro area countries. Since the new Taylor regression is based on aggregate inflation and output gap levels for the euro area, where the majority of the countries have inputs closer to for example the BeNeLuxA countries than to the PIIGS countries, it makes sense that the regression is less applicable to the PIIGS countries. However the conclusion we draw from the regional regression table is that most regions have a Taylor rate coefficient close to 1 and thus it seems like the ECB take all regions into account when setting interest rates, rather than just focusing on the major or most troubled economies.

Following up with a normative discussion, we suggest the ECB should not follow the standard Taylor formula. Instead, they should follow a Taylor rule specifically adapted to the euro area. In this paper, such a formula has been presented and we argue that this formula could be adopted as part of the monetary policy strategy of the ECB. The reason for this, as mentioned in Taylor (1993), is because monetary policy rules have major advantages over a monetary policy without a pre-defined contingency plan for improving economic performance. However, we do not suggest the Taylor rule to be followed in detail, especially not in the presence of non-standard monetary policy measures. What we do suggest though, is that this proposed Taylor rule should be used as a guidepost for monetary policy just as Carlstrom and Fuerst (2003) argue. Guideposts would provide the credibility of strict rules while still making it possible to temporarily deviate from the principle to respond to unforeseen events. If the new Taylor rule would have been part of the ECB's monetary policy, the ECB should have started to raise their interest rate a few years ago, which can be seen in graph 4. Instead, the ECB did the opposite and lowered the interest rates. In addition to this, they loosed the monetary conditions further through non-standard monetary policy measures. Therefore, if the Taylor rule is to be used as an indication, we suggest the ECB should start to either increase their interest rates or loosen their non-standard measures. As mentioned earlier, Alcidi, Busse and Gros (2017) also argue based on the Taylor rule that the ECB should start to normalise their monetary policy. However, on the press conference that was held the 26 April 2018, the ECB announced that neither the key interest rates nor the pace of the net asset purchasing would change at this moment (Constancio and Draghi, 2018).

As mentioned, both the standard Taylor rule as well as the new Taylor formula shows that the policy of the ECB is least applicable to the PIIGS countries, which may be explained by the fact that their economic conditions differed much from the other regions during and after the financial crisis. A suggestion for future research would therefore be to further investigate how the monetary policy of the ECB can account for these differences between regions in times of crisis.

7. Conclusion

The purpose of this paper has been to analyse if the original Taylor rule can be used to describe the monetary policy carried out by the ECB, either when using the aggregated inflation and output gap for the whole Eurozone or when using inputs from a specific region. The aim has also been to develop a new Taylor rule if the original rule was not useful and test for how well this new rule describes the specific regions in the euro area. The results from our tests showed that the original Taylor rule was not useful in describing the ECB monetary policy. Therefore a new regression was performed and a euro area Taylor rule was developed. This new Taylor rule puts a slightly larger weight on the output gap and a lower weight on the deviation from the inflation target than the original rule. This new Taylor rule equation confirms the results from previous research in this area. One of our contributions to previous research has been to test this new equation on the chosen regions FG (France, Germany), PIIGS (Portugal, Ireland, Italy, Greece, Spain) and BeNeLuxA (Belgium, Netherlands, Luxembourg, Austria). The results showed that the rule fits FG and BeNeluxA quite well, but less so for the PIIGS countries. As the PIIGS countries have been the countries with differing inflation and output gap numbers compared to the rest of Europe, the results are not unexpected. Considering the extreme circumstances prevalent in the years during and following the financial crisis, we propose that further research should be made, investigating how the monetary policy of the ECB can account for these differences between regions in times of crisis.

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Appendix A

Tests for unit root and cointegration

Before regressing the ECB interest rate to the interest rate implied by the Taylor rule, we test for unit roots and cointegration for the variables composing the Taylor formula, as described in the methodology section.

ADF test

An ADF test was carried out for each variable included in the Taylor formula. The results from the ADF test (see Table 1–3 below) show that we fail to reject the null hypothesis of non-stationarity for the variables of interest rate, inflation and output gap. We see this because the test statistic is larger than the critical values on all the significance levels and the p-values are larger than 10% for all three variables. Thus, we cannot exclude the possibility that the variables contain unit roots, which makes our results aligned with previous research. When taking the first difference of the variables, they mostly showed to be stationary on a 1% probability level. Consequently, our results imply that a test for cointegration is required.

Dickey-Fuller test for unit root   Number of obs   =   62

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	**-1.674**	**-4.124**	**-3.488**	**-3.173**

MacKinnon approximate p-value for Z(t) = **0.7621**

Table 1: Results for ADF testing for the variable interest rate

Dickey-Fuller test for unit root   Number of obs   =   62

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	**-2.651**	**-4.124**	**-3.488**	**-3.173**

MacKinnon approximate p-value for Z(t) = **0.2572**

Table 2: Results for ADF testing for the variable deviation from target inflation (statadiff)

Dickey-Fuller test for unit root Number of obs = **62**

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
		Interpolated Dickey-Fuller		
Z(t)	**-2.374**	**-4.124**	**-3.488**	**-3.173**

MacKinnon approximate p-value for Z(t) = **0.3933**

Table 3: Results for ADF testing for the variable output gap

Johansen test

A condition for non-stationary variables to be included in a regression is cointegration. A maximum rank of 0 gives a null hypothesis of no cointegration. When testing for the recommended number of lags using lag-order statistics with VEC diagnostics, four out of five criteria in the test recommend two lags. Therefore two lags are used. The results from the Johansen's trace statistic method, displayed in Table 4, show that we can reject the null hypothesis at r=0 since the trace statistic of 18.5547 is greater than the 5% critical value of 15.41. Since the trace statistic at r=1 of 5.1116 is larger than its critical value of 3.76, we can say that there are at least two cointegrating equations. This implies that the variables can be included in the regression. The results differ from that of Österholm (2003) which may be explained by the fact that Österholm does not use data from the ECB, but for other central banks.

Johansen tests for cointegration

Trend: constant Number of obs = **61**

Sample: **3 - 63** Lags = **2**

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	**6**	**-112.89411**	**.**	**18.5547**	**15.41**
1	**9**	**-106.17256**	**0.19779**	**5.1116**	**3.76**
2	**10**	**-103.61675**	**0.08038**		

Table 4: Johansen testing for the variables of deviation from target inflation (statadiff) and output gap

Appendix B

In this appendix we present the results from the pre-tests carried out in order to ensure that the linear regression is an appropriate regression model. The tests check how well our data meet the assumptions of an OLS regression.

Test of the linearity and no significant outliers assumption

Scatterplots with fitted line

As seen from the below regression there seems to exist a strong linear relationship between the output gap and the ECB interest rate (Figure 1). However, when plotting the deviation from the inflation target "*statadiff*", the linear relationship is not as perfect but still somewhat existing (Figure 2). One possibility when dealing with non-linear relationship is to transform the variable into another form, for example log (). Unfortunately, this does not leave us with better results so we decide to keep the variable as it is. There are no significant outliers in the dataset, rather groups of observations, which deviates from the fitted line. After thoughtful consideration we decide to keep all observations as deleting observations can have a negative impact on the model's accuracy in explaining and predicting the ECB monetary policy.

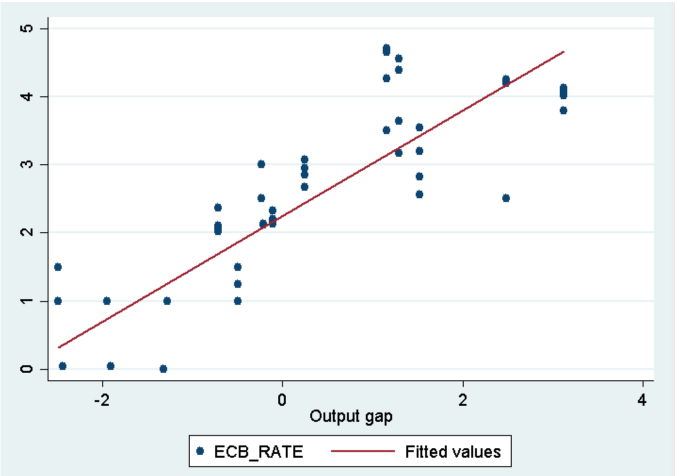

Figure 1: Scatterplot of ECB interest rates on outputgap

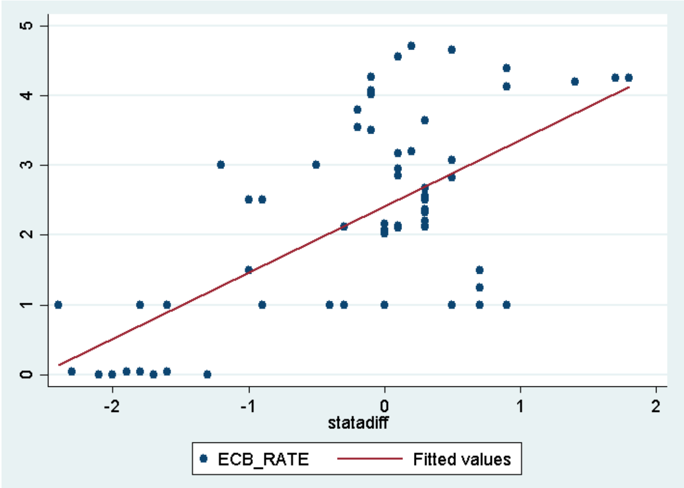

Figure 2: Scatterplot of ECB interest rates on statdiff

Test of the independence of observations assumption

Breusch-Godfrey test

Since we are dealing with time series data, a test for autocorrelation in the error terms is made. The Breusch-Godfrey test is sensitive for the number of lags and there are no strict rules for how many lags that are suitable in this case. For example, for the 4 lag test we reject the null hypothesis of no serial correlation. On the other hand for the 28 lag we cannot reject the null hypothesis of no serial correlation. Thus, depending on the number of lags used, we get different results. However, autocorrelation itself leaves the coefficient estimates unbiased, unless, it is caused by excluding an explanatory variable in the model. Since we only seek to define a new Taylor formula for the euro area, no other independent variables should be included in this particular case. The main issue if we in fact have autocorrelation in our dataset is, thus, an increased variance and the standard errors in our OLS regression being smaller than the true values. Despite this, we decide to proceed with our regression, as the coefficients are our main focus in this thesis. This is because our aim is to see how this new euro area regression compares to previous research, and to see how well the different regions fit into the new regression rather than to exactly estimate the implied rate at each specific point in time.

Test of the homoskedasticity assumption

Breusch-Pagan test

Heteroscedasticity is first tested using the Breusch-Pagan test. As seen from the below regression *Prob > F = 0.3586* which means we cannot reject the null hypothesis that there is joint significance (homoskedasticity), even on the 10% significance level.

Source	SS	df	MS			
				Number of obs	=	64
				F(2, 61)	=	1.04
Model	.799326059	2	.39966303	Prob > F	=	0.3586
Residual	23.3759858	61	.383212882	R-squared	=	0.0331
				Adj R-squared	=	0.0014
Total	24.1753119	63	.383735109	Root MSE	=	.61904

e2	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Outputgap	.084283	.0647134	1.30	0.198	-.0451195	.2136855
statadiff	-.1372451	.103613	-1.32	0.190	-.344432	.0699419
_cons	.4477731	.0804831	5.56	0.000	.2868372	.608709

Table 1: Breusch Pagan test

The alternative White-test

Since we could not reject the null hypothesis of homoscedasticity by using the Breusch-Pagan test, we also conduct the White test to be certain of our results. For the White test we obtain the predicted y-values after estimating the model and generate the squared predicted y. Then we regress the squared residuals on both the Y and Y^2. In this regression the *Prob > F* value is 0.9245, which means that we cannot reject the null hypothesis that there is homoscedasticity.

Source	SS	df	MS			
				Number of obs	=	64
				F(2, 61)	=	0.08
Model	.062105821	2	.03105291	Prob > F	=	0.9245
Residual	24.1132061	61	.39529846	R-squared	=	0.0026
				Adj R-squared	=	-0.0301
Total	24.1753119	63	.383735109	Root MSE	=	.62873

e2	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
yhat	.0539942	.2237267	0.24	0.810	-.393375	.5013634
yhat2	-.0066626	.0468172	-0.14	0.887	-.1002794	.0869542
_cons	.3987791	.2356639	1.69	0.096	-.0724599	.8700182

Table 2 The alternative White-test

The original White-test

Lastly we also conduct the original White test where we regress the squared residual on *statadiff, Outputgap, the squared statadiff, the squared Outputgap* as well as *the cross product* of the two independent variables. The null hypothesis is the same as before. In this test we are once again unable to reject the null hypothesis, due to a *prob > F* of 0.7015. We therefore conclude that we cannot reject the null hypothesis of homoscedasticity in our dataset by using any of these tests.

Source	SS	df	MS			
				Number of obs	=	64
				F(5, 58)	=	0.60
Model	1.18537416	5	.237074832	Prob > F	=	0.7015
Residual	22.9899377	58	.396378237	R-squared	=	0.0490
				Adj R-squared	=	-0.0329
Total	24.1753119	63	.383735109	Root MSE	=	.62959

e2	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Outputgap	.1188837	.0753046	1.58	0.120	-.0318548	.2696221
statadiff	-.1664202	.1286008	-1.29	0.201	-.4238427	.0910022
Outputgap2	-.0341632	.0383144	-0.89	0.376	-.1108578	.0425314
statadiff2	.0158706	.1420373	0.11	0.911	-.268448	.3001892
outputdiff	.0028004	.1175064	0.02	0.981	-.2324142	.2380149
_cons	.5095171	.1176561	4.33	0.000	.2740029	.7450313

Table 3: The original White-test

The concluding test on heteroskedasticity

However, it is odd that we don't get heteroskedasticity in the dataset, since this is actually the most common result when dealing with real life datasets. As a last test we therefore plot the residuals on both of our predictors to see if we can truly rule out heteroskedasticity. First we regress the residual on the *stadiff* predictor. The graph presents a random scatter of residuals and thus it does not contradict the linearity assumption of homoskedasticity (Figure 3). Second we regress the residual on the output gap predictor. This plot does also seem random and the variability seems to be more or less the same for different values of the predictor (Figure 4). At last, we therefore conclude that we do not have heteroskedasticity in our data.

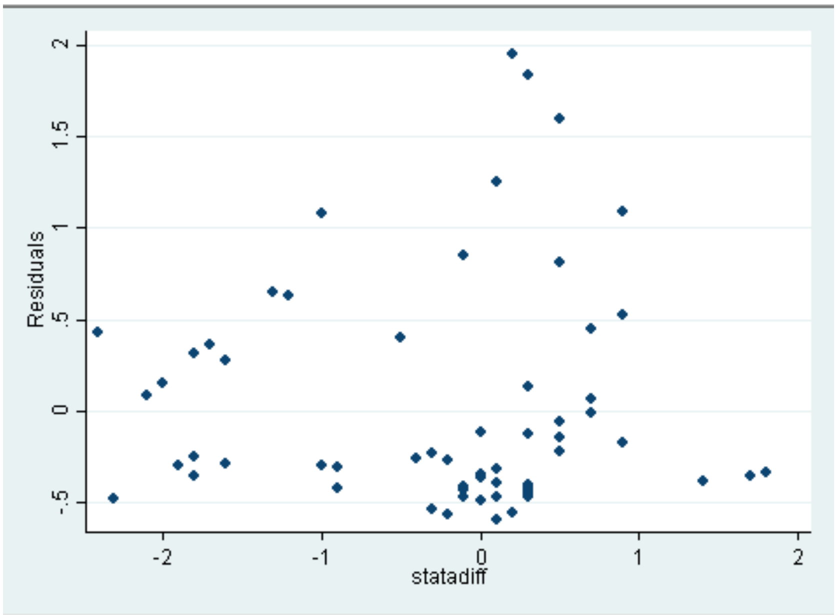

Figure 3: Residual plot on stadiff

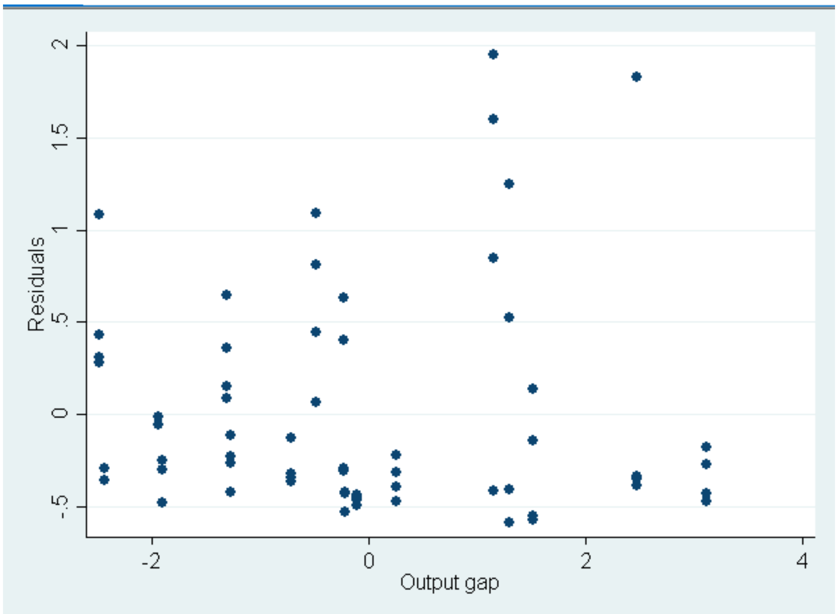

Figure 4: Residual plot on outputgap

Test for multicollinearity

The VIF test

To test for multicollinearity between the independent variables, the VIF test is used. If *VIF* is above 5, there is a problem with multicollinearity. But as in this case VIF is below 5, which means there is no multicollinearity between the independent variables.

Variable	VIF	1/VIF
Outputgap	1.71	0.586239
statadiff	1.71	0.586239
Mean VIF	1.71	

Table 4: The VIF test

Test for normally distributed errors

Histogram of residuals

First, we plot a histogram on the errors (residuals) of our regression. As we can see from the below diagram the residuals seem to be normally distributed.

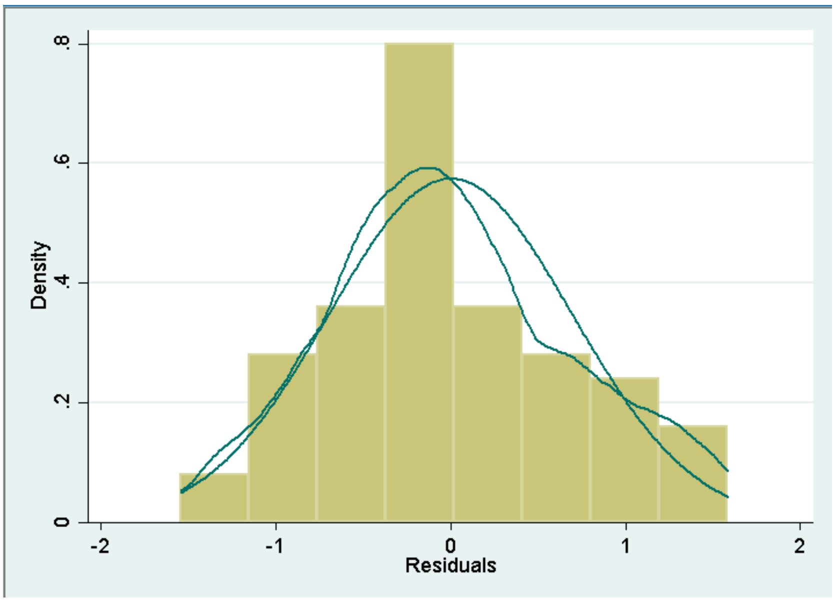

Figure 5: Histogram of residuals

Jarque-Bera test

Secondly, we conduct the Jarque-Bera test, to be certain that the residuals are in fact normally distributed in line with our assumption. As mentioned, the Jarque-Bera test has a null hypothesis of normal distribution. As seen in Table 5 the p-value in our test is 0.5577 and therefore we do not reject the null hypothesis. Based on the histogram and our Jarque-Bera test we conclude that the errors are normally distributed.

```
Jarque-Bera normality test:  1.168 Chi(2)  .5577
Jarque-Bera test for Ho: normality:
```

Table 5: The Jarque-Bera test