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„What determines the interest rate- setting- behavior of the European Central Bank?“

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Abstract

This thesis investigates the interest rate- setting- behavior of the European Central Bank (ECB) over three different time periods: 2006 to 2010, 2010 to 2016, and 2014 to 2023. These periods refer to different crises in the Euro area, resulting in diverse business cycle episodes of downturns and upturns. The study aims to explore whether the ECB's reaction function remained consistent across these periods and if it continuously considered the same variables in a Taylor- type rule. The analysis focuses on different macroeconomic variables which might influence the ECB in deciding to increase, decrease, or to not change the main refinancing operations (MRO) rate. To test this, an ordered probit regression is estimated in which the MRO rate is the dependent variable. The key results can be summarized in the following way: Inflation, specifically headline, core and expected inflation play a crucial role in influencing the ECB's decisions from 2006 to July 2023. The Governing Council is more likely to increase the MRO rate if inflation increases. Moreover, other influential variables include the lagged value and the change in the MRO rate. Real GDP and monetary growth also enter as significant determinants. However monetary growth is only considered from 2006 until 2016. Regarding expectations data, the analysis suggests that only expected inflation enters the reaction function, and not expected real GDP.

Kurzfassung

In dieser Arbeit wird das Zinssetzungsverhalten der Europäischen Zentralbank (EZB) über drei verschiedene Zeitabschnitte untersucht: 2006 bis 2010, 2010 bis 2016 und 2014 bis 2023. Diese Zeiträume beziehen sich auf verschiedene Krisen im Euroraum, die zu unterschiedlichen Konjunkturzyklen mit Abschwüngen und Aufschwüngen geführt haben. In der Studie wird untersucht, ob die Reaktionsfunktion der EZB über diese Zeiträume hinweg konstant war und ob sie kontinuierlich dieselben Variablen in einer Taylor- artigen Regel berücksichtigt hat. Die Analyse konzentriert sich auf verschiedene makroökonomische Variablen, die die Entscheidungen der EZB beeinflussen könnten, den Hauptrefinanzierungssatz (HRG) zu erhöhen, zu senken, oder nicht zu ändern. Um dies zu testen, wird eine geordnete Probit-Regression geschätzt, bei der der HRG- Satz die abhängige Variable ist. Die wichtigsten Ergebnisse lassen sich wie folgt zusammenfassen: Die Inflation, insbesondere die Gesamtinflation, die Kerninflation und die erwartete Inflation spielen eine entscheidende Rolle bei der Beeinflussung der Entscheidungen der EZB von 2006 bis Juli 2023. Es ist wahrscheinlicher, dass der EZB- Rat den Hauptrefinanzierungssatz erhöht, wenn die Inflation steigt. Zu den weiteren Einflussvariablen gehören der verzögerte Wert und die Veränderung des HRG- Satzes. Das reale Bruttoinlandsprodukt (BIP) und das Geldmengenwachstum werden ebenfalls als signifikante Determinanten berücksichtigt. Allerdings wird das Geldmengenwachstum nur von 2006 bis 2016 in Betracht gezogen. Was die Erwartungsdaten betrifft, so zeigt die Analyse, dass nur die erwartete Inflation in die Reaktionsfunktion eingeht, nicht aber das erwartete reale BIP.

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List of Abbreviations

BMA .... Bayesian Model Averaging
DFR .... Deposit Facility Rate
ECB .... European Central Bank
EER .... Nominal Effective Exchange Rate
ELB .... Effective Lower Bound
EONIA .... Euro Overnight Index Average
FRED .... Federal Reserve Economic Data
GDP .... Gross Domestic Product
HICP .... Harmonized Index of Consumer Prices
LTROs .... Long- Term Refinancing Operations
M3 .... Broad Monetary Aggregate
MLFR .... Marginal Lending Facility Rate
MRO .... Main Refinancing Operations
OECD .... Organization for Economic Cooperation and Development
OLS .... Ordinary Least Squares
REPOS .... Short- Term Repurchase Agreements
SPF .... Survey of Professional Forecasters
ZLB .... Zero Lower Bound

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1. Introduction

Since the introduction of the euro and the establishment of an independent central bank for the Euro area, the European Central Bank (ECB) had to encounter various challenges during the last two decades. These include navigating through crises such as the financial crisis which hit in 2007 until 2009, followed by the post- sovereign debt crisis (2008-2013) and addressing the low- inflation recovery from 2014 to 2017 (European Central Bank, 2019). Most recently the Euro area has faced obstacles due to the Corona Crisis and the Russia- Ukraine situation. Daily news and statements from the ECB include: "Inflation is projected to remain too high for too long. The Governing Council is determined to ensure that inflation returns to its 2% medium-term target in a timely manner. It therefore decided at its meeting on 15 June 2023 to raise the three key ECB interest rates by 25 basis points" (Economic Bulletin Issue 4, 2023, p.3). In October 2022, inflation peaked at 10.6% marking a historically high level. To give context, this significant increase occurred within a relatively short time span of one and a half years starting to rise from 2% in May 2021 (*ECB Data Portal*, 2023). In response to this, the ECB started raising its key interest rates again which had been in negative territory for some time. On 28 July 2022 the main refinancing operations (MRO) rate was risen from 0% to 0.50%. Thereafter it was increased again in September 2022 to 1.25%. This process continued and the MRO rate has reached meanwhile a level of 4.5% (*ECB Data Portal*, 2023). Indeed, one of the ECB's main policy instruments is the MRO rate. When prices are rising too fast and inflation is accelerating, indicating excessive levels, the ECB raises interest rates as a measure to guide inflation back toward their medium- term target of 2% (European Central Bank, 2022).

These news really caught my interest and I am particularly interested in exploring the factors that guide the ECB's decisions regarding adjustments to the MRO rate. The purpose of my research is to analyze recent developments in ECB's repurchase agreement (REPO) rate setting, specifically during and after the financial crisis as well as during the period encompassing the beginning of the Covid- 19 crisis until 2023. These different business cycle episodes leading to downturns and upturns make it even more interesting to explore whether the reaction function of the ECB stayed the same and whether it continuously considered the same variables in a Taylor- type rule.

To narrow the question down I would like to focus on specific macroeconomic variables, including economic activity, inflation, money growth, the rate of appreciation of the euro, the previous level of the repo rate, and the change in the MRO rate which is based on the paper of Gerlach (2007). Hence, the following research question will guide this work:

What determines the interest rate- setting- behavior of the ECB?

The literature on ECB reaction functions is substantial (Berger et al., 2011; Boeckx, 2010; Cour-Thimann & Jung, 2021; Gerlach, 2007; Gross & Zahner, 2021). However only a few papers analyze how the crisis has affected ECB rate- setting behavior (Boeckx, 2010; Gerlach, 2011; Gerlach & Lewis, 2010, 2014). In fact, Gerlach's seminal work (2007) encompasses the period from January 1999 until December 2006. In other words, his findings describe the interest rate- setting- behavior of the ECB before the global financial crisis. In this thesis I want to analyze if his results still hold for the period during the financial crisis as well as after the financial crisis. This means, this paper will build on the method of Gerlach (2007), but with more recent data. More precisely, this thesis studies the interest rate- setting- behavior of the ECB during three different time spans: Firstly, it is analyzed how the ECB behaved during the financial crisis from 2006 until 2010. The crisis is typically seen as having started in August 2007. Including the year 2006 makes it more interesting to see how the ECB reacted to the financial crisis. Then the period 2010- 2016 will be estimated and finally the last period from 2014- 2022 which includes the Corona- Crisis and the beginning of the Russia- Ukraine War. Moreover, there also exists a more recent paper from Gerlach (2011) where he analyzes how the ECB sets its MRO rate during the financial crisis. On the one hand his more recent paper is built on his work from 2007, as he uses the same variables. On the other hand, he uses another method, namely an ordered logit model instead of an ordered probit model. This makes it possible for me to compare my results also to his more recent paper including the financial crisis. Moreover there exist divers others papers which analyze how the ECB sets its MRO rate during and after the financial crisis (Berger et al., 2011; Cour-Thimann & Jung, 2021; Gross & Zahner, 2021).

More generally, this paper is closely related to earlier studies that investigate the interest rate setting of the ECB using Taylor- type policy rules and real- time data on economic variables to describe the policy reaction function (Cour-Thimann & Jung, 2021; European Central Bank., 2020; Gerlach, 2007, 2011; Gerlach & Lewis, 2014; Sturm & De Haan, 2011; Boeckx, 2010; Carstensen, 2006; Taylor, 1999). The contribution of this thesis to this debate is twofold: first, I give an overview of studies estimating the interest rate- setting- behavior of the ECB. Doing this, I cover most relevant and frequently cited studies until the end of 2008, but also some studies which cover the last two decades from the ECB, meaning from 1999 to 2018. Second, based on the study of Gerlach (2007) I will estimate a reaction function for the ECB with the same variables used in his paper, only with more recent data.

My thesis will be organized as follows: In section 2 the two- pillar framework and the basic concepts of the main refinancing operations are outlined, while in section 3 the most relevant empirical literature concerning ECB reaction functions is reviewed. The estimation method, the data used, and estimation results are described in section 4. Section 5 concludes.

2. Main refinancing rate: Basic concepts

In this section, I give an overview of what the MRO rate is, how it is used by the ECB, how it is connected to other short- term interest rates of the ECB and what its limitations are. However before delving into these details, I briefly outline the framework guiding the ECB's monetary policy decisions, specifically its two- pillar strategy. This preliminary explanation aims to enhance understanding of how this institution operates.

2.1. Two-pillar strategy

Since the introduction of the euro in 1999, the ECB has the role as an independent institution to define and implement monetary policy for the Euro area. The ECB's primary objective consists in maintaining price stability. If this is fulfilled it can consider to encourage growth and full employment (Hartmann & Smets, 2018a). To guide its decisions on interest rates, it therefore employs a two-pillar monetary policy strategy. Adopted in 1998, this stability-oriented strategy consists of a quantitative definition of price stability and a two- pillar framework for evaluating risks in the Euro area (*ECB Monthly Bulletin*, 2000). The so called "two pillars" involve an economic analysis to identify short to medium- term risks and a monetary analysis to assess medium to long- term inflation trends. In fact the Governing Council places a higher emphasis on monetary analysis compared to many other central banks (Jung et al., 2010).

More precisely, in the first pillar, the ECB places a prominent role on money, considering inflation in the long run as a monetary phenomenon. The Governing Council has established a quantitative reference value for the annual growth rate of a broad monetary aggregate (M3) (ibid.). The second pillar of the ECB's monetary strategy involves monitoring a broad set of economic and financial variables indicating threats to price stability. Some key measures include, for instance, output gap measures, nominal and real effective exchange rates, and interest rate spreads (Carstensen, 2006; Sauer & Sturm, 2003).

All in all, the ECB uses a unique approach to organizing and cross- checking information relevant for assessing risks to price stability. This highlights the importance of the interdependent economic and monetary analyses which ensure effective decision- making (Sauer & Sturm, 2003).

2.2. Main refinancing operations

In order to fulfill its mandate and to steer inflation towards its 2% target, the ECB has different types of monetary policy tools it can use. Some of these tools influence the amount and cost of loans that people and companies receive. This means that the ECB uses these instruments to influence the level of economic activity in the Euro area which in turn affects inflation (European Central Bank, 2021).

In fact, the MRO rate is “the interest rate banks pay when they borrow money from the ECB for one week” (European Central Bank, 2018). On the contrary banks have to provide collateral to guarantee that they will pay back the money. Hence the MRO rate is one of the three interest rates the ECB sets every six weeks in order to keep prices stable in the Euro area (ibid.). It provides the bulk of liquidity to the banking system. Banks in the Euro area are obliged to hold a fraction of their short- term liabilities (2% until January 2012, 1% thereafter) in their Eurosystem accounts. These mandatory reserves are remunerated at the MRO rate determined by the Governing Council of the ECB (Hartmann & Smets, 2018a). Commercial banks which are in need of reserves, can exchange assets against reserves. Those banks that want to reduce their reserves can buy assets from the central bank and pay for them by reserves. These exchanges refer to the short- term repurchase agreements (REPOS). Moreover, in order to receive such reserves, commercial banks have to submit bid schedules indicating the price they are willing to offer for accessing liquidity. The ECB then decides on the total amount allocated to counterparties. Before the European crisis the MRO rate constituted a key policy rate for the Governing Council.

In addition, commercial banks can borrow reserves from the central bank overnight at the marginal lending facility (against eligible collateral), or deposit excess reserves with the central bank and earn interest using the deposit facility, or trade reserves with one another on the interbank market (EONIA, LIBOR). The Deposit Facility Rate (DFR) is set lower than the MRO rate, whereas the Marginal Lending Facility Rate (MLFR) is set above the MRO rate. Hence the DFR and the MLFR define a floor and a ceiling for the overnight interest rate at which banks lend to each other. The MRO rate lies between both rates which forms the interest rate corridor for money markets (European Central Bank, 2021). Moreover, a second type of open market operations are long- term refinancing operations (LTROs) with a maturity of three months (ibid.). In fact, short- term and longer-term interest rates are connected through no-arbitrage conditions which means that the central bank can influence medium and long- term interest rates through its short-term open market operations. The following figure depicts the evolution of the interest rate corridor.

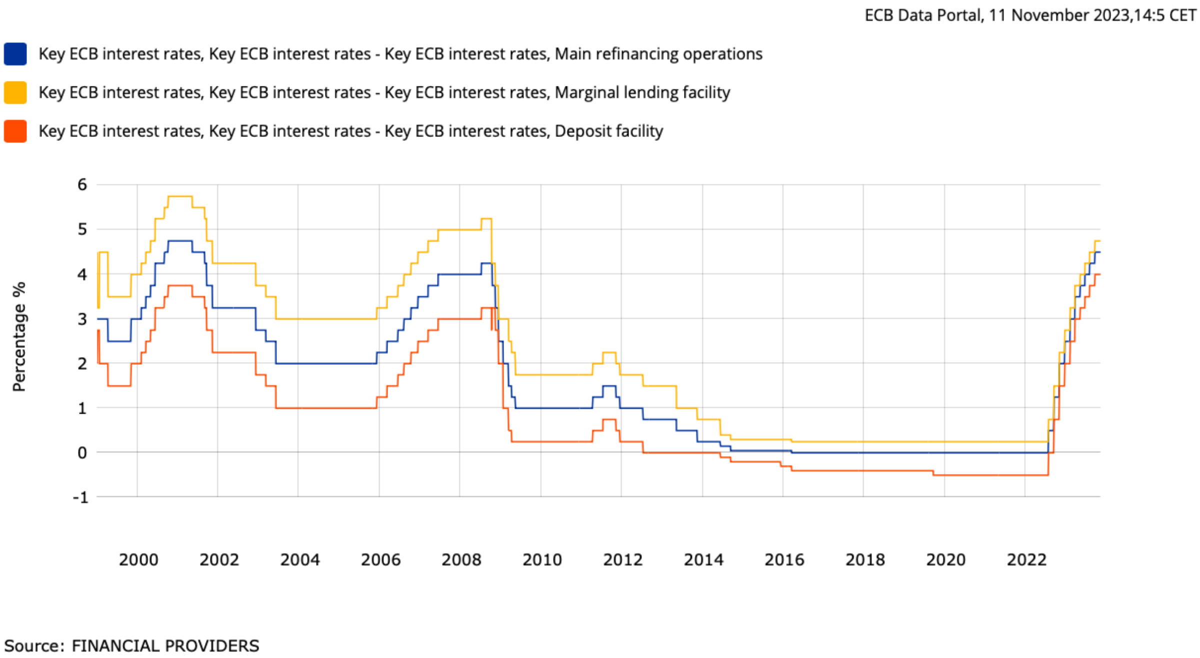

Figure 1: Interest rate corridor (Key ECB Interest Rates | ECB Data Portal, 2023)

This figure visually shows that the MRO rate clearly lies for most of the time between the DFR and MLFR. Additionally, one can observe that the interest rate corridor has become narrower over time, especially after 2022.

2.3. Evolution of the REPO rate

First of all, Figure 1 from the previous section shows that there has been a significant transformation in the interest rate cycle during the last two decades. The large increases and decreases reflect the business cycle, especially for the first periods. In 1999 the Governing Council initially increased the MRO rate up to 4.75% in order to response to upside risks to price stability. Then following this first business cycle episode the MRO rate was decreased sharply and even reached 2%, a historically low level for the Euro area. After that, the MRO rate was kept steady for two and a half years allowing the economy to recover. Then again in response to increasing upside risks to price stability the policy rates were raised at the end of 2005 and reached 4% at the end of June 2007 (Hartmann & Smets, 2018a). Following the financial crisis, the interest rate cycle underwent a change, with rates tending to be lower and persisting for longer durations than in previous periods. The trend became flatter. Starting from the year 2014 it is eye-catching that the MRO rate reached the zero lower bound (ZLB). In fact, this was in June 2014 where the ECB proceeded to decrease only its deposit facility afterwards. This action introduced negative interest rates, establishing an effective lower bound (ELB) at negative rates. Consequently, the DFR became a more indicative signal of the monetary policy stance (European Central Bank., 2020). Moreover, the graph also visualizes that for the most recent business cycle period the ECB continuously increased the MRO rate again. It even arrived at 4.5% on 20 September 2023 (*Key ECB Interest Rates | ECB Data Portal*, 2023). These were the measures taken to fight against a too fast increasing inflation caused by quickly rising prices. Since the beginning of the Russia- Ukraine War, inflation is too high and the economy too slow. Prices have increased dramatically especially for energy and food because of the war. The aim in increasing interest rates further and further is to keep prices stable and bring inflation back to 2% and above all keep inflation expectations under control (European Central Bank, 2022).

Finally, the graph also visualizes another aspect of the MRO's rate evolution, highlighting the ECB's tendency to adjust its policy rates in small steps (European Central Bank, 2020a). The following table provides further insight, revealing that for most of the time the ECB maintains the MRO rate unchanged. Specifically, over the period from 1999 to 2023, out of 300 monetary policy meetings, there were no changes in 284 instances. Additionally, when changes to the MRO rate do occur, they are typically modest, involving increases or decreases of 25 basis points. Occurrences of a 75 basis point increase or decrease are relatively rare.

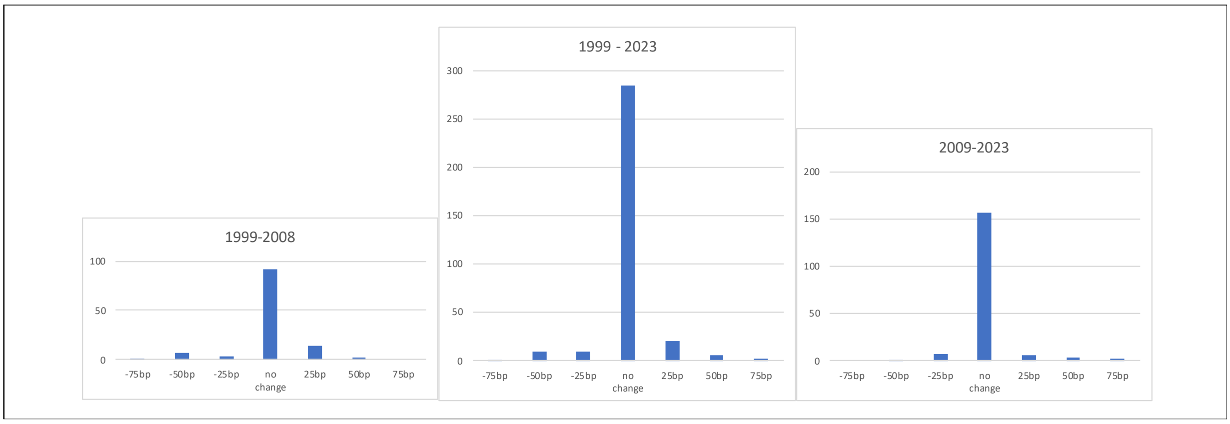

Figure 2: MRO rate changes, adapted from the European Central Bank (2020a)

2.4. Limitations

Before the financial crisis, the ECB mainly conducted monetary policy by setting the key interest rates (European Central Bank, 2021). However this slightly changed after the financial crisis and especially during the low- inflation recovery period from 2014 to 2017. This more recent episode is marked by the ECB's actions to overcome the ZLB of interest rates. The ECB had to fight deflation risks and bring inflation back close to 2% during that episode. Indeed, when short- term interest rates approach the ZLB, central banks cannot boost demand by lowering the interest rates and the economy might enter into a liquidity trap (European Central Bank., 2019). More precisely, the ZLB constraint arises because individuals in the market can evade negative interest rates by opting for cash holdings over interest- bearing assets. The feasibility of driving the interest rate to zero, a small positive, or a slight negative number hinges on the specified preferences and the role of money in the economy. In typical circumstances, when the short- term interest rate is substantially above the zero bound, a central bank can ease monetary policy by increasing the supply of the monetary base, thereby lowering the short-term interest rate. As prices of goods and services take longer to adjust compared to those of financial instruments, such a monetary injection reduces real interest rates, stimulating the economy. The zero bound introduces a restriction on this mechanism. The central bank can infuse enough liquidity into the economy to effectively bring the overnight rate to zero. Beyond, this treshold, further increases in the monetary base no longer significantly impact short- term nominal interest rates. Consequently, if the interest rate channel is the primary instrument through which monetary policy operates, the zero bound can pose a substantial obstacle to the policy process (Orphanides & Wieland, 2000). This is why it is highly debated in literature whether the ZLB constitutes a limitation for the MRO rate of a central bank and if conventional monetary policy in turn might become ineffective (European Central Bank., 2019).

In fact, the ECB turned to other policies such as quantitative easing, asset purchase programs and explicit forward guidance. In June 2014, it was the first major central bank that used negative interest rates. The ECB lowered its deposit facility rate into negative territory from 0 to -0.10%. Then in September 2014 it was further reduced to -0.20%. The ECB continued to decrease the DFR until September 2019 where it reached -0.50% (European Central Bank., 2019; Hartmann & Smets, 2018a). By then, the DFR became the primary policy rate of the ECB since excess liquidity increased dramatically, causing the Euro overnight index average (EONIA) to fall below the MRO rate (ibid.). The reason behind introducing a negative DFR was twofold: "to trigger a repricing of the expected future path of short- term interest rates by breaking through the zero lower bound and to encourage banks to provide more credit to the economy" (European Central Bank, 2020). Indeed, the negative DFR restored a crucial aspect of monetary policy. The opportunity for the market to foresee additionl cuts, allowing for "frontloading of policy accommodation". By that the ZLB no longer restricted market expectations (ibid.).

Globally, there does not seem to exist consensus in the economic literature on the efficacy of negative interest rate policies. In the paper of European Central Bank (2019) it is concluded for instance that the transmission mechanism of monetary policy remains effective below the ZLB. Beneath the ZLB, healthier banks exhibit a greater ability to pass on negative rates to their depositors compared to other banks. This means that the positive impact of negative interest rate policies on the economy is more pronounced when banks are in good financial health and can implement negative rates on deposits (ibid.). All in all, according to the speech by Isabel Schnabel, Member of the Executive Board, at the Roundtable on Monetary Policy in August 2020 "the transmission of negative rates has worked smoothly and, in combination with other policy measures, they have been effective in stimulating the economy and raising inflation" (European Central Bank, 2020).

3. Related literature

In this section, I briefly review the relevant literature concerning estimation reaction functions for the ECB, particularly during the financial crisis. Although they generally employ similar methodologies, there are variations in time spans considered. Following this, I offer a concise overview of the Taylor rule and its connection to the relevant literature. Subsequently I highlight the most relevant explanatory variables involved in the reaction functions. The section concludes with a detailed explanation of the content of Gerlach's paper (2007).

3.1. ECB reaction functions and the financial crisis

The two contributions most closely connected to my thesis are Gerlach (2007) and the work of European Central Bank (2020a), respectively. In fact, Gerlach (2007) studies how different macroeconomic variables influence the ECB in setting its main monetary policy tool, which will be explored in more detail in the next section. The paper from the European Central Bank (2020a) analyzes the interest rate- setting- behavior of the ECB as well. They use a similar method to Gerlach (2007) and to the time frame I use. Indeed, they estimate empirical reaction functions based on ordered probit techniques, similar to the approach of Gerlach's paper (2007). However, they present findings from three distinct time periods: the entire dataset from 1999 to 2018, a pre- crisis timeframe spanning 1999 to 2008 and a pre- ZLB era from 1999 to 2014. By this, they want to detect potential shifts in the determinants influencing ECB's interest rate decisions. Moreover, apart from inflation and growth projections and M3 growth, they also include the federal funds rate into their regression, same as Cour-Thimann & Jung (2021). Thereby both confirm the significance of international interest rate connections which the ECB takes into account. Cour-Thimann & Jung (2021) use a similar method as well. They also go further and analyze the ECB's monetary policy decisions over longer periods of data, namely from 1999 to 2018 which comes closer to this work. Same as in the working paper of the European Central Bank (2020a) they present estimation findings for the entire dataset (1999-2018) and for two shorter periods, 1999 to 2008 and 1999 to 2014. So the first data sample excludes the financial crisis and the second leaves out the ZLB episode. Boeckx (2010) estimates monetary policy reaction functions for two different time spans as well. His full sample spans from 1999 to 2010, covering the financial turmoil, while his smaller sample excluding it, is from 1999 to 2008. He even concludes that the smaller sample period is more reliable than the whole sample. Moreover, Boeckx (2010) employs a simple forward- looking Taylor rule which includes one year ahead growth and inflation forecasts obtained from the ECB's Survey of Professional Forecasters (SPF). He estimates the regression using an ordered probit technique and highlights that this diverges from the "traditional Taylor rule view" as it is necessary to employ other estimation techniques than ordinary least squares (OLS) (Boeckx, 2010, p.5). Another more recent paper of Morelli & Seghezza (2021) aims to establish a connection between the ECB's historical behavior and its response to the most recent crisis, namely the Corona Crisis. More precisely they want to find out why the ECB reacted much faster to the COVID-19 pandemic than to the financial crisis in 2008. Using a traditional Taylor rule, they demonstrate that a central bank within a monetary union has a slower learning pace compared to a conventional central bank.

Regarding the financial crisis, Gerlach & Lewis (2014) study the interest rate-setting- behavior during this period and analyze how long and by how much the ZLB consituted a constraint to interest rates from 2008 to 2011. They find that the reaction function of the ECB shifted in November 2008 and switched back in 2010. The ECB reduced interest rates more rapidly in response to deteriorating economic conditions. Gross & Zahner (2021) also confirm that the ECB's monetary policy strategy shifted in the post- crisis period. Following the bankruptcy of Lehman Brothers, the ECB redirects its attention towards the inflation rate and much less to economic activity. Additionally, another academic work which focuses on this issue is from Gerlach & Lewis (2010) who explicitly focus on the ECB interest rate decisions during the financial turmoil of 2007-2009. In July 2008, the ECB increased interest rates to 4.25% due to the ongoing rise in oil prices, which exerted upward pressure on the harmonized index of consumer prices (HICP) inflation. Then in October 2008 the ECB began cutting rates due to downside risks to price stability. This process continued until the beginning of 2009, still justified by decreasing inflationary pressures leading to a cut of 325 basis points in only seven months. This shows that the ECB's adjustment of interest rates aligns with theoretical literature on the ZLB: rates have been reduced more aggressively when the prospect of reaching the ZLB becomes apparent (Gerlach & Lewis, 2010). To conclude, the shift of the ECB's interest rate- setting approach occurred following the collapse of Lehman Brothers, specifically only more than a year after the upheavel in the interbank market in August 2007. This change can be linked to the swift decline in real GDP growth during that timeframe (Gerlach & Lewis, 2010). Finally, Boeckx (2010) claims that during the financial crisis, the signal derived from the MRO rate concerning the monetary policy stance became unclear, which complicates the analysis. Various measures have been taken to implement a more expansionary monetary policy beyond what is indicated by a simple assessment of the policy rate. Since the fall of 2008, the monetary policy stance has been relaxed trough several measures, including a fixed- rate full allotment liquidity policy, increased longer- term operations, a broader range of eligible collateral, and securities purchase programs.

To conclude this section, one can see that the literature which estimates the monetary policy decisions based on empirical reaction functions and ordered probit models is quite extential. In addition, a lot of authors augment their empirical reaction functions with communication indicators to analyze how the Governing Council assesses the economic environment (Heinemann & Ullrich, 2005.; Picault & Renault, 2017; Rosa & Verga, 2007; Sturm & De Haan, 2011). Cour-Thimann & Jung (2021) state that central bank communication does not have to be integrated in the analysis as long as the central bank's reaction function is well understood. However in times of high uncertainty, central bank communication may become even more important than its actions. It may help to stabilize the economy as communication influences expectations. Especially after the financial crisis forward guidance became more and more prominent.

Relatively to this, I will solely focus on studying the reaction function for the ECB based on different macroeconomic variables. This means I will only use the first part of Gerlach's (2007) empirical section. Having covered the first part of the most relevant literature, I will now proceed to the next chapter which focuses on the Taylor Rule, which constitutes the foundational methodology to analyze the interest rate setting (Gross & Zahner, 2021).

3.2. Taylor Rule

The policy rule introduced by Taylor in 1993 gained significant prominence. He proved that his rule fitted the actual policy performance of the US very well from 1987 to 1992. Later on different authors also wanted to test whether the Euro area, (and the US) adapted that rule (Sauer & Sturm, 2003). According to Taylor (1993) the federal funds rate depends on inflation and the deviaton of real gross domestic product (GDP) from its target. The original formula is written in the following way (Taylor, 1993, p.202):

$$r = p + .5\gamma + .5(p - 2) + 2$$

r denotes the federal funds rate, p is the rate of inflation over the previous four quarters and γ shows the percent deviation of real GDP from a target. Moreover, γ is defined as follows: $y = 100(Y - Y^*)/Y^*$, where Y is real GDP and Y^* denotes trend real GDP (Taylor, 1993, p.202). The formula shows that the federal funds rate increases if inflation rises above a target of 2%, or if real GDP increases above trend GDP (Taylor, 1993).

Now, one common device or rule which is used to explore the interest rate- setting-behavior of central banks refers to this Taylor rule or rather Taylor- type policy rules. This is highly discussed in literature. Some authors pretend that Taylor- type policy rules would work well for the Euro area (Hartmann & Smets, 2018; Orphanides & Wieland, 2013), whereas others acknowledge that simple policy rules are not sufficient to explain monetary policy decisions (Gross & Zahner, 2021; Orphanides, 2001). Even if the main objectives of the ECB consist in stabilizing inflation and output, a simple Taylor rule will not be optimal to asses the monetary policy of central banks (Svensson, 2003). Gorter et al. (2008) propose for instance that expected inflation and expected output should be used instead of conventional data as monetary policy has to be forward- looking since changes of interest rates affect inflation and output with a lag. This refers to utilizing real-time data that is actually accessible to the central bank during its decisions-making process (Orphanides, 2001). Boeckx (2010), for instance uses a forward- looking Taylor rule as well and highlights that it has to diverge from the "traditional Taylor rule view" as it is necessary to employ other estimation techniques than OLS (Boeckx, 2010, p.5). Gross & Zahner (2021) emphasize that it does not seem realistic to restrict central bankers policy decisions to a monetary policy rule that is based on only two variables. This is why the standard Taylor rule should be extended. In fact they analyze how it could be extended by applying a Bayesian model averaging (BMA) approach for the period April 1999 until March 2018. This allows them to compute 33.000 model combinations of potential variables that might influence the interest rate setting. They use numerous explanatory variables such as business cycle variables and financial markets variables. The first ones include for instance inflation, output and unemployment whereas the financial markets variables refer to credit measures, euro exchange rate, stock price, money supply, and Euro area government bond yield. Their results suggest that the ECB mainly focuses on the inflation rate, as the HICP is included in all relevant models. Moreover the central bank reacts to an increase in the expected unemployment rate with expansionary monetary policy. The model with the 2nd highest likelihood additionally includes the effective Euro exchange rate. Some of these variables are also included in the reaction function of Gerlach (2007). Indeed, he also adds money growth, the risk premium and the Euro exchange rate in his analysis which might contain additional information on future inflation and output.

The subsequent discussion focuses on the key variables entering Taylor- type rules as employed in the empirical work by Gerlach (2007). These variables might influence how the ECB sets its MRO rate.

3.3. Explanatory variables

The first main variables to be discussed are the inflation rate and expected growth. According to Gross & Zahner (2021) the inflation rate and economic activity are both key determinants for the ECB's monetary policy during the pre- crisis period. They even show that the Governing Council focused more on economic activity than on inflation which does not correspond to the traditional hierarchy of focus of the ECB. However after the financial crisis the ECB's monetary policy shifted. In other words, after the bankruptcy of Lehman Brothers the ECB solely continued focusing on the HICP inflation rate and not on economic activity anymore. It is also confirmed by the European Central Bank (2020a), that the ECB takes expected inflation into account but also reacts to economic growth as well, for the sample period 1999- 2018. According to Gerlach & Lewis (2014) forecast inflation and real GDP growth are not significant for the period during the financial crisis. However the long- run response to both variables indicates that the ECB has cared strongly about inflation and economic growth which is an important driver of inflation in itself. Cour-Thimann & Jung (2021) highlight that during the pre- crisis period (and pre- ZLB period) inflation and expected growth are both highly significant which contradicts the findings of Gerlach (2007). Hartmann & Smets (2018a) analyze the ECB's interest rate decisions as well for the period from 1999 to 2018. They run empirical interest rate reaction functions. In other words, they use a simple first- difference rule which links the ECB's primary policy rate to discrepancies between the one- year inflation forecast from their inflation target and deviations in one- year ahead real GDP growth forecasts from potential output growth. They find that this simple rule significantly explains the increases and decreases of the ECB's MRO rate.

Next, one highly debated and controversial element in the ECB's strategy is the significance of money (Berger et al., 2011). According to the work of Berger et al. (2011) money did not play an important role in determining ECB interest rate decisions. This stands

in contrast to the findings of Gerlach (2007) which states that the ECB responded to the rate of growth of M3 but only when economic activity is strong. Both authors approximately analyzed the same time period, namely the period before the financial crisis. However Berger et al. (2011) utilized another method. In their paper the policy decisions contained in the introductory statements are analyzed and quantified without relying on an economic model, like a Taylor-type rule. Hartmann and Smets (2018a) also conclude that money growth is not significant. They include it in their simple first- difference rule. Nevertheless another study, Cour-Thimann & Jung (2021) approves with the result of Gerlach (2007) on the relevance of M3 growth for explaining future interest rate changes to credit growth, but only for a limited time period. They show that this result only holds for the pre- crisis period 1999- 2008, but not afterwards.
This is why I will also include monetary growth as an explanatory variable in my analysis. It is included in the seminal work from Gerlach (2007). Moreover, as literature has shown, it is a contentious variable which makes it even more interesting to find out whether it stayed significant during the financial crisis and afterwards.

Another prominent variable which often enters reaction functions is the exchange rate. Gerlach (2007) and Gerlach & Lewis (2010) find that an appreciation of the euro in effective terms leads to monetary easing. Moreover the sign of the coefficient is negative, suggesting that the Governing Council is inclined to increase interest rates when the currency is depreciating and vice versa. This indicates that the ECB responds to inflationary pressures originating from the exchange rate channel.

The last variables included are the lagged change and the lagged level in the repo rate. In the estimation of Taylor- type rules, economists often observe an enhanced fit when incorporating the lagged policy rate as one of the regressors (Boeckx, 2010; Castelnuovo, 2007). On the one hand, some authors claim that the ECB tends to change its policy rates in small steps (European Central Bank, 2020a). This gradual adjustment is frequently referred to as “interest rate smoothing” (Castelnuovo, 2007, p.2). One reason for this could be the presence of uncertainty, leading a central bank to exercise greater caution in adjusting interest rates (Boeckx, 2010). Additionally, a gradual approach has the potential to enhance the effectiveness of monetary policy, as small rate adjustments are anticipatd to be followed by subsequent changes in the same direction. This magnifies the impact of a single interest rate move (Woodford, 2003). Gerlach & Lewis (2010) also confirm a considerable inclination towards gradualism in the interest rate- setting- behavior, during the pre- crisis period. On the other hand, Cour-Thimann & Jung (2021) confirm the findings of Gerlach (2007) that interest rate changes are made “to clear the air” (Gerlach, 2007, p.13). This would suggest that it is less probable for a central bank to alter interest rates in two consecutive meetings. Additionally, Gerlach (2011) confirms that a shift in the repo rate in one direction is likely to be succeeded by another, whereas Gerlach & Lewis (2010) state that the ECB is less likely to raise (cut) rates if it did so in the preceding month during the pre- crisis period.

These discrepencies make it even more intriguing to include the same variables in the regression for this thesis. However before moving on to the empirical part, the paper of Gerlach (2007) will be explained and discussed in more detail. I will highlight why I chose this paper, what Gerlach (2007) does, which variables he uses and which time frame he analyzes.

3.4. Review of Gerlach (2007)

To start, I would like to explain why I chose this paper as the basis for my approach. Confirmed by other studies, Gerlach (2007) seems to include interesting and relevant economic variables for the extended Taylor rule. They are approved for having a significant impact on the interest rate- setting- behavior of the ECB in other scientific papers. They also change over time and are influenced by the changing environment. For instance, Gross & Zahner (2021) find out that the main drivers are the inflation rate (HICP) and economic activity which also enter the regression of Gerlach's work. Moreover their individual model with the second highest probability additionally incorporates the effective Euro exchange rate which is also included in the regression of Gerlach. Addionally, Svensson (2003) and Gorter et al. (2008) highlight that the ECB takes expected inflation and expected output growth into account rather than conventional data. In general, expectations data seems to be more strongly correlated to the short- term interest rate, at least for the period January 1997 until december 2006 (Gorter et al., 2008). The ECB itself also states that given the time- lags in transmitting monetary policy signals to the price level, it needs to adopt a forward- looking approach (*ECB Monthly Bulletin*, 2000). Finally, Gerlach examines the period February 1999 to June 2006. This makes it interesting to use his method and analyze it with more recent data.

The aim of his paper is twofold. On the one hand he estimates empirical reaction functions for the ECB with ordered probit models and thereby analyzes the ECB's deeds. On the other hand, he does not solely focus on a simple, conventional economic model, but he also evaluates the words of the ECB. In other words, he expands the existing research gap on reaction functions for the Euro area by utilizing information from the statements published in the ECB's Monthly Bulletin. These statements help create indicators that capture the evaluations of the Governing Council regarding inflation pressures trends, developments in real economic activity and M3 growth. He wants to find out how these variables influence the ECB in setting its main monetary policy tool, the MRO rate.

First, the author estimates an ordered probit model for the time period February 1999 to June 2006. He emphasizes that it would be inappropriate to use an OLS regression as the ECB faces a discrete choice problem and changes its interest rates in small steps. Gerlach outlines for instance that the repo rate was changed only in 18 months out of 89 months. The next step consists in analyzing the deeds of the ECB by estimating empirical reaction functions. This is also the part on which I construct my empirical part on. Hence, the following equation is used in his paper to express the target level for the interest rate (Gerlach, 2007, p.6):

$$i_t^T = \alpha_\gamma \gamma_t + \alpha_\pi \pi_t + \alpha_\mu \mu_t + \alpha_\varepsilon \varepsilon_t, \qquad (1)$$

Where i_t, i_t^T π_t, γ_t, μ_t, and ε_t denote the repo rate, the Governing Council's target for the repo rate, inflation, real economic activity, money growth, and the rate of appreciation of the nominal effective exchange rate. The constant is omitted and α_γ, α_π, α_μ are positive and α_ε is negative. Afterwards Gerlach follows Judd and Rudebusch (1998) for gradual adjustment of the actual interest rate, where e_t is a residual (Judd & Rudebusch, 1998).

$$i_t - i_{t-1} = \beta_0 (i_t^T - i_{t-1}) + \beta_1 \Delta i_{t-1} + e_t, \qquad (2)$$

Equation (2) suggests that interest rate adjustments should occur coninuously. Yet, due to the ECB's practice of setting interest rates in steps, only discrete changes are observed. By combining equations (1) and (2) while taking into account the ECB's stepwise approach to interest rate setting, the following can be derived (Gerlach, 2007, p.6):

$$i_t^* - i_{t-1} = \tilde{\alpha}_\gamma \gamma_t + \tilde{\alpha}_\pi \pi_t + \tilde{\alpha}_\mu \mu_t + \tilde{\alpha}_\varepsilon \varepsilon_t - \beta_0 i_{t-1} + \beta_1 \Delta i_{t-1} + e_t, \qquad (3)$$

For this equation it holds that $\tilde{\alpha}_i \equiv \alpha_i \beta_0$ and the asterik, *, shows that the interest rate represents an unobserved variable. The actual change in the interest rate is what is observed and which is contingent on the position of the underlying variable relative to a predefined set of treshold values, denoted as γ_i:

$$
\begin{aligned}
&\Delta i_t = -0.50\% \quad if\ i_t^* - i_{t-1} \leq \gamma_1 \\
&\Delta i_t = -0.25\% \quad if\ \gamma_1 < i_t^* - i_{t-1} \leq \gamma_2 \\
&\Delta i_t = 0 \qquad\quad\ \ if\ \gamma_2 < i_t^* - i_{t-1} \leq \gamma_3 \\
&\Delta i_t = +0.25\% \quad if\ \gamma_3 < i_t^* - i_{t-1} \leq \gamma_4 \\
&\Delta i_t = +0.50\% \quad if\ \gamma_4 < i_t^* - i_{t-1}.
\end{aligned} \tag{4}
$$

Equations (3) and (4) form an ordered- response model, indicating that the Governing Council's decision on a policy option depends on the variables, inflation, economic activity, money growth, the rate of appreciation of the euro as well as the previous level (and its change) of the repo rate.

Having this set of equations, the author estimates the model in a following step. However before summarizing his results it is important to highlight which data he exactly uses as I will use the same variables in the empirical part of my thesis. The main part of the data he uses stems from the ECB website which is also one further reason I use his method as basis, since this data is publicly available. First, the lagged level of the repo rate and the change in the repo rate are used amongst other as independent variables. Another very important variable he includes in the analysis is money growth, as it captures the monetary developments for the Euro area. More precisely, Gerlach uses the three- month moving average of the annual growth rate of M3 growth, also as one regressor. The next variable included is inflation. However, the inflation rate is a more tricky variable as it has to be decided whether to use headline or core inflation. Gerlach therefore integrates a measure of the HICP, excluding fresh- food and energy prices in his model, which is used as a measure for core inflation. Furthermore, as already mentioned some authors have proven that it is even better to involve a measure of expected inflation instead of conventional data (Gorter et al., 2008; Svensson, 2003). Gerlach also constructs a measure of expected inflation, using data from the polls of forecasters published in *The Economist*. Next, inspired from Heinemann & Ullrich (2005) the "percentage change over twelve months in the nominal effective exchange rate of the euro against a basket of forty- three currencies" is entailed in the reaction function, where an increase displays an appreciation of the euro (Gerlach, 2007, p.8). Finally the last variable embraced is a measure of real economic activity. However this is also a highly complicated measure as it is widely discussed in literature whether to include the output gap or the real GDP for instance. Gerlach therefore includes economic sentiment data, reflecting real economic activity which is created by the European Commission. Additionally he also uses a measure of expected real GDP which he also takes from the poll of forecasters published monthly in *The Economist*. In fact, subjective measures of economic activity like Gerlach uses, are available with very short lags, in contrast to output gaps which are constructed with long time lags and are particularly uncertain. Gerlach also accentuates that one must consider the lags by which the data are available to the ECB. Put differently, the variables must be lagged appropriately as some data are available with a three-month lag, real ecoomic activity and the output gap for instance, whereas expectation data is available for a one- month lag. In total, he estimates 10 different models. The author uses different combinations of data. For instance, the first three reaction functions are estimated using sentiment data for the economic growth. In the next three, he uses expected growth and finally the output gap. He does the same for the rate of inflation, where he either uses headline, core, or expected inflation. Or in the last model he neither includes headline, nor core, nor expected inflation as they were not significant in the previous models.

Next the results of his work can be summarized as follows. Stronger real economic activity led to raising interest rates. However the coefficient on headline inflation is insignificant. This means that the ECB did not react to (past) inflation. By contrast, the parameters on M3 growth and on the exchange rate are highly significant in all models. To clarify, if money growths faster, the ECB tightens monetary policy. A depreciation of the euro in effective terms leads to monetary tightening as well. This means that the ECB is tended to reduce interest rates when the currency appreciates. Furthermore, the change in the interest rate and the lagged level of the interest rate are significant as well. The coefficient for the lagged level of the interest rate is negative which would mean that after changing the interest rates, the ECB waits for some time before changing them again. Gerlach concludes that the Governing Council changes the interest rates to "clear the air" rather than smoothing them (Gerlach, 2007, p.13).

Finally, these results imply some further important questions for his paper. First, what prompts the Governing Council to respond to real economic activity while remaining less responsive to inflation? Is this due to a greater concern for the state of the real economy compared to inflationary pressures? Additionally, why does it take into account money growth but not inflation? Second, how accurately do these models forecast the Governing Council's interest rate choices? Third, in what manner does money growth influence the likelihood of interest rate adjustments?

To find possible answers Gerlach additionally analyzes the editorials of the ECB's *Monthly Bulletin* from January 1999 until July 2006. These editorials contain information of the Governing Council's assessment of the economic environment and explanations why interest rates were changed or unchanged. Nevertheless Gerlach has to construct its own indicator variables to be able to augment the Taylor rule with the communication indicator. This is seen as a very challenging part in the literature (Heinemann & Ullrich, 2005; Rosa & Verga, 2007). More precisely in the work of Gerlach this indicator should entail the Governing Council's views of the "risks to price stability" caused by changes in real economic activity, inflation and M3 growth (Gerlach, 2007, p.15). Using such indicators should complement the information derived from macroeconomic data which might not always be sufficient and fully informative.

Some conclusions can be drawn from analyzing the words of the ECB. First, real economic activity is highly significant in the reaction function as it is seen as an important driver for future inflation pressures. In contrast, inflation seems to be less tied to interest rate changes than economic activity as shocks to actual inflation are seen as temporary, reflecting price level shocks which do not impact future inflation. Moreover the relation between money growth and interest rates seems ambigous. Gerlach shows that if money growth is below average, interest rates are higher which would not be expected in general. However money growth is also seen important as it captures risks to price stability. Finally as already mentioned some authors claim that money growth is not a significant determinant for macroeconomic policy decisions (Berger et al, 2011). Gerlach explains this by showing that under "normal" economic conditions, money growth has little impact on the probability of a policy change (Gerlach, 2007, p.28). However if economic conditions are weaker or stronger, money growth has an impact on the interest rate setting of the ECB. Hence it depends on the business cycle of the economy.

4. Empirics

4.1. Method

As already mentioned, I aim to analyze different macroeconomic variables which might influence the ECB in deciding to increase, decrease, or to not change the MRO rate. To test this, I use an ordered probit regression in which the MRO rate is the dependent variable. In fact, in numerous papers ordered probit regressions are used to analyze the interest rate- setting- behavior of a central bank (Boeckx, 2010; Cour-Thimann & Jung, 2021; European Central Bank., 2020a; Gerlach, 2007; Hartmann & Smets, 2018). Indeed, a Probit model allows to capture non- linearities in the interest rate- setting- behavior in response to changes in the macroeconomic environment (Cour-Thimann & Jung, 2021; European Central Bank., 2020a). As the ECB decides at each monetary policy meeting to adjust interest rates in increments of 25 basis points or to not change them, the dependent variable is rather discrete and not continuous (Boeckx, 2010; Cour-Thimann & Jung, 2021).

Moreover, as I focus on the paper of Gerlach (2007), I use the same variables as he did, only for different time periods. Gerlach (2007) estimated reaction functions for the period February 1999 to June 2006. The ordered probit model for this thesis is estimated for the following time intervals: the first period includes the financial crisis and is estimated for the span 2006 to 2010. The second interval comprises the low inflation recovery and covers 2010 to 2016. Finally, the last period is more extensive and encompasses, among other events, the Corona Crisis and the beginning of the Russia- Ukraine Conflict and is extended over 2014 to 2022. This means in total three regressions are estimated. The purpose is to find out which variables stay significant, compared to other studies, which ones are not noteworthy anymore or which ones become substantial. Moreover, I mentioned in the previous section that Gerlach (2007) estimated 10 different model combinations where he includes different combinations of data for each model. For this thesis I partly do the same. In other words, for the variable inflation I estimate different policy reaction functions which either include headline inflation, or core inflation, or expected inflation. To measure real economic activity I use expected real GDP, or real GDP, or the growth rate of GDP respectively. For all the other factors (M3 growth, exchange rate, lagged change in Repo Rate, lagged level of Repo Rate), I only use one measure. In the next section I precise which exact data I use and from where it is downloaded.

4.2. Data

First, monthly data is employed since this aligns with the frequency at which rates are determined by the Governing Council (Gerlach & Lewis, 2010). The data is taken from the ECB statistics website, the Federal Reserve Economic Data (FRED) website and the Organization for Economic Cooperation and Development (OECD) Data Portal respectively. The following variables are utilized in the regression:

MRO rate: The MRO rate will be used as the endogenous variable. More precisely, I will use the "ECB Main refinancing operations – Minimum bid rate/ fixed rate" from the ECB Data Portal *(ECB Data Portal*, 2023).

Lagged level of the repo rate: This variable is created using Stata. The MRO rate is lagged by two periods.

Change in the repo rate: This variable is generated in Stata as well. In fact it is the difference between the MRO rate and the lagged value of the MRO rate.

Money growth: To measure money growth the "monetary aggregate M3 reported by MFIs, central gov. and post office giro institutions in the Euro area (annual growth rate)" is employed, as well from the ECB statistics website (*ECB Data Portal*, 2023).

Exchange rate of the euro: Regarding the exchange rate the "nominal effective exchange rate (EER) – 41/ Euro" from the ECB statistics website is applied (*ECB Data Portal*, 2023). It is worth noting that Gerlach (2007) employed the Euro's exchange rate against a basket of 43 currencies, whereas I use a basket of 41 currencies, as this is the only option provided on the ECB website at the moment. Moreover I compute the percentage change in the euro exchange rate, aligning with the approach employed by most authors who analyze percentage changes.

Inflation: I follow Gerlach (2007) in utilizing core inflation, which excludes fresh- food and energy prices, as a key variable and which is based on the "HICP- All items excluding energy and food" (*ECB Data Portal*, 2023). Similarly, I incorporate HICP inflation in certain models, aligning with Gerlach's (2007) approach. Additionally he includes expected inflation using data from the polls of forecasters published in *The Economist.* In my analysis, I rely on data from the OECD website, specifically identified as "Inflation forecast, total, annual growth rate (%)" (*Prices - Inflation Forecast - OECD Data*, 2023). However this data is only available quarterly, so I interpolate it linearly in Stata in order to integrate it in a monthly format. In an ideal scenario, explanations for central bank interest rate adjustments would rely on internal central bank forecasts of inflation (and growth) made one year ahead. Unfortunately, these internal ECB forecasts, conducted at the frequency of policy meetings, are not accessible to the public (Boeckx, 2010). Therefore I turn to inflation projections sourced from the OECD.

Real economic activity: This thesis incorporates seasonally adjusted real GDP from the FRED website (Eurostat, 1995) in the regression analysis due to the unavailability of economic sentiment data, which Gerlach (2007) uses. In line with Gerlach (2007), who develops a measure of expected GDP using data from *The Economist*, I include a forecast of real GDP provided by the OECD Data (*GDP and Spending - Real GDP Forecast - OECD Data*, 2023). It is worth noting that both real GDP and expected real GDP are not provided on a monthly basis. They are only accessible quarterly. Consequently, this data is interpolated linearly into a monthly format, facilitating the integration of monthly data for all variables in the regression. Moreover, in some models, I also include the growth rate of GDP, which is provided in a monthly format on the FRED website (Organization for Economic Co-operation and Development, 1961). This may provide a more precise representation of economic activity compared to linear interpolation and makes it possible to check which data fits the regression best.

4.3. Estimation Results

In the following three subsections the most important estimation results for the three different time periods are outlined. As already mentioned, I estimate 10 models for the first two regressions and 7 models for the last regression. For the last model I do not include the GDP growth rate, as this data is currently only available until August 2022. Monetary growth, the percentage change in the exchange rate and the lagged value of the MRO rate are included in every model. The variables representing inflation and economic activity are different for some models.

4.3.1. Financial crisis period

The following table illustrates the first regression for the time period 2006 to 2010. In fact, during this timeframe some MRO rate changes were made which is clearly visible on the first figure on page 15, representing the interest rate corridor. Out of 60 observations, the ECB increased the MRO rate eight times by 0.25 basis points and cut the rate two times by 0.25 basis points, four times by 50 basis points and one time by 0.75 basis points.

Table 1: Ordered probit models (2006 - 2010)

Model	1	2	3	4	5	6	7	8	9	10
GDP growth rate	0.372 (0.112)	0.408** (0.033)	0.455* (0.081)							
Expected GDP				0.0535 (0.699)	0.160 (0.130)	0.0648 (0.678)				0.186* (0.065)
Real GDP							0.0000176 (0.168)	0.0000257** (0.024)	0.0000222* (0.093)	
Headline inflation	1.798*** (0.007)			1.847*** (0.006)			1.925*** (0.005)			
Core inflation		-1.028 (0.532)			-1.540 (0.336)			-1.618 (0.314)		
Expected inflation			2.775*** (0.008)			2.631*** (0.005)			2.892*** (0.004)	
M3 Growth	0.686** (0.011)	0.306 (0.152)	1.056*** (0.005)	0.809** (0.012)	0.407* (0.062)	1.141*** (0.005)	0.817*** (0.002)	0.479** (0.015)	1.198*** (0.001)	0.331 (0.106)
Exchange Rate	-0.209 (0.285)	-0.267 (0.125)	-0.215 (0.297)	-0.169 (0.388)	-0.254 (0.140)	-0.166 (0.411)	-0.207 (0.301)	-0.311* (0.081)	-0.219 (0.299)	-0.229 (0.175)
Change in MRO rate	7.068*** (0.000)	7.221*** (0.000)	8.050*** (0.000)	7.103*** (0.000)	7.050*** (0.000)	7.957*** (0.000)	7.145*** (0.000)	6.792*** (0.000)	8.295*** (0.000)	6.943*** (0.000)
Lagged level of MRO rate	7.602*** (0.000)	7.667*** (0.000)	7.685*** (0.000)	6.163*** (0.000)	6.984*** (0.000)	5.827*** (0.000)	6.103*** (0.000)	5.941*** (0.000)	5.875*** (0.000)	6.623*** (0.000)
Number of observations	60	60	60	60	60	60	60	60	60	60
Pseudo-R-square	0.780	0.726	0.790	0.770	0.716	0.778	0.776	0.726	0.788	0.713
Chi2	196.3	182.9	198.9	193.8	180.3	195.9	195.4	182.7	198.4	179.4
Notes: p-values in parantheses (* p<0.1, **p<0.05, ***p<0.01), adapted from Gerlach (2007)										

First, the model with the best fit seems to be the third model as it has a pseudo-R-square of 0.79. This means that the independent variables are predicted to explain 79% of the changes made in the MRO rate which is rather high. The explanatory variables for this model are the GDP growth rate, expected inflation, M3 growth, the percentage change in the exchange rate, the lagged value of the MRO rate and the change in the MRO rate. Almost all variables are statistically significant in this model except for the exchange rate.

Furthermore, it is eye-catching that expected inflation and headline inflation are highly significant and positive in all cases. This contradicts the findings of Gerlach (2007) where neither headline nor core inflation were significant in his reaction function. This is explained in his work by the fact that deviations in actual inflation are commonly perceived as transitory and are consequently viewed as having minimal implications for future inflation. He also highlights it would be better to include core inflation which is unfortunately not significant in any of the models for the time span 2006 to 2010. Nevertheless, according to the first estimation the Governing Council is more likely to increase the MRO rate if expected inflation or headline inflation increase. This conclusion is consistent with some studies that analyzed the interest rate- setting- behavior of the ECB during the financial crisis. Especially after the collapse of

Lehman Brothers in September 2008 the ECB focused on the HICP inflation rate as well as expected inflation (European Central Bank, 2020a; Hartmann & Smets, 2018a). In the paper of Carstensen (2006) it is also shown that using core inflation instead of headline inflation does not lead to a better outcome.

Additionally, the Governing Council seems to consider economic activity, given the significance of GDP growth and real GDP. All coefficients are positive, meaning that higher economic activity, or an increasing GDP growth rate would lead the ECB to increase the MRO rate. However, it is worth mentioning that real GDP and the growth rate of GDP are not significant in all models, and some are only marginally significant. More precisely, both variables are not significant if headline inflation is also used as an explanatory variable. In all other instances both variables are significant. Expected GDP is not significant in any of the cases which seems questionable as some authors have shown that expected GDP (and expected inflation) are important factors to be included in the reaction function (Boeckx, 2010; Gorter et al., 2008; Svensson, 2003).

Moreover, monetary growth is significant and positive in almost all cases, affirming the findings of Gerlach (2007) and Cour-Thimann & Jung (2021) that the ECB reacts to money growth. In other words, if money growth rises, the Governing Council is more likely to increase the MRO rate. Since Cour-Thimann & Jung (2021) state that money growth is only taken into consideration by the Governing Council until 2008, it will be interesting to observe whether it remains significant in the next regression.

Unfortunately, the percentage change in the nominal effective exchange rate is not significant in any model. This would suggest that the ECB does not react to the change in the exchange rate which does not coincide with the seminal work of Gerlach (2007). According to his paper the Governing Council is more likely to increase interest rates when the currency is depreciating.

Next, the lagged value of the MRO rate is positive and highly significant as well, confirming the results of Gerlach (2011), but not the findings of Gerlach (2007). The positive coefficient would imply that an increase in the lagged MRO rate is associated with an increase in the likelihood of moving to a higher level of the MRO rate in the current period. In other words, the ECB is more likely to increase the MRO rate if it did so in the month before and vice versa. Finally, the change in the MRO rate is highly significant as well, indicating with its positive coefficient that the Governing Council is more likely to gradually raise the MRO rate over successive months by smaller steps. This contradicts the findings of Gerlach (2007) that the ECB changes interest rates to "clear the air" rather than smooth them (Gerlach, 2007, p.13).

4.3.2. Low- inflation recovery period

Moving on to the next table, which illustrates the reaction function for the time frame 2010 to 2016 during which the Governing Council stepwise increased the rate from 2011 and decreased it again from 2012 to 2016. Since the end of 2014 there were almost no changes made until 2022. As already mentioned, this time span is constrained by the ZLB. In total there were 84 observations, where the ECB only increased the MRO rate two times by 0.25 basis points and decreased it five times by 0.25 basis points.

Table 2: Ordered probit models (2010 - 2016)

Model	1	2	3	4	5	6	7	8	9	10
GDP growth rate	0.602 (0.313)	0.586 (0.223)	0.901 (0.194)							
Expected GDP				-0.0228 (0.913)	0.0777 (0.703)	0.0907 (0.694)				-0.0191 (0.924)
Real GDP							-0.0000491*** (0.001)	-0.0000305** (0.012)	-0.0000797*** (0.001)	
Headline inflation	0.883 (0.106)			0.841 (0.129)			2.000*** (0.008)			
Core inflation		3.332*** (0.009)			3.056** (0.012)			2.548** (0.045)		
Expected inflation			2.023*** (0.004)			1.951*** (0.007)			5.224*** (0.001)	
M3 Growth	-0.565* (0.064)	-0.934*** (0.007)	-0.827** (0.036)	-8.746** (0.029)	-1.024*** (0.004)	-1.057** (0.011)	-0.688* (0.055)	-0.688* (0.081)	-2.153*** (0.003)	-0.539** (0.041)
Exchange Rate	-0.0671 (0.661)	-0.154 (0.381)	-0.0916 (0.572)	-0.0121 (0.932)	-0.0770 (0.619)	-0.0269 (0.854)	0.0327 (0.838)	0.0481 (0.762)	0.0239 (0.898)	0.0265 (0.846)
Change in MRO rate	16.10*** (0.000)	16.65*** (0.000)	15.74*** (0.000)	15.32*** (0.000)	15.96*** (0.000)	14.79*** (0.000)	14.96*** (0.000)	15.58*** (0.000)	14.65*** (0.000)	15.99*** (0.000)
Lagged level of MRO rate	16.31*** (0.000)	16.02*** (0.000)	15.59*** (0.000)	14.01*** (0.000)	14.28*** (0.000)	12.82*** (0.000)	12.13*** (0.000)	13.56*** (0.000)	8.638*** (0.000)	15.42*** (0.000)
Number of observations	84	84	84	84	84	84	84	84	84	84
Pseudo-R-square	0.778	0.796	0.797	0.773	0.790	0.790	0.822	0.811	0.862	0.766
Chi2	260.4	266.4	266.6	258.8	264.3	264.4	275.1	271.6	288.6	256.4
Notes: p-values in parantheses (* p<0.1, **p<0.05, ***p<0.01), adapted from Gerlach (2007)										

For the second regression, the model with the best fit is the 9th model. It has a pseudo-R-square of 0.862. This means that the independent variables are predicted to explain 86.2% of the changes made in the MRO rate which is even more than in the first regression. This model includes M3 growth, the exchange rate, the lagged value of the MRO rate, the change in the MRO rate, expected inflation and real GDP. The percentage change in the exchange rate is still not significant in any of the models, suggesting that the ECB would not react to it as well during the second period.

Moreover, real GDP is highly significant, but the sign has changed. The negative sign would indicate that the ECB is more likely to decrease the interest rates if real GDP increases which seems rather questionable as various theoretical models and papers have shown that it is the other way around. In an ideal scenario when GDP increases, central banks would increase interest rates in order to manage inflation and ensure economic stability. Since an increasing GDP normally indicates that the economy is growing the central bank might increase interest rates in order to maintain price stability and avoid higher levels of inflation (Gerlach, 2007; Taylor, 1993). Furthermore, the growth rate of GDP and expected GDP are not significant whereas core and expected inflation are highly significant in all cases. This supports the results of Gross & Zahner (2021) who show that the ECB's monetary policy shifted after the financial crisis. Put differently, following the bankruptcy of Lehman Brothers, the ECB exclusively focuses on the HICP inflation rate and gives less attention to economic activity. Moreover, the results concerning inflation seem to have changed, as in the previous regression headline inflation was significant and not core inflation.

In addition, monetary growth seems to stay highly important to the Governing Council for the second period, but it has become negative now. This implies that an increase in monetary growth would heighten the probability of the ECB decreasing the MRO rate. This does not coincide with the paper of Gerlach (2007). Since he analyzes the ECB's Monthly Bulletin he finds out that money growth is indicating risks to price stability to the Governing Council. This would suggest that the ECB is more likely to increase the MRO rate if money growth increases. This would make the negative sign in the second regression more questionable. However it often depends on the broader economic context, meaning that if the central bank is supporting growth and employment it might tolerate a higher level of monetary growth.

Finally, the lagged value of the MRO rate and the change in the MRO rate are still highly significant and positive.

4.3.3. Corona Crisis and Russia- Ukraine War

Finally, the ultimate regression is conducted for the period from 2014 to July 2023. As already mentioned, only seven models are estimated for this table since the GDP growth rate data is available only until August 2022, while all the other variables extend until July 2023. Consequently, only two variables are included to represent economic activity instead of three.

Throughout the period from 2014 to July 2023 the MRO remained at 0 for most of the time and the Governing Council refrained from changing the MRO rate until June 2022. Indeed, out of 115 observations the rate was increased two times by 0.25 basis points, four times by 0.50 basis points and two times by 0.75 basis points.

Table 3: Ordered probit models (2014 - 2023)

Model	1	2	3	4	5	6	7
Expected GDP	0.000316 (0.992)	-0.00243 (0.970)	0.000198 (0.995)				0.000720 (0.975)
Real GDP				-0.0000114*** (0.001)	-0.0000179*** (0.000)	-0.0000128*** (0.000)	
Headline inflation	0.137* (0.083)			0.542*** (0.001)			
Core inflation		0.856*** (0.001)			2.601*** (0.000)		
Expected inflation			0.182** (0.035)			0.686*** (0.000)	
M3 Growth	-0.141 (0.243)	-0.295 (0.132)	-0.145 (0.246)	-0.271 (0.111)	-0.707*** (0.001)	-0.339* (0.067)	-0.104 (0.304)
Exchange Rate	-0.0258 (0.831)	-0.0259 (0.835)	-0.0217 (0.858)	-0.0207 (0.866)	-0.0453 (0.740)	-0.0147 (0.906)	-0.0405 (0.734)
Change in MRO rate	8.447*** (0.000)	8.017*** (0.000)	8.448*** (0.000)	7.028*** (0.000)	6.807*** (0.000)	7.167*** (0.000)	9.092*** (0.000)
Lagged level of MRO rate	17.62*** (0.000)	18.43*** (0.000)	18.24*** (0.000)	11.21*** (0.000)	7.609** (0.000)	11.27*** (0.000)	16.29*** (0.000)
Number of observations	115	115	115	115	115	115	115
Pseudo-R-square	0.618	0.657	0.623	0.662	0.748	0.679	0.608
Chi2	180.7	192.2	182.1	193.7	218.8	198.5	177.8
Notes: p-values in parantheses (* p<0.1, **p<0.05, ***p<0.01), adapted from Gerlach (2007)							

First, the model with the best fit is the 5th model which has a Pseudo- R- square of 0.748. This implies that the independent variables are predicted to explain 74.8% of the variations observed in the MRO rate. Notably, this model encompasses real GDP, core inflation, M3 growth, the exchange rate, the change in the MRO rate and the lagged value of the MRO rate. All variables are statistically significant except for the exchange rate. What is more, the 5th model is the only one where monetary growth is highly significant. In contrast, in all other cases money growth is not significant anymore or is only marginally significant (as seen in the 6th model), aligning with the findings of Cour-Thimann & Jung (2021), Hartmann and Smets (2018a) and Berger et al. (2011). This suggests that the ECB does not react to money growth anymore. In the work of Gerlach (2007), he states that there were periods, for instance from 1999 to 2000 where the

Governing Council did not see money growth as indicating risks to price stability which might also be the reason why it is not significant in the last regression for this thesis. Indeed, a substantial rise in money growth could also reflect a result of heightened demand for money and by that not generate inflation risks (Gerlach, 2007).

Furthermore, headline, core and expected inflation also stay significant and positive for the last regression. This suggests that during the COVID-19 pandemic and the beginning of the Russia- Ukraine War, the Governing Council is more likely to increase the MRO rate in response to increasing inflation. Indeed, as mentioned in the first part of the thesis, inflation has risen to exceptionally high levels in 2022/ 2023 and the ECB has reacted by increasing the MRO rate up to 4.50%.

The significance of economic activity remains consistent with the findings from the 2nd regression. Expected GDP is not significant, whereas real GDP is highly significant and negative in all cases. This indicates that the ECB is still considering economic growth in its reaction function. This finding is consistent with the result of the second regression and still questionable as it would imply that the ECB is more likely to decrease the MRO rate if real GDP increases.

In addition, the exchange rate stays insignificant as well for the last regression, while both the change in the MRO rate and the lagged value of the MRO rate are highly significant and positive in all scenarios.

4.3.4. Comparison of the three regressions

First, from 2006 to 2023 inflation seems to be a very crucial factor which the Governing Council considers in setting its MRO rate. In fact, the last model which does not include inflation does not have the best predictive power for none of the regressions. In the first regression, using headline inflation instead of core inflation leads to a better fit, whereas in the second regression it seems better to rely on core inflation. Hence it is difficult to determine which of both variables appears better to rely on.

Furthermore, the change in the MRO rate and the lagged value of the rate stay highly significant throughout the whole sample as well. The ECB smoothes the rate and is more likely to increase it if it did so in the prior month. Additionally monetary growth seems to play a crucial role as well in setting interest rates from 2006 to 2016. For the last period, however it seems that the ECB does not consider it anymore. Real GDP is an essential determinant as well.

It stays significant throughout the three regressions. Especially for the second regression, it seems that including real GDP leads to a better fit than including the growth rate of GDP.

Furthermore, another rather questionable finding is that expectations data is not significant in all cases, especially in the case of expected economic activity. Expected GDP is not significant in any of the regressions, which would mean that the Governing Council would not take into account expected GDP from 2006 to 2023 in setting its MRO rate. On the contrary expected inflation is highly significant for the whole period, from 2006 to 2023. The models with the best predictive power in the first two regressions even both include expected inflation. This implies that the Governing Council is more likely to increase the MRO rate if expected inflation increases in every period. Finally, a last more ambiguous finding is that the exchange rate is not significant in any of the regressions, which does not coincide with earlier literature.

All in all, these findings approximately support the two- pillar strategy of the ECB. Monetary growth and inflation represent the first pillar (Carstensen, 2006). Money growth is highly significant for the first two periods, while inflation holds significance for the entire sample. All other variables are associated with the second pillar (Carstensen, 2006), in which economic activity, the change in the MRO rate, and the lagged value of the rate are significant, while the exchange rate is not.

4.4. Challenges, Limitations, and future Research

First, the last regression was harder to address as the ECB did not change the MRO rate often during that period and it took the value 0 for most of the time. Therefore, I had to include a longer time span for the last period. In other words, I wanted to estimate three regressions namely from 2006 to 2010, from 2010 to 2016 and finally from 2016 to the beginning of 2023. However, the last regression could not be converged in Stata. Consequently I had to extend the analysis by two more years and the estimation now covers the period from 2014 to July 2023, instead of the initially intended range from 2016 to 2023.

Moreover, some other challenges consisted in finding the right data. This is why I rely on three different data bases and not only one, as the ECB website.

In addition, there exist some limitations concerning this thesis. Indeed, communication of central banks nowadays plays a very crucial role especially if the interest rate has reached the ZLB. Hence in the literature a lot of papers have included their own communication indicators in Taylor- type regressions and come to the conclusion that communication complements the information provided by basic macroeconomic models (Cour- Thimann & Jung, 2020; Heinemann & Ullrich, 2007; Rosa & Verga, 2007; Sturm & De Haan, 2010). This illustrates a weakness for this thesis as communication is not included and might even help to get a better understanding of the Governing Council's assessment of economic conditions. In fact, the ordered probit models only show which coefficients are statistically significant and by that which variables determine the interest rate setting but these estimations do not explain why it is the case. For instance, monetary growth is highly significant in the first two regressions but not in the last, so a rational question would be to ask why this is the case. Then it would be helpful to analyze in detail the communication and speeches of the ECB.

Furthermore, another limitation consists in the fact, that there might be various other economic variables which could be included in the reaction function and explain the behavior of the ECB. For instance, Cour- Thimann & Jung (2021) and European Central Bank (2020) include the federal funds rate as explanatory variable in their regression. Both papers conclude that the variable is significant. This means, in other words, that the ECB also takes into account the Fed's interest rate path, indicating that both seem to be interdependent.

Finally, to close this section there exist some interesting gaps for future research. The coding of ECB communication seems to be very crucial in order to assess the Governing Council's view of the economic environment and how the ECB views the threats to price stability. It appears to stay a significant challenge in literature to determine how to code press conferences, for instance, as there is often the risk that the wording indicators might be constructed in a too subjective manner (Heinemann & Ullrich, 2007; Rosa & Verga, 2005). Hence investigating forward guidance and communication strategies of central banks and how they influence market expectations might be interesting for future research.

Moreover, there are numerous papers that focus on the interest rate- setting- behavior of the ECB before the financial crisis and some during the financial crisis. Exploring more recent crises, such as the Corona Crisis or the impact of the Russia- Ukraine War on the Euro area, could also be of significant interest. For instance, to the best of my knowledge there exists one recent paper of Morelli & Seghezza (2021) which seeks to establish a link between the historical behavior of the ECB and its response to the Corona Crisis.

5. Conclusion

The aim of my thesis was to provide an analysis of the ECB's monetary policy, especially how it sets its MRO rate and if it changed during the last twenty years.

The key results of the study and the answer to the research question "What determines the interest rate- setting- behavior of the European Central Bank" can be summarized in the following way. First, I have shown that inflation, more precisely headline, core and expected inflation are key determinants which influence the ECB's decisions from 2006 to July 2023. The Governing Council is more likely to increase the MRO rate if inflation increases. Moreover, other variables which determine the rate setting of the ECB include the lagged value and the change in the MRO rate. Hence it is important for the Governing Council to consider if and how it changed the MRO rate in previous months. Furthermore, the empirical research presented in this paper suggests that real GDP and monetary growth are key determinants as well. However monetary growth is only considered from 2006 until 2016. Concerning expectations data, as empirical evidence suggests should be highly important to the Governing Council in setting its MRO rate. However, the analysis from this thesis suggests that only expected inflation enters the reaction function and not expected real GDP.

Finally, it can be said that the ECB acts according to its two- pillar framework. These results go hand in hand with findings from other studies as well.

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