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Interest rate setting behaviour of the European Central Bank

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Preface and acknowledgements

This thesis is addressed to anyone who wishes to have a greater in-depth understanding of what type of macroeconomic information is influencing the Governing Council of European Central Bank in setting the policy interest rate. This is especially useful for all who wish to make accurate forecasts of the future direction of interest rates in the euro area. Also helpful information is provided relating to the effects of the financial turmoil on ECB's interest rate reaction function.

Utmost patience and counselling of Dr. David J.C. Smant enabled me to accomplish this research. I am ever grateful to him for his comprehensive and excellent supervision.

Also I would like to thank a special person in my life that has been a great source of motivation and inspiration.

This thesis is dedicated to my parents for their love, endless support and encouragement.

Abstract

What type of macroeconomic information is influencing the Governing Council in setting the policy interest rate? Traditional Taylor rule variables are sufficient to explain their interest setting behaviour, or by making use of a large set of macroeconomic variables the changes in the policy interest rate are better captured? What differences occurred in the response coefficients of ECB's interest rate reaction function after the financial turmoil? This study tries to answer these questions by making use of a limited dependent framework, as to better take into account for the discrete amount by which the policy interest rate is changed. Furthermore, in order to have a realistic view on the data availability to the policy maker at the time is setting the interest rate, in the current study real-time data will be utilised, instead of realised ex-post values.

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1 Introduction

In order to explain the behaviour of a central bank, with reference to its monetary policy, usually it has been done by making use of a reaction function based type "rule" that systematically explains its actions in relation with the varying macroeconomic environment. Following the 90's, as the attention given to monetary policy increased substantially, lots of "rules" were proposed by many important economists. Among the various examples the McCallum-Nelson model could be included, as well as the Svensson and Taylor rule model. For instance, a model which was highly discussed in the last two decades is the one based on the influential paper of Taylor (1993). The main feature which attracted both academics and policy makers was that it captured quite well the interest rate setting process of Federal Reserve System (Fed) during the first Greenspan era (1987-1992). Since that period is considered to be a very successful one, in terms of its monetary policy, such a "rule" was seen as one that could be followed and further employed in explaining other central banks behaviour as well. Its applicability has been examined for both well developed economies, but also for the emerging markets economies. In both cases the effectiveness and capability of capturing the essentials of their central banks behaviour was recognized. The achievement of assessing their responses in relation to some key macroeconomic variables could be, firstly, that it might stand as an fundamental part to assess the central bank policy and the effects of other policy manners, and secondly, and more importantly for the financial markets practitioners, as it can offer a starting point to forecast the change in the main central bank policy instrument, namely the short-term interest rate.

Taylor (1993) suggested this instrumental rule as a linkage between the nominal interest rate and deviations of inflation from its targeted rate and of output from its long-run potential level. Given that numerous academics have questioned the rule, rather than taking it as it was proposed, there have been various modifications that altered its baseline specification. In some papers it has been done by changing the coefficients of key variables, while in others by incorporating them with either lags, contemporaneous or expected data. Nevertheless, one form seems to have gained supremacy, due to growing importance in the theoretical science of expectations, specifically the forward-looking Taylor type rule promoted by Clarida et al. (1996, 1998). Furthermore, in support of the forward-looking version, Svensson (2003b) demonstrates that the Taylor rule in its baseline specification could not be considered, within a macroeconomic model, as an optimal central bank response to the change in inflation and output. This was purely for the reason that the interest rate transmission mechanism is affecting the economy with a considerable lag. Therefore, according to

Svensson (2003b) the central bank should react to expected, instead of realised or contemporaneous values of the underlying variables. Moreover, McCallum (1999) highlighted one of the major pitfalls in the model. He argued that it is highly unrealistic for the policy maker to have at his disposal, at the exact time when he is setting the interest rate, current period realizations of GDP as implied in the model. One simple reason is given by the publication lags. Thus, using realised values of the underlying variables would be misleading. Actually, Orphanides (2001) employing real-time data, as a replacement for the well-known utilized ex-post figures, uncovered a very different path and description of the interest setting process which a Taylor-type rule could present.

In this context the present paper is on one hand filling this gap, which is scarcely and with contradictory findings, on the subject of employing real-time data, instead of utilising realised ex-post values. And of the other hand, by answering the questions *what type of macroeconomic information is influencing the Governing Council when it decides the monetary policy stance for the euro area*, and *are standard Taylor rule variables sufficient to explain their interest setting behaviour, or by making use of a large set of macroeconomic variables the policy interest rate changes are better captured*, is looking to add to the strand of literature on estimating the European Central Bank (ECB henceforth) interest rate reaction function. Moreover, as the period under consideration will be from January 1999 to October 2010, thus, including the credit crisis, a comparison will be made between estimates of reaction functions which employ data until January 2008, with estimates that covers the whole sample period. The purpose of such a comparison is to observe how, and if, the interest rate setting behaviour of the Governing Council was affected by the financial turmoil.

In the literature of monetary policy rules usually the research has been conducted considering the interest rate as a continuously adjusted variable. A prerequisite assumption, however, that is not what the monetary authority does in practice. Actually, a central bank leaves the short-term interest rate unchanged most of the times, and when a change occurs, this is done only by a discrete amount. Moreover, as it is accustomed in continuously interest rate studies, the OLS or GMM framework could not properly take into account for the discreteness in interest rate changes, as such the dynamic ordered probit model will be preferred. Furthermore, the out-of-sample estimations of the model will be compared, in order to determine which information set could better capture the interest setting process of ECB. The paper is organized as follows. In the next section I will elaborate on the role and structure of ECB, with an emphasis on its monetary policy. The third part will cover the theoretical foundations of the Taylor rule, taking into account the extensions and limitations associated with its implementation. After that, the framework of the ordered probit model will be

outlined, along with the empirical findings and applications regarding the ECB. In the fourth and fifth sections the choice of data will be motivated, and subsequently, the results of in-sample and out-of-sample estimates will be discussed. Finally, in the sixth section I will provide the concluding remarks.

2 European Central Bank

This chapter includes a brief introduction on the role and structure of ECB, as well as a description of its monetary policy instruments and strategy. Considerable importance will be given to the different macroeconomic variables that seem to come into play when the Governing Council determines the monetary policy stance for the euro area.

2.1 The role and structure

Following the "Delors Report"[1] in 1989, when at the request of the European Council a clear blueprint was drafted, an agreement in the direction of Economic and Monetary Union (EMU) had been reached. The road to the EMU was planned in three "discrete but evolutionary steps" with the final aim of creating a single European currency. During the initial phase, when the European Union (EU) was established upon the "Maastricht Treaty" in 1992, the focus was on removing all obstacles standing in the way to financial integration, and to reduce discrepancies between the economic policies for its member states. The next period was identified as the "Second Stage", which served as a period of transition for the preparation of the single currency, its central bank and monetary policy (Issing et al., 2001). The whole process was undertaken by the European Monetary Institute (EMI), created at the beginning of 1994, and the participating National Central Banks (NCBs) of its member states. Furthermore two new European bodies were created, namely The European Central Bank (ECB), evolving from EMI, and The European System of Central Banks (ESCB), both established in May 1998 and started their operations from January 1999. Outlining the time when monetary sovereignty for the participating countries was transferred to the ECB, and the creation of a single European currency became from dream, a reality. Starting with 1 January 1999, having fulfilled the conditions required for participation in the third stage of EMU, eleven Member States from fifteen made history, by adopting and sharing concomitantly the newly created European currency – namely the euro. These countries were Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain. Today there are 17 of the 27 EU Member States who now belong to the Eurosystem[2]. In chronological order of acceptance, following the above mentioned ones, these are Greece (2001), Slovenia (2007), Cyprus and Malta (2008), Slovakia (2009) and last but not least Estonia (2011).

When the Euro was launched in 1999, there were numerous sceptics especially concerned with the fact that the ECB, a central bank without precedent and any sort of relevant experience, could run

[1] Named after the chairman of "Committee for the Study of Economic and Monetary Union" Jacques Delors
[2] The Eurosystem comprises, in addition to ECB, the NCBs of the Member States that have adopted the euro

the euro zone monetary policy. Nevertheless, given that it has been more than ten years after its founding, it seems that it was not a matter of surviving. In fact, looking back at how well it adapted due to the growing euro area membership, ECB can have a huge sentiment of satisfaction. Responsible to formulate the monetary policy and to take decisions that are necessary for the Eurosystem is the Governing Council of ECB, consisting of the Executive Board and the governors of the euro area NCBs. The other two of the three decision making bodies that lie at its core are the Executive Board and the General Council. The former includes the President, Vice-President and four other members, and is responsible to implement the decisions taken by the Governing Council. While the latter, which has in its composition the governors of all EU Member States NCBs, in addition to the President and Vice-President, is described as a transitional body with the most important role to offer support and coordination among EU members who had not yet adopted the euro and intend to do so (ECB, 2004).

Following the "Maastricht Treaty" ECB acquired a unique level of independence, translated into a supra-national institution, and a fundamental mission towards price stability within the euro zone, defined as the primary objective. As a clarification, at the outset in 1998, the Governing Council illustrated the main elements of ESCB's "stability-oriented monetary policy", identified as the "two pillars", and provided a quantitative definition for price stability "as a year-on-year increase in the Harmonized Index of Consumer Prices (HICP) for the euro area of below 2%", having to be maintained "over the medium term". For the "first pillar", known as the monetary analysis, "a prominent role for money with a reference value for the growth of a monetary aggregate" was assigned, while the "second pillar" consisted of "a broadly-based assessment of the look for future price developments", acknowledged as the economic analysis[3]. Before explaining in more detail the "stability-oriented monetary policy" of ECB, a short description of the instruments used in order to achieve price stability within the euro area will be presented.

2.2 The instruments of monetary policy

Understanding how the monetary policy affects the economy in general and the price level in particular, is of crucial importance for the Governing Council. Deciding on the official interest rates of ECB operations, at which liquidity for the banking system is provided, exerts an influential effect on the money market conditions, thus, on the money market interest rates. In order to influence the money market interest rates in the economy, on one hand, ECB is making use of its monopoly as sole

[3] Made public during the press release "A stability-Oriented Monetary policy for the ESCB", on October 13 1998, available at http://www.ecb.int/press/pr/date/1998/pr981013_1.en.html

supplier of “base money”, hence managing the liquidity of the banking system. And on the other hand, as it is able to change the conditions of its transactions with the credit institutions, it signals the monetary policy stance. In this respect, the instruments used in its monetary policy, are the open market operations, the standing facilities and the minimum reserve system. Moreover, through various channels of communication, it is able to influence the private sector long-term expectations of inflation.

The open market operations could be divided furthermore in four categories. The most important ones are the main refinancing operations (MROs), followed by the longer-term refinancing operations, fine-tuning operations and finally the structural operations. The MROs are representing the central process by which the monetary policy stance is given, and the banking system is supplied with ECB’s money. These operations are executed through tenders, currently at a fixed rate and held on a weekly manner, where all eligible credit institutions from the euro area are allowed to participate. The MROs initially were conducted at a fixed rate until June 2000, when ECB changed them to be carried out at a variable rate tender. The decision was motivated on the fact that, at a given interest rate, the bids of the credit institutions exceeded the amount of liquidity allotted by the Governing Council. This was taking “extreme dimensions” as pointed by Issing (2008), therefore switching to variable rate tenders, allowed the minimum interest rate at which the bids are accepted to be a given. The decision lasted until October 2008, when it was changed back to fixed rate tenders, in order to help the banking system, given the severe conditions in financial markets during the credit crisis. Under a fixed rate tender the Governing Council decides on the single interest rate at which the bids are accepted, while at a variable rate tender only the minimum interest rate is decided, and the highest interest rate bidders are first allotted (ECB, 2008). The procedure starts with the credit institutions placing bids via their national central banks (NCBs) to ECB, following with the overall allotment decision of the Executive Board. Afterwards, their decision is communicated back to the NCBs, where it all ends with the money transaction settlements, whether under the form of a loan against collateral or under an asset repurchase agreement (Issing, 2008).

Furthermore, given that these funds normally have a maturity of one week, in order to help the liquidity needs of the banking system for a longer time, the use of the longer-term refinancing operations facilitates that, having a maturity of three months. These operations are as well executed through fixed rate tenders, but compared to the MROs, organised on a monthly basis. Moreover, these operations are not used with the intention of signalling its monetary policy stance, thus it rather acts as a rate taker (ECB, 2011). Fine-tuning operations, on the other hand, are used

deliberately to steer the market interest rates, with a pronounced application on smoothing them due to unanticipated liquidity imbalances. Executed on ad hoc basis and usually through quick tenders at the NCBs, primarily takes the form of reverse transactions. Although, given the special circumstances under which these operations are held, might be adapted to the respective needs. Ultimately, ECB may use structural operations in order to adjust its position, with reference to the financial sector, by issuing debt certificates or by making use of reverse transactions and outright transaction.

Moreover, it has at disposal two standing facilities intended to smooth the overnight market interest rates, firstly, by providing overnight liquidity with the marginal lending facility, and secondly, by absorbing any overnight surpluses with the deposit facility. These facilities are available to all eligible credit institutions at their own initiative and without any limits, apart to the requirement of having sufficient assets against the funds in case of borrowing. In addition, by setting the interest rates on both facilities, the Governing Council is creating a "corridor" for the overnight market interest rate, with the upper limit given by the marginal lending facility, while the lower limit given by the deposit facility. In order to measure the conditions on the overnight money market, the Euro Over Night Index Average (EONIA) is representative. It is calculated as a weighted average of the interest rates on overnight lending transactions, reported in EONIA Panel. The figure below presents a graphical illustration of the two standing facilities, together with the MROs and EONIA.

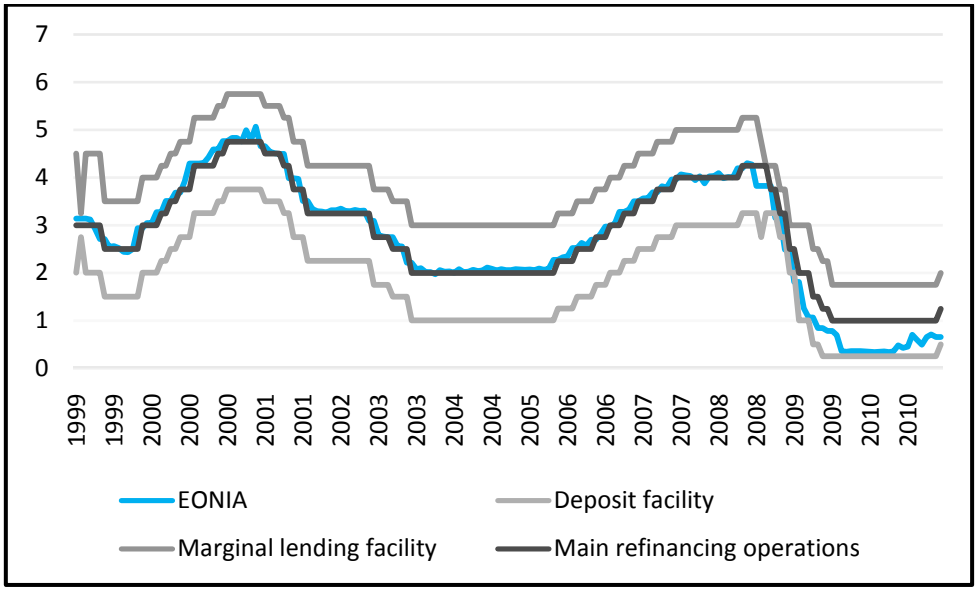

Figure 1 – ECB interest rates and money market interest rate, Source: ECB

The last instrument used in the monetary policy of ECB is the minimum reserve system. It was established on the Bundesbank experience, given that it proved to be a valuable mechanism in its successful monetary policy (Issing, 2008). As pointed above, the credit institutions must be eligible in order to enter in transactions with ECB, which requires them to be integrated within the minimum reserve system, besides the fact that certain requirements, in terms of operationality, must be passed. To be integrated in the system, deposits must be held at their NCB's, representing a reserve requirement determined by some elements on their balance sheet. Moreover, in order to not be perceived as a "tax", ECB is paying short-term interest rates on the underlying deposits. The aim of the reserve system is two folded. On one hand, is producing within the banking system an adequate structural liquidity demand, and on the other hand, is stabilising the money market interest rates.

In the view of the fact that in the short-run inflation could be distorted by exogenous shocks, such as a rise in the oil prices or a change in the global economy, the Governing Council must influence the private sector in terms of long-term expectations of inflation. Hence, it must anchor inflation expectations at a level consistent with price stability in the long run. In this respect, the most important part is played by the ECB transparency, given that is building its required credibility. The transparency, in forms of external communication channels, is given either through the speeches, interviews and public hearings of the president and other members of the Executive Board of the ECB, or it is taking the printed form in various published papers. The most important one is the Monthly Bulletin, where a detailed euro area economic description is given, in addition to the website of ECB, where a considerable statistical database is available. Moreover, as ECB is not making public the discussions of the Governing Council meetings, compared for instance to Fed which publishes the FOMC minutes, it prefers to hold a press conference after each meeting in order to inform and motivate their decisions.

2.3 The monetary policy strategy

From the very beginning in the definition of price stability the significance of HICP is recognized, as it is providing, on one hand for the ECB, a comprehensive measure of inflation, and on the other hand for the public, a variable that could be used in assessing whether price stability has been achieved and maintained throughout its policies. The motivation behind the choice of the HICP to serve as a price index for the euro area as a whole, a lot was attributed to the fact that the Governing Council will take policy decisions that will have an impact on the entire euro area. Consequently, differences at a national or regional level in inflation will not have an influence on their decisions (Monthly Bulletin, Jan. 1999). Furthermore, although among practitioners the creation of such an index was very welcome, due to its availability on a monthly basis and large harmonization across the euro

area, there were inevitably also lots of questions raised. Most of them related to its variation and high short-term volatility of some of its components, as it contains energy and commodity prices (Gali, 2002). Nevertheless, more intriguingly in the "stability-oriented monetary policy" definition of price stability was the lack of a lower bound specification for inflation, which could offer a band within investors could anchor their inflation expectations. This was further clarified a month later by Willem F. Duisenberg, first President of the ECB, specifying that deflation, interpreted as a decrease in HICP, "would not be considered consistent with price stability". Moreover, specifying that price stability was considered "over the medium term", the Governing Council makes it clear that it is not accountable for the temporary and inevitable deviations that could be possible in the short run. Clearly from the graph provided, small differences can only be noticed in the first year and during the credit crises, which indicates that overall price stability has been indeed achieved.

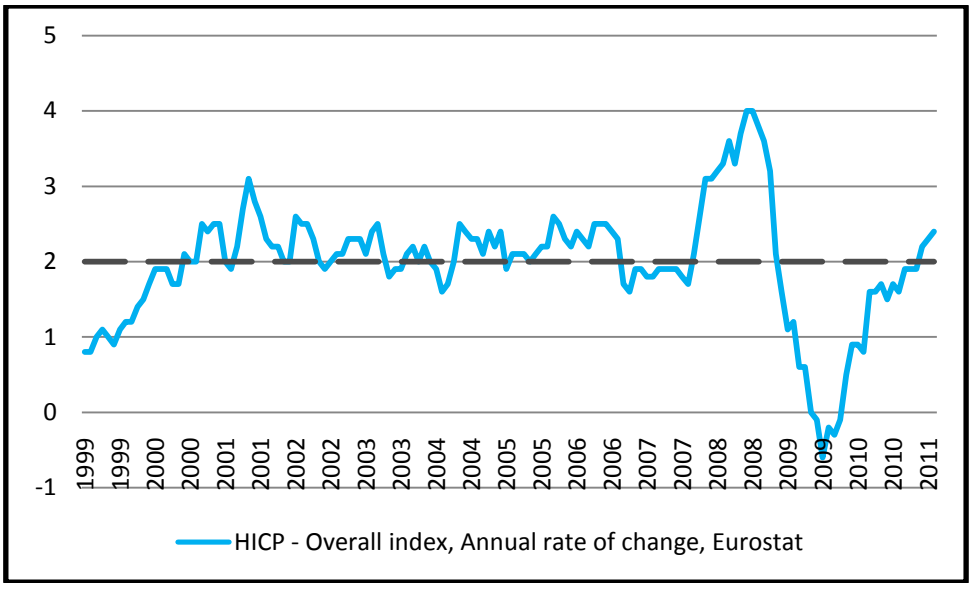

Figure 2 –Inflation in the euro area measured by HICP, Source: Eurostat

With regards to the role of money, known as the "first pillar", probably it was one of the most criticised aspects in ECB's strategy. One reason for this fact, confirmed empirically though, was the weak link between inflation and money growth in the short run. Furthermore, Gali (2002) argued that, reacting to the reference value, the economy could be supplied with "unnecessary fluctuations in output and inflation". On the other hand, the long-term implications between money growth and inflation, the relationship stands as a fundamental block in economics. A possible theoretical explanation is that an increase in the monetary aggregates, in excess of what the economy could support, is translated ultimately in inflation. As a consequence, ECB could assign to money the role of a "natural indicator for future inflationary pressures", as noted by Otmar Issing, in defending and

motivating the choice of money in ECB's strategy.[4] Moreover having inherited this characteristic from the Deutsche Bundesbank, which was known for its monetary targeting framework, it proved to be very difficult for ECB to explain the particular position given to money, as it was not included with other sources of risks to price stability in its strategy. Nevertheless, actually this characteristic allowed ECB's monetary policy to become a very unique one, as it was relying on two different aspects, when comparing it to other central banks monetary policies. Yet, this also came at a price, given that it posed so many problems in explaining it to the wider public. And this is regardless of the fact that impressive efforts were made to clarify some special factors, such as the shifts in international portfolios, which could obscure "the informational content of the monetary indicator" (Berge et. al, 2008). Furthermore, divergences in monetary growth from its reference value were seen as not influencing the Governing Council decisions in setting the policy interest rate, interpreted for instance by Gerlach (2004a), as "not signalling risks to price stability". As can be seen graphically below, money growth was above the reference value of 4.5%, with just few exceptions covering last two years, for most of the time.[5]

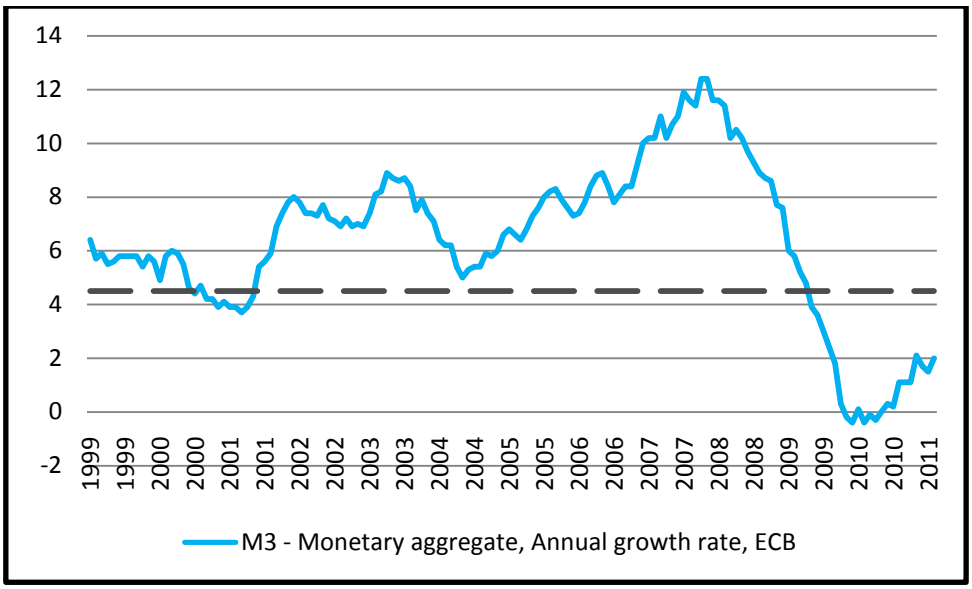

Figure 3 – Monetary aggregates developments in the euro area, Source: ECB

In comparison, the second pillar was perceived and accepted as a normal component of any monetary policy strategy that attempts to achieve and maintain price stability. In analysing the

[4] Speech by Otmar Issing, Member of the Executive Board of ECB, at the Conference "The ECB and Its Watchers VII", available at http://www.ecb.int/press/key/date/2005/html/sp050603.en.html
[5] The quantitative reference value available at http://ecb.europa.eu/press/pr/date/1998/html/pr981201_3.en.html

developments of prices and the threats, in the euro area as a whole, which have a negative effect on its mandate of price stability, a large number of economical and financial indicators are continuously reviewed. Among these an important part, after identifying the nature and magnitude of disturbances affecting the economy, is assigned to the development in overall output, demand and market conditions, and to a broad range of price and cost indicators (ECB, 2004). These are of primary concern, given that a comprehensive representation of the movements in aggregate demand and supply could be assessed, in addition to the degree of capacity utilisation. In order to quantify them, the Governing Council is closely monitoring for the cyclical position of the economy the deflator and real euro area GDP as well as its components, along with confidence indicators, such as the economic sentiment indicator (ESIN) and various consumer and business sector indicators. While for the market conditions, an important role plays labour market data, given by employment and unemployment rates (De Haan et al., 2005). In determining the prices and costs developments, along with HICP and its components, measures of producer prices and labour costs, which have a significant impact on price formation, together with commodity prices, such as oil, are also taken into account. In addition, making use of financial market indicators and asset prices, in order to extract the implicit market expectations about future price developments, is identifying the current and expected shocks affecting the economy. Another implication for price stability arise by the movements in exchange rates, since the competitiveness of domestic goods on international markets could be deteriorated, which in turn could influence demand and possible their prices, thus, both real and nominal effective exchange rates are vigilantly inspected. The last aspect considered in the economic analysis is the utilization of staff macroeconomic projections, along with other institutions forecasts, such as the Consensus Economics.

As mentioned before, the “stability-oriented monetary policy” of ECB, as it was laid down by the Governing Council, has been actively criticized by numerous observers, which especially focused on the aspect of money. Moreover, the coexistence of two pillars, offered potentially contradictory signals, since for the ECB it may be difficult to transmit to the markets clear communications and the transparency of its policy decisions, which are essential for a central bank to become credible. For instance, Svensson (2001) is describing it as “a combination of a weak type of monetary targeting and an implicit form of inflation targeting”, although both strategies from the very beginning were contradicted by Issing (1999).

In order to give a response to the above mentioned problems and critics, ECB actually modified its strategy, even though not significantly as pointed out by many watchers[6], after a thorough evaluation during an internal revision in 2003.[7] Firstly, in the definition of price stability it added that inflation rates will be maintained "below, but close to, 2%" and highlighted that this component comes "to provide a safety margin to guard against the risks of deflation". Moreover, the Governing Council also slightly changed the framework of the two pillars, emphasizing on the relationship between them. More specifically, for the economic analysis it assigned a short to medium-term outlook to identify the risks to price stability and, as before, included an analysis of shocks affecting the Eurosystem and the prognosis of key macroeconomic variables. Subsequently, for the monetary analysis, the measurement of the trends in inflation, considering the long run relationship between money and prices, will have a medium to long-term perspective. In addition, the Governing Council also highlighted that the monetary analysis will serve "as a means of cross-checking" the information that is available from the economic analysis, and also stated that a review of the reference value for monetary growth will no longer be conducted on an annual basis, emphasizing its longer-term nature (Monthly Bulletin, Jun. 2003).

[6] See for more information Svensson (2003a)

[7] The internal revision available at http://www.ecb.europa.eu/press/pr/date/2003/html/pr030508_2.en.html

3 Monetary policy rules

In this chapter I will briefly elaborate on monetary policy rules, pointing out the fundamental characteristics of targeting rules, and subsequently, instrument rules. Furthermore, the theoretical foundations of the Taylor rule will be outlined, revealing the modifications that have been made over time and altered its baseline design. Extensive attention will also be given to the construction of the variables which are used within the model, taking pros and cons into account. Moreover, the framework of the ordered probit model will be described, along with the empirical findings and applications regarding the ECB reaction function.

3.1 The notion of monetary policy rule

A monetary authority in order to achieve its objectives, such as economic stability or a constant aggregate price level, given that it has limited knowledge on the model of economy, could opt to act in a discretionary fashion. Such an approach could be characterised in the sense that it is accommodating its actions and way of thinking, period by period, to present conditions. On the other hand, it might also have the option to follow a specific "rule", which would eliminate any judgemental elements from its actions. These two alternatives were debated for a long time, by both academics and central bankers, in order to establish which one is more suitable to be used as a stabilization policy.[8] However, a growing consensus has emerged towards a required transparency which a central bank must have, and can be attained by following a rule. One explanation could be that this is strongly linked to its credibility, which in turn allows its decisions to be more efficiently transmitted to the markets. And as a result, in the course of this process, it makes possible to reduce inflation at a lower cost in terms of output, and ultimately to achieve the essential goal of price stability. Therefore, by committing to a rule, not only the central bank objectives are better understood by the public, but also the financial market practitioners might win, as the "rule" could provide a mechanism to forecasts the future course of its monetary policy.

A monetary policy rule could be defined "as a description – expressed algebraically, numerically, graphically – of how the instruments of policy, such as the monetary base or the federal funds rate, change in response to economic variables" (Taylor, 1999). In other words, such a rule could illustrate how the policy instruments of a central bank are adjusted in response to the varying macroeconomic environment. Equivalently, a monetary policy rule is common to be referred as an interest rate rule, for the reason that in empirical studies the most preferred policy instrument over time turned out to

[8] For more information related to the debate on monetary policy rules versus discretion see McCallum(1999)

be the short-term interest rate. However, not all monetary policy rules are subject to this referral, for the reason that as policy instrument the money supply could be used as well. Hence, in the former type of monetary policy rules, the instrument of policy making is the short-term interest rate, while in the latter the central bank may choose to expand at a constant rate the money supply in the economy. For instance, a simple example of such a rule, where the money supply is expanding, in parallel to the rate of growth of real GDP, is the one proposed by Milton Friedman (1960). In the literature of monetary policy rules two types of rules could be distinguished, namely targeting rules and instrument rules.

The notion of "targeting rules" is to a great extent accredited to Svensson (1997), in the view of the fact that through a large number of papers he promoted them as a method which could better capture the essentials of monetary policy making in countries where inflation targeting has been adopted. Under a targeting rule, the monetary policy is described in terms of the particular objectives and constraints which are faced by the central banker. The assignment of such a rule stands on the basis of a vector of target variables, along with a vector of target levels, corresponding to the specific loss function that has to be minimized. Algebraically it could be expressed as an equation, or a system of equations, that the targets variables must fulfil (Svensson, 1998). Furthermore, such rules could be divided in "general targeting rules" and "specific targeting rules". The former ones specify the objectives to be achieved in an operational way (i.e. as numerical targets, instead of a broad concept such as price stability), which designate the monetary authority to commit in minimizing the respective loss function. While in specific targeting rules, the target variables that must be fulfilled are specified as a condition, thus, the central bank is committed "to set the instrument rate so as to achieve a specific target criterion for the target variables" (Svensson, 2002). For instance, a monetary authority that adheres to inflation targeting, more precisely inflation-forecasts targeting – such as the Bank of England, could be approximated by a specific targeting rule (Goodhart, 2001).

An instrument rule could be described in a broad sense as a formula which prescribes for the monetary authority the favoured policy instrument as a function of observable variables. Depending on the character of the utilised variables, instrument rules could be differentiated in two classes. If the policy instrument is a function of predetermined variables only (i.e. current macroeconomic data), the rule is referred to as explicit instrument rule. While in implicit instrument rules, the policy instrument is prescribed as a function of forward-looking variables (i.e. forecasts of macroeconomic data). The well-known Taylor rule is an example of both such rules, given that it could be either an

explicit instrument rule, when the variables used are predetermined, or an implicit instrument rule, when forward-looking data is utilised. Another popular example of an explicit instrument rule is the rule proposed by McCallum (1988), where the growth of monetary base is utilised as monetary policy instrument, in comparison to the exploitation of short-term interest rate in Taylor rule.

3.2 Original Taylor Rule

Taylor (1993) assumed that Fed is changing the funds rate in response to the current inflation and economic activity. More precisely, the baseline of the rule suggests a benchmark recommendation for the policy interest rate that depends on four variables. The first and the second terms correspond to the "natural" or equilibrium real interest rate, assumed to be constant, and to the current inflation rate. The third is the inflation gap, which is measuring the deviations of current inflation rate from a given target rate. While the fourth represents the output gap, expressed as percentage deviations of real GDP from an approximation of its long run potential level. The rationale behind the proposed rule lays on the assumption that in equilibrium or in a steady state of the economy both deviations of inflation and output from their targets should be zero, otherwise, the rule is generating responses which signal the need to change the policy interest rate in order to bring inflation and output at their targeted values. Taylor originally proposed the rule in the following form:

$$i_t = r^* + \pi_t + \beta_\pi(\pi_t - \pi^*) + \beta_y(y_t - y^*) \quad (1)$$

where (i_t) denotes the policy interest rate, (r^*) the equilibrium real interest rate, ($\pi_t - \pi^*$) the inflation gap, comprising (π_t) the inflation rate and (π^*) the targeted rate of inflation, and ($y_t - y^*$) represent the output gap, with (y_t) GDP and (y_t^*) its long run potential level. Furthermore, the parameters (β_π) and (β_y) are measuring the intensity of Fed's response to deviations of inflation from its target and, respectively, output from potential level.

Taylor (1993) suggested the value of 2% for both the equilibrium real interest rate and the targeted rate of inflation, and as he did not estimated the coefficients of inflation (β_π) and output gap (β_y), assumptions instead were made and fixed at 0.5. In spite of the fact that the proposed values for the coefficients obtained a very good description of Fed interest rate setting process for the considered period, several authors have tried to estimate, rather than taking them as given. Since those weights are method and sample dependent, it would certainly make sense, as well as the particularities of a

central bank monetary policy to be taken into account (Gerdesmeier and Roffia, 2003). Typically, when estimating the parameters, an equivalent form of eq. (1) is employed as follows:

$$i_t = \alpha + \beta\pi_t + \gamma\tilde{y} \quad (2)$$

where $\alpha = r^* - \beta_\pi \pi^*$, $\beta = 1 + \beta_\pi$, $\gamma = \beta_y$ and ($\tilde{y}$) is the output gap. An important empirical question is related to the weights of the two coefficients. More specifically, several authors have questioned the appropriate value that should be assigned to the coefficients of the two gaps, as the response of a central bank to be considered optimal. For instance, with regards to inflation gap coefficient, Taylor (1998) illustrates that only when a value of "well above one" is assigned, a stabilizing effect on inflation could be exerted. This would imply that when inflation rises above its target, as a response, the central bank should raise the policy interest rate by more than the amount inflation exceeds its target. This important characteristic was also stressed in Woodford (2001), where it was categorized to what is now known as the Taylor principle. The rationale following this principle requires the policy interest rate to be increased enough to raise the real interest rate, since only then demand is contracted and inflationary pressures are diminished, and ultimately inflation is brought to its target. Otherwise, the response would not be appropriate and the features of an interest rate rule that assigns a value of less or equal to one to the coefficient, "are likely to be destabilizing or, at best, accommodative of shocks to the economy" (Clarida et al., 1998). In other words, the central bank still raises the policy interest rate, yet this is not sufficiently to have an influence on the real interest rate, consequently a counterweight effect on inflation.

Furthermore, referring to the output gap, the underlying rule works analogous as in the case of an increase in inflation. Thus in circumstances where the economy is overheating and actual output is pushed above its long-run potential or full-employment level, to counteract this fact, an increase in the policy interest rate would be required, causing output to shift back towards the desired path. Additionally, motivating its inclusion in the rule can be two-folded. On one hand, besides the fact that a central bank key objective, along with low inflation, is also to minimise employment fluctuations or the gap itself, including it, given that it has theoretically the most comprehensive concept which is covering the cyclical position in the economy, this could be achieved. And on the other hand, it can be used as an indicator of future inflation, as stipulated in the Philips curve theory[9], thus it is entering the equation having the proprieties of a variable that is used as a proxy

[9] The Philips curve theory specifies that movements in inflation are strongly influenced by the economic conditions, relative to its production capacity, which is measured by the long-run potential level of GDP consistent with full-employment, besides other factors. Mishkin (2007)

for expected inflation, causing the central bank to consider and accordingly respond to it. Moreover, with respect to its coefficient, in order to have a stabilizing attribute, the optimal response is not as restrictive and aggressive as in the situation of the inflation gap coefficient, and the only condition that has to be satisfied is to be positive. However, an extremely high value may transmit a disproportion in inflation and output variability trade-off, having an increasing effect on the former (Garcia-Iglesias, 2007), as such the value of this coefficient is expected to be small. For a comprehensive discussion on this matter, where the costs and benefits associated with the weights, and how both variables are influencing each other, see McCallum and Nelson (1999).

3.3 Extensions for Taylor-type Rules

Ullrich (2003) is describing this type of reaction function as "more or less a rule of thumb", given that "no consensus for the appropriate specification of the function" is available. As a result, over time lots of extensions and specifications were proposed, in order to find the "alpha" rule.

3.3.1 Contemporaneous, backward and forward-looking rules

The Taylor rule, as it was originally proposed, was described as a "contemporaneous" interest rate rule for the reason that the macroeconomic variables utilized within the model were all referring to the same time (i.e. the recommended interest rate is at time t, as well as the explanatory variables). Given that these variables were based on current, or so-called "ex-post" data, and such information was unavailable since it might take months until the final releases were available (McCallum, 1999), the "backward-looking" interest rate rule was proposed. This form allowed for the possibility of publication lags, and where lagged instead of current data is used. However, with regards to the timing of the variables, it has been argued that a more appropriate approach would have been to have a forward-looking perspective, since monetary policy transmission affects with a sizeable lag the economy. In support of this Rudebush and Svensson (1999), underlined the required anticipation, in terms of the outlook in prices, more precisely "forecasts of inflation", which should guide a policymaker in setting the policy interest rate.[10] To compensate for this feature, Clarida et al. (1996, 1998) introduced the "forward-looking" interest rate rule, which made possible to include within the model expected data, instead of lagged or current variables. Formalized, such a forward-looking type reaction function, with ($\mathrm{E}[-]$) symbolizing the expectation operator and (I_t)

[10] Also Svensson (2003) demonstrates, within a macroeconomic model, since the interest rate transmission mechanism is affecting with a considerable lag the economy, the central bank should react to expected, instead of, realised or contemporaneous values of inflation and output, in order to consider that the rule would give an optimal response to change in inflation and output.

standing for the set of information available to the policy maker when the interest rate is set, could take the following form:

$$i_t = \alpha + \beta_\pi \mathrm{E}[\pi_{t+k} | I_t] + \beta_y \tilde{y}_{t+q} \quad (3)$$

where π_{t+k} is the k periods ahead rate of inflation, $\tilde{y}_{t+q}$ is the q periods ahead output gap, and all other variables are denoted as before. Clarida et al. (1998) specifically underlined that such interest rate reaction function could be seen as a "generalisation of the type of the simple interest rule proposed by Taylor (1993)", since when the time subscripts k and q are set to zero, and instead of expectations the current information is used, it is simplifying to the original form. In the same spirit, also the backward-looking form could be achieved, by assigning reflecting the preferred lags, negative values for the time subscripts k and q, and replacing with actual the expectations data.

Gerdesmeier and Roffia (2004) found that a forward looking rule provides a better description of the actual behaviour of the European Central Bank than a contemporaneous rule, as well as Orphanides (2001) concluded in studying the Fed. However, Taylor (1998) argues that the forward-looking rules are no more different than the ones in which current or lagged data is used, given that those forward looking rules are employing "forecasts of the future" which are based on "current and/or lagged data", hence are reacting actually to the same data.

3.3.2. Augmented rules

The omission of variables is a possible cause of misspecification when a Taylor rule type interest rate reaction function is estimated, since as explanatory variables, only inflation and output are included within the model. It is well known that a central bank in setting the interest rate is considering, and has at its disposal, lots of other indicators which could affect the policy maker decision. If relevant variables are omitted, when the equation is estimated, bias and inconsistency in the coefficients would become a problem. To allow for the possibility of other variables to explain the movements in the interest rate, employing a forward-looking behaviour, the following extension could be used:

$$i_t = \alpha + \beta_\pi \mathrm{E}[\pi_{t+k} | I_t] + \beta_y \tilde{y}_{t+q} + \delta_\theta \theta_{t+n}$$

where θ_{t+n} denotes n periods ahead any other variable than inflation and output gap, while δ_θ stands for the coefficient attributed to the considered figure. Possible candidates in estimating an augmented version of a Taylor rule are the exchange rate, growth of exchange rate, foreign interest

rate and output gap, monetary aggregates, financial market variables (asset prices, measures of risk), balance of payments, unemployment rate, etc. For instance, Gerdesmeier and Roffia (2003) in studying the euro area have considered as additional variables the euro effective exchange rate, euro exchange rate vis-à-vis the US Dollar, world commodity prices, US Federal Funds rate, DJ Euro Stoxx 50 and money growth. While Gerlach-Kristen (2004) in examining the Fed, connecting an unobserved variable with the major financial events, suggested that the risk premium on corporate bonds could capture the financial stress and the implicit policy responses to those variations.

3.3.3. Interest rate smoothing

Another popular extension applied to the Taylor rule, since the predicted path of the interest rates is to a certain degree unrealistic compared to the central bank adjustments, is the inclusion of lagged interest rate within the model. To capture the "smoothing" behaviour of a central bank, the policy interest rate from eq. (1) is transformed into a target interest rate as follows:

$$i_t^* = r^* + \pi_t + \beta_\pi(\pi_t - \pi^*) + \beta_y(y_t - y^*)$$

while to gradually arrive at the policy interest rate is employed:

$$i_t = p i_{t-1} + (1-p) i_t^*$$

where (p) $\in [0,1]$ is reflecting the degree by which the interest rate is smoothed. As an interpretation, when (p) equals 0, there would be an instant adjustment, and the targeted interest rate would be changed immediately. As the value is increased, the slower the adjustment would be, allowing the central bank to gradually modify its policy interest rate towards the desired one. For instance, employing such a "partial adjustment", when estimating a forward-looking interest rate reaction function for the Deutsche Bundesbank, Clarida et al. (1998), Faust et al. (2001) and Smant (2002), found the smoothing parameter to be 0.91. This would imply a very slow adjustment, up to less than 10% of the desired change in its interest rate setting behaviour. In support of this extension several arguments were mentioned in the literature, such as fear of disrupting capital markets and loss of credibility due to sudden and large policy reversals (Goodfriend, 1991), the need for consensus building to support a policy change (Clarida et al., 1998), model uncertainty (Clarida et al., 1999) and data uncertainty (Orphanides, 1998) which is forcing the policy maker to slowly adjust the interest rate to the desired target (Sack and Wieland, 1999). On the other hand, Rudebusch (2002) argues that such large values of the parameter, which often appear in the literature, actually are

reflecting the serially correlated errors caused by the omitted shocks, such as financial turmoils, rather than the smoothing behaviour. Under this circumstance, Rudebusch (2002) has proposed the following equation including a first-order serially correlated error instead of a parameter which accounts for the "partial adjustment":

$$i_t = i_t^* + \vartheta_t$$

$$\vartheta_t = \omega\vartheta_t + \mu_t$$

with ϑ_t denoting the serially correlated error term, ω the serial correlation parameter, and the other variables are defined as before. Furthermore, Rudebusch (2006) underlines that this criticism only applies when quarterly rather than monthly frequencies empirical policy rules are estimated. As a reason for this, he argues that the gradually adjustments on a monthly basis of a central bank, until the targeted interest rate is reached, are "essentially independent" of assuming for several quarters that still policy inertia is the cause. Furthermore, English et al. (2003) proposed a "nested model" to account for both partial adjustments and serially correlated errors as follows:[11]

$$i_t^* = r^* + \pi_t + \beta_\pi(\pi_t - \pi^*) + \beta_y(y_t - y^*)$$

$$i_t = pi_{t-1} + (1-p)i_t^* + \vartheta_t$$

$$\vartheta_t = \omega\vartheta_t + \mu_t$$

For instance, Gerlach (2007) making use of a probit model to account for the discreetness in the policy interest rate changes, found little evidence with respect to interest rate smoothing. As a matter of fact, the likelihood of a change in the interest rate this month, given that a change last month has been made, he found that is to a certain degree diminished, and concludes that the changes are made "to reduce the need for further" ones and to "clear the air".

3.4 Difficulties associated with Taylor-type Rules

Throughout time several issues have been observed and linked with the exploitation of the Taylor type rules. Although some of them are very important, such as the usage of real time data instead of

[11] For more information related to the interest rate smoothing parameter see Judd and Rudebusch (1998), Castelnuovo (2004); Castelnuovo (2007).

relying on ex-post realised values, much of the empirical estimates are ignoring, or tend to forget some aspects, making them of questionable value. I will briefly elaborate on them.

3.4.1. Data critique

In terms of Taylor rule operationality, McCallum (1999) provides one of the most important points of criticism. He argues that the assumption of price or GDP level availability, either nominal or real, in terms of true current-period realizations to the policy maker, in order to base the interest rate decision on them, is highly unrealistic. This may be, on one hand, due to the differences between the release dates in the macroeconomic information, and on the other hand, given that some data is considerably and frequently revised over time, the final releases could be very different from the first published ones. With respect to the last argument, this applies especially in the case of the output gap, since in defining both real and potential output conceptual changes may occur. For those reasons, employing such real-time instead of ex-post data, a substantial discrepancy in the results could be possible. Actually, pioneer in this line of studies, Orphanides (2001) investigating the FED and using the same period as in Taylor (1993), using real-time data and comparing with the initially used ex-post data, finds a significant different path for the recommended policy interest rate. Similar findings have been also reported in the context of ECB, when employing a forward-looking Taylor type rule, in Gerdesmeier and Roffia (2004).

Orphanides (2001) also specifies a number of reasons why the informational problems are significantly influencing the implementation of a Taylor-type rule. A point emphasized also by McCallum (1999) is that the policy maker must use current information when it is setting the same period interest rate, and since it is unavailable makes the rule un-operational. Moreover, it could be possible to set the policy interest rate in accordance with the Taylor rule, but for the reason that the data is considerable revised over time, it may turn after all that the interest rates were not adjusted appropriately. This could apply to all monetary policy rules which are making use of ex-post data and more importantly, in indentifying a historical interest rate reaction function of a central bank, not employing real-time data could provide misleading results. In this spirit, the present paper, will allocate a considerable attention to the data assembly in order to respect its real-time availability.

3.4.2. Inflation and output gap measurements

With regards to the measurements of price level and real economic activity, as great as their importance is, since the whole description is centered on them, just as extensive is the debate. This is because there is no consensus on how to measure, or which proxies are more appropriate to be used for the underlying variables. Taking for instance inflation, in Taylor's original formulation, it was

measured as the average of the previous four quarters percentage change in the price deflator of GDP. Other researchers, studying also the behaviour of Fed, in addition to the GDP price deflator, have tried the Consumer Price Index (CPI) (Clarida et al., 1998), core CPI or PCE Price Index (Judd and Rudebusch, 1998). And all come to the same conclusion, that the estimations of interest rate reaction functions are not very sensitive if different measures of inflation are employed. On the contrary, Kozicki (1999) has found that policy recommendations are not robust at all to different measures of inflation, and large differences could be possible. Besides, there could be choices of using monthly, quarterly or annual figures, and in addition, if it would be more appropriate instead of taking the preferred figure average, to make use of its growth rate. Furthermore, with respect to the euro area, pre-ECB studies have employed similar instruments of measuring inflation as the above mentioned ones in studying the Fed (for example Faust et al. (2001) use the 12-month growth rate of CPI), while in the case of actual ECB, since price stability was defined in terms of HICP, the underlying index was much more favored. Although, as Gerlach (2007) is arguing, due to the large shocks in energy prices over the recent years, considering that a central bank might see this as a temporary effect on inflation, maybe it would be more suitable to use a measure of core inflation. As a result, from the HICP were excluded fresh-food and energy prices.

As for the measurement of real economic activity, the situation appears to be even more complicated than in the case of inflation. This is because potential output cannot be observed, thus, must be estimated. This is introducing the possibility of an error in the measurement, which in turn is reflecting in the estimates of the output gap, creating uncertainty about the true value and questioning its reliability and precision. Moreover, constructing real-time data instead of using revised ex post data, may introduce additional informational problems as shown in Orphanides and Van Norden (2002), where different techniques in estimating potential output have been examined. A common procedure to estimate potential output is to detrend the actual output, i.e. to decompose real output into a component attributed to its trend and another component attributed to the business cycle.

For instance, Taylor (1993) made use of such a detrending technique, by fitting the actual output, measured by real GDP, with a linear time trend in order to measure potential output. He further took the deviations from the actual to the estimated potential one, as to obtain the output gap. Subsequent studies have tried different methods to measure potential output such as segmented linear and quadratic trend (Judd and Rudebusch, 1998), the well known filter popularized by Hodrick and Prescott (1997) (Taylor, 1999), or using a production function approach, such as the estimates

given by the Congressional Budget Office (CBO) (Smant, 2011), OECD and Standard & Poor's DRI (Kozicki, 1999). With regards to the robustness of the recommended policy interest rate, estimating using a Taylor type rule and employing different methods in calculating potential output, opinions are not as divided as in the case of inflation, and most of them tend to conclude that estimates are very sensitive to alternative measures of potential output (Judd and Rudebusch, 1998; Kozicki, 1999; Orphanides, 2001). This may be viewed, since it is measured with a high degree of uncertainty, as a possible and partially explanation why the response coefficient of output gap is smaller than the one of inflation, as stressed by Smets (1998). Moreover, as the above mentioned studies were all referring in examining a Taylor type interest rate reaction function to the Fed, a comparable situation could be observed in the studies of Euro area as well. For instance, Gerdesmeier and Roffia (2003) fitted a linear and quadratic trend, in addition of HP filter method, to both industrial production and real GDP in order to estimate potential output, concluded that the estimates are "affected by the measure employed for real activity". Eleftheriou (2003), on the other hand, only for the output gap series constructed with the OECD data seems to agree on the findings of Gerdesmeier and Roffia (2003). While for the industrial production, GDP and unemployment gaps the parameters he finds are robust. Also Fendel and Frankel (2006) agree that little sensitivity could be observed with respect to the choice of the output gap.

3.4.3. Real interest rate uncertainty

The suggestion to differentiate between the nominal rate of interest and the "natural" or real rate of interest much is accredited to Wicksell's (1898) "Interest and Prices". This important concept, which has proved to be a cornerstone in the current monetary policy, allows the policy maker to manipulate the real rate of interest through the nominal rate of interest, in order to achieve price stability. Yet, given its crucial notion, must be estimated, as it is an unobservable variable, and again a high level of uncertainty is linked with those estimations. One frequent approach, in estimating the real interest rate, given that in eq. (2) the constant term $\alpha = r^* - \beta_\pi \pi^*$, knowing the targeted rate of inflation is to calculate directly. Although most empirical studies are not paying much attention, as is part of the estimated equation, in the case that the central bank is not making public the inflation target, through the constant term becomes impracticable, having in its composition two unknowns. A common method to overcome this issue, employed for instance by Kozicki (1999) in studying the Fed, is to estimate it as the difference between the federal funds rate and the average inflation rate. Also by assuming a value for the variable of inflation target, and calculate it through the constant term could be a solution, as is done in Judd and Rudebusch (1998) where both methods are employed and compared.

Moreover, the assumption of being constant, when in fact it varies, is as well of questionable nature.[12] Among the firsts to allow for the real interest rate to vary within the Taylor rule are Belke and Klose (2009), who are estimating it using the Fischer equation with adaptive expectations, and further applying the Hodrick and Prescott filter.

3.5 Dynamic Ordered Probit Framework

A common approach when estimating a Taylor type rule is to employ the money market interest rates, for the reason that they are continuously adjusted. However, estimating the reaction function in such manner, also the private sector expectations of future most likely changes in the policy interest rate are captured. Thus, such method could not focus only on the policy maker decisions, which are essentially to determine accurately the interest rate setting behaviour. And for the reason that the results might be to a certain degree distorted, the policy interest rate is preferred. Moreover, making use of OLS or GMM framework, which is typically preferred in the former circumstances, would be inappropriate when the policy interest rate is employed. One reason is that OLS or GMM framework could not properly take into account for the fact that the central banker leaves most of the times unchanged the policy interest rate, and when a change occurs, this is usually done by a multiple of 25 basis points. Hence, in order to overcome this problem, a discrete choice model would be more suitable to be used in estimating the reaction function. The model was originally developed by Eichengreen et al. (1985), and later modified by Dueker (1999). The major advantage that an ordered probit model has over other methods is the ability to precisely capture the central banker response, as it can distinguish between the times when the policy interest rate remains unchanged, is raised or lowered. [13]

In order to establish the relation between the policy interest rate and various macroeconomic variables, the directional change in the policy interest rate will be used as dependent variable, denoted as (Δi_t). Moreover, assuming that the actual policy interest rate changes are made towards the desired policy interest rate (i_t^*), determined by an information set (X_t) which comprises the chosen macroeconomic variables, the following expression could be employed:

$$i_t^* - i_{t-1} = X_t' \beta^* + \epsilon_t$$

[12] See for a case on euro area Mésonnier and Renne (2007)

[13] For more information related on the ordered probit estimation method see Ruud, (2000, Chapter 27), and for an application on the Bank of England see Kim et al. (2006)

where $X_t^{'}$ is a vector of relevant macroeconomic variables, $\beta^* = (\beta_0^*, \beta_1^*, \dots, \beta_k^*)$ and ϵ_t is the error term. Such an expression cannot be directly estimated, as it is an unobservable or latent variable, and in fact, what could be observed are the actual policy interest rate changes, which are depending on the position of the latent variable relative to a set of threshold values as follows:[14]

$$\Delta i_t = \{-0.50, -0.25\} \iff i_t^* - i_{t-1} < \tau_1$$
$$\Delta i_t = \{0\} \iff \tau_1 < i_t^* - i_{t-1} < \tau_2$$
$$\Delta i_t = \{+0.50, +0.25\} \iff \tau_2 < i_t^* - i_{t-1}$$

where τ_1 and τ_2 are the estimated threshold values. Both eq. 12 and 13 constitute an ordered probit model which establishes a connection between the choices of the Governing Council in the policy interest rate, depending on the utilized set of macroeconomic variables. In order to compare the out-of-sample proprieties of the chosen information set, the probabilities of a raise, cut or no change are given by:

$$P_0 = \Pr(\Delta i_t < 0) = \Phi(\tau_1 - X_t^{'}\beta^*)$$
$$P_1 = \Pr(\Delta i_t = 0) = \Phi(\tau_2 - X_t^{'}\beta^*) - \Phi(\tau_1 - X_t^{'}\beta^*)$$
$$P_2 = \Pr(\Delta i_t > 0) = 1 - \Phi(\tau_2 - X_t^{'}\beta^*)$$

where Φ is denoting the cumulative standard normal distribution. In order to assess the probability of the directional change in the next policy interest rate, the maximum between P_0, P_1 and P_2 is calculated. If it is corresponding to P_0 there would be a cut in the next policy rate change, if to P_1 there would be no change, and if to P_2 there would be a raise.

In order to distinguish between the predictive ability of different sets of explanatory variables, the out-of-sample estimations will be compared with the actual changes in the policy interest rate. By construction a contingency table, where the predicted probabilities of directional changes are cross-tabulated against the actual changes in the policy interest rate, the proportion of correct predictions is calculated as the sum of all diagonal terms divided by the total number of observations. Moreover, for the reason that such a method could not assess properly the predictive ability of the model, given that the changes in the interest rates are rare events, thus the outcome of no change is most of the times. Also the Henricksson and Merton (1981) proposed form, to measure the

[14] For the reason that the actual changes in the policy interest rate could be positive, negative or no changes, the estimations are carried out employing the changes as a ternary variable, which takes the values of 0 when there are no changes, -1 in case of a cut and +1 when the policy interest rate is raised

performances of the model, will be computed. The distinctive ability of this method is that it could take into account for the three outcomes that could arise in the interest rate changes, namely a raise, cut or no change. And by analyzing the predicted with the actual changes in such a manner, the problem of no changes in most of the actual changes could be resolved. The following formula will be used:

$$HM_j = \frac{1}{J-1}\sum_{k=-1}^{+1}\left[\frac{\sum_{t=1}^{T-1}\mathbf{1}\left(sign\left(\widehat{l_{t-1}-l_t}\right) = k\right)\cdot\mathbf{1}(sign(i_{t+1}-i_t)=k)}{\sum_{t=1}^{T-1}\mathbf{1}(sign(i_{t+1}-i_t)=k)}\right]$$

where J is the total number of possible outcomes, $1(.)$is a function for the indicator that takes the values of one in true events and zero in false ones, and $sign\left(\widehat{l_{t-1}-l_t}\right)$ gives the next change prediction. The figure ranges between $-1/(J-1)$ and 1, where a negative value is regarded as being lower than in the case of predicting at least one of the three events, zero when there is no predictive ability and 1 when the forecasts are perfect.

3.6 Studies of ECB interest rate reaction function

The literature in examining the descriptive and prescriptive proprieties of a Taylor type rule, with respect to the euro area, could be separated in studies prior to and after the establishment of the ECB. Prior to ECB studies are referring to either the examination of a "fictious" euro area central bank, constructed using euro area aggregated data before the Third Stage of EMU (Clausen and Hayo, 2002; Gerlach and Schnabel, 1999; Peersman and Smets, 1999), or by considering the Deutsche Bundesbank reaction function as a comparable benchmark for the ECB (Clausen and Hayo, 2002; Faust et al., 2001; Hayo and Hoffman, 2005; Smant, 2002). Post ECB studies, on the other hand, are analysing the actual ECB reaction function, given the limited available data thereafter (Belke and Klose, 2009; Belke and Polleit, 2007; Carstensen and Colavecchio, 2004; Fendel and Frenkel, 2006, 2009; Fourçans and Vranceanu, 2004, 2007; Garcia-Iglesias, 2007; Gerdesmeier and Roffia, 2004; Gerlach 2007; Rosa and Verga, 2005, 2007; Sauer and Sturm, 2007; Surico, 2007). Furthermore, besides the above mentioned ones, a number of researchers have also considered expanding the sample, by including aggregated euro data prior to 1999, in order to be sufficient and reliable for estimation purposes (Carstensen, 2006; Gerdesmeier and Roffia, 2003; Gerdesmeier et al. 2010; Gerlach-Kristen, 2003; Gorter et al., 2007, 2010; Eleftheriou, 2003; Surico, 2003).[15]

[15] See Ulrich (2003) for a comparative analysis between the two types of data

As can be noticed, given the interesting topic surrounding the ECB's monetary policy, numerous researchers have scrutinized and questioned whether it should, or if actually is following, and to what extent various forms of the Taylor type rules. Yet, while the literature provides extensive empirical studies, as a matter of fact only a few have estimated the actual ECB interest rate reaction function properly taking into account the data availability at the time the policy maker is setting the interest rate, and even fewer have employed a limited dependent model which accounts for the discreetness in the policy interest rate changes. Differentiating between them, in addition of mentioning the articles which provided guidance in my research, a brief survey will be provided.

3.6.1. Studies utilising the money market interest rate

Among the first researchers who studied the ECB reaction function proprieties, utilizing real-time instead of ex-post data, are Gerdesmeier and Roffia (2004). They estimated the reaction function from its outset until mid 2003, taking as dependent variable EONIA. Using a contemporaneous rule with revised data, their findings indicated a stabilizing monetary policy conducted by the ECB, given the inflation coefficient higher than one, and a lower than one on output. In the case of the real-time estimates, the picture changes considerably, as the output gap coefficient exceeds inflation coefficient, concluding that the Taylor principle is not anymore satisfied. Inflation was measured by HICP, while as to have a more reliable measure for the economic activity, they constructed the output gap by taking the average between the OECD, European Commission estimates and GDP output gap. In case of real-time data, first releases from the Monthly Bulletin were taken. Moreover, using 12 months forecasts of inflation from SPF, although the coefficient of inflation is estimated above unity, the output gap parameter remained too large. Likewise they concluded, as Orphanides (2001) for Fed, that forward looking rules provide a better description of the interest rate when real-time data is used, while contemporaneous rules are better suited with ex-post realized values.

Furthermore, Fendel and Frankel (2006) employing only ex-post data, constructed seven different output gaps in order to observe any differences which might arise between their estimates. For the period Jan 1999 to Dec 2002, within a forward-looking framework, they found for all of them that the Taylor principle is satisfied. The output gaps were constructed from industrial production, GDP (performing a monthly interpolation from quarterly), and the area-wide unemployment rates. As in the previous study, EONIA was employed here as well. In addition, they found that excess money growth has not influenced the interest setting of ECB, offering support to the findings of Fourçans and Vranceanu (2004). Another important finding reported in their paper is the implicit inflation

target, which was extracted from the constant. They showed, given that it ranges between 1.56 and 2.46 that would actually fit “quite impressive” the Governing Council definition of price stability.

Fourçans and Vranceanu (2007), performing a qualitative investigation, are questioning the credibility nature of ECB, given that they observed inflation in the first six years above the declared goal. Furthermore, in a new quantitative analysis of ECB interest rule over the period Jan 1999 until Mar 2006, they confirmed the results from their earlier paper, by expanding the estimation sample in the current study. Estimating the equations using NLS and employing ex-post data for inflation (HICP) and economic activity (industrial production), they constructed the output gap either from monthly deviations of industrial production from its trend (HP filter) or taking the growth rate, as percentage change in the index from one month to the same month of the previous year. Comparing the results between the contemporaneous and forward-looking rules, they concluded that the former cannot be supported by the data, given the insignificant coefficient on inflation, while the latter are reliable, as both one-year-ahead inflation and real economic activity measures are significantly influencing the policy rate. They also add that the strong response on deviation of inflation from its target and output from potential could be attributed to the fact that ECB, in spite of the first mentioned observation, is concerned to build its credibility.

Another very interesting study is the one of Sauer and Sturm (2007), based upon an earlier version from 2003, where as a measure of economic activity, in addition to the use of ex-post industrial production data, two forms of real-time output gaps (constructed from first releases of industrial production and the ESIN) are used. And also as to measure inflation, two real-time instruments (first releases of HICP and inflation forecasts from The Economists) are added to ex-post HICP. Using GMM and the contemporaneous Taylor type rule, they also found little support, as the inflation coefficients are negative. Even in the case of real-time industrial production gap, the results suggested an accommodating comportment regarding inflation, and denoted a destabilizing monetary policy. Moreover, they underlined that such an impression is given by the “lack of a forward-looking perspective”, rather than the data, since when real-time data based on forecasts of inflation and economic activity are employed within a forward-looking rule, a stabilizing effect on inflation could be observed. Although looking at the estimates, when 6 months ahead real-time inflation and 3 month ahead real-time industrial production are used, the coefficients are highly questionable, and as a reason for this, they explain that it might be due to the “little variability in inflation” over the period examined.

Using forecasts of inflation and output growth, published in Consensus Economics, Gorter et al. (2007) estimated reaction functions for the ECB covering the period 1997.01 – 2006.12, and compared those estimates with the ones given by the use of ex-post realized values of inflation (HICP) and economic activity (industrial production). Using EURIBOR as dependent variable and employing NLS, they found that ECB followed a stabilizing monetary policy only when forecasts are utilized and, on the other hand, little support in favor of ex-post data, as the coefficient of inflation turns out to be insignificant. Also they employed as explanatory variables the money growth, risk premium (given by the difference of the yield on a ten-year euro government bond and the yield on a combination of long-term euro corporate loans) and the euro-dollar rate. Although the results turned out to be robust to other variables, which could include information on future inflation, none of the selected variables are found to be significant. Moreover, updating their study in Gorter et al. (2010), they expanded the sample until 2009.07. Once more they underlined that the ECB interest setting process is much better approximated by forward-looking variables, providing support to their previous findings, and further emphasized that ECB is not giving only to inflation a considerable attention, but also to output growth. Furthermore, since the coefficient of output growth lowered, as the sample expanded, they explained that this occurred due to the inclusion of the beginning of the credit crisis data, and suggested, that price stability is indeed the primary concern of ECB, given that the coefficient of inflation remained all most the same.

Belke and Klose (2009) are arguing that the study conducted by Gorter et al (2007) is unable to observe properly the differences between the use of real-time and ex-post data, only by referring to forecasts. As such, they constructed real-time data to compare it with ex-post data, and further to forecasts, in order to differentiate between the two features. Moreover, using the Fischer equation with adaptive expectations, they constructed the real interest rate, and employed as explanatory variable, allowing it to vary. Furthermore, the output gap is constructed from GDP, while inflation was measured by HICP. For the real-time estimates, the first releases from the ECB Monthly Bulletin are taken. Comparing the real-time with ex-post results, they found of greater importance to be the inflation rate than the output gap in real time, while the ex-post estimates shows the opposite, thus, contradicting the findings of Gerdesmeier and Roffia (2004) who showed that in real time the coefficient of output gap is larger than the one of inflation. Moreover, comparing real-time data with the forecasts of the underlying variables, the results provided are mixed. They gave as a reason for this fact that only when the forecasts match the forecasts of the Governing Council would make sense, otherwise “an unavoidable source of differences” will be introduced.

3.6.2. Studies utilising the policy interest rate

Employing ordered probit framework Gerlach (2004b) utilized as measures of inflation the HICP, with and without energy and unprocessed food prices, and the forecasts published by the Consensus Economics. While for the economic activity the three-month moving average of industrial production, ESIN, EuroCOIN[16] and the forecasts of real GDP growth from the Consensus Economics, in addition to the growth in monetary aggregates. Moreover, in assessing the probabilities assigned to the next change in the repo rate, in addition to the macroeconomic variables, a wording indicator for each one of them was constructed from the Monthly Bulletins. Estimating the reaction function from 1999 to 2004, he found that the interest rate changes are more closely linked to economic activity, in particular survey type of information (ESIN), than to the developments in inflation and money growth. As a reason for this fact, with regards to inflation, given that during the examined period was in line with the declared goal of below, but close, to 2%, he argued that the Governing Council might interpreted any movements as temporary, thus, not reacting to them. Moreover, the growth in M3 although appears to have an impact in the change of the policy interest rate, he observed that much depends on the state of the other variables under consideration. Expanding the sample until 2006, Gerlach (2007) furthermore emphasizes on the important role of economic activity in describing the interest rate changes, offering support to the previous findings.

Furthermore, also by making use of a limited dependent framework, Rosa and Verga (2005) are analysing the usefulness of ECB communication in predicting the change in the policy interest rate. More specifically, by providing a quantitative value for the introductory statement of the President to the monthly press conference, they compared the predictive ability of the created indicator with and without the information attached in the macroeconomic variables. Using real-time data, in the set of macroeconomic variables they included the short-term effective real interest rate, obtained from the difference between the policy interest rate and a measure of core inflation, and as a measure of economic activity, using factorial analysis, the ESIN, EuroGrowth[17] and EuroCOIN are captured within a single figure. They found that the ECB communication indicator offered a very good description of the policy interest rate changes, as the significance is present even after including the set of macroeconomic variables. Although this is to a lower degree, forcing them to

[16] EuroCOIN is a monthly indicator of the euro area business cycle published by Banca D'Italia and CEPR, described in the data section.

[17] The EuroGrowth indicator is calculated by EUROFRAME, and includes in its composition survey from the industry, the retail and construction sectors, the short term real interest rate (in relation to the GDP growth rate), the euro/us dollar real exchange rate, a raw material price index and the US ISM.

conclude that the information embedded in the rhetoric of ECB "provides complementary, rather than substitutable, information with respect to the macroeconomic variables".

Also in the same line of studies, examining the ECB from the beginning of 1999 until May 2002, Jansen and De Haan (2009) contradicted the findings of Rosa and Verga (2005), concluding that the out-of-sample estimations of the model based on communication do not have improved predictive ability, compared with the models which incorporates macroeconomic data. In order to measure the ECB communications they constructed an indicator based on the news wire of Bloomberg. While for the macroeconomic data, inflation was measured by HICP and the forecast published by the Consensus Economics, and the economic activity was considered as output gaps from the industrial production index and ESIN. Moreover, also the growth in monetary aggregates was utilized, by taking the three month moving average of annual growth rate in M3. With regards to the macroeconomic data estimations, they found that the ECB is most influenced by expected inflation and ESIN, while for the growth in monetary aggregates, the estimates were found insignificant. The predictive ability, given the dissimilar measures of communication constructed and utilized macroeconomic variables, compared to the previous studies, they also underlined that this might be the reason for the different results.

Furthermore, Sturm and De Haan (2009) in order to overcome this problem, utilised five different measures of communication indicators based on the introductory statement of the President at the press conference following the policy meeting, and compared them with expected macroeconomic type of information. Making use of forecasts of inflation and GDP growth, published by the Consensus Economist, as measures of macroeconomic data, and estimating the policy interest rate for the period 1999 until 2007, they conclude, that although the communication indicators are to a certain degree very different, all of them add to the predictive ability of model.

4 Data

In this section the choice of the utilised type of macroeconomic information will be motivated and, when needed, an explanation of its construction will be provided. The analysis is conducted using monthly data and the sample period under consideration is starting from 1999, the establishment of ECB, until October 2010. Moreover, as stressed in the previous chapter with regards to the importance of data availability at the time the Governing Council is setting the policy interest rate, real-time data will be utilised rather than ex-post realised values. Unless otherwise stated, all the data is taken from the website of ECB, more specifically from the Euro Area Real-Time Database (RTDB)[18], which provides a snapshot of the actual macroeconomic information available to the Governing Council when the policy interest rate is set, as it consists of information reported in the ECB's Monthly Bulletin. As dependent variable in all estimated equations the directional change in the policy interest rate was employed, given by the change in MROs. For the period June 2000 until October 2008, during which the MROs were conducted under a variable rate tender, the minimum bid rate was used, while for the rest of the sample the fixed rate.

4.1 Measuring inflation

In order to decide on which variables to be used as to capture the euro area movements in price level, given that the definition of price stability is assessed in terms of HICP, the year-on-year increase in the overall index was used as to measure headline inflation. The choice of employing this indicator to measure inflation could be further motivated on the fact that its developments are often referred in the Monthly Bulletins. Also by looking at the Monthly Bulletins, the publication lag for the HICP has been determined at one month.

As it can be observed this type of information might be regarded as backward-looking, in the sense that the Governing Council would react to past rather than to current period realisations of inflation, which motivate the fact, in order to capture the required forward-looking behaviour, to use also a measure of expected inflation. The choice of employing ECB forecasts of inflation, although it would seem natural to be preferred, the forecasts published by the Consensus Economics[19] are utilized, given their monthly availability compared to the quarterly publications of ECB. Moreover, as these forecasts are timely available at the beginning of every month and not revised over time, they could

[18] The database has been constructed in the context of the Real-Time DataBase (RTDB) project that is being coordinated by the Euro Area Business Cycle Network (EABCN), available at http://sdw.ecb.europa.eu/browseSelection.do?node=4843526

[19] The Economist surveys every month over 250 prominent financial and economic forecasters for their estimates on inflation and real GDP growth, among others, for the current and subsequent year and publishes their point means estimates.

in fact be used by the Governing Council in the economic analysis. Following Gerlach (2007) and Gorter (2007), the measure of expected inflation is constructed for month m of year t as $(13 - m)/12$ times the forecasts of current year t plus $(m - 1)/12$ times the forecasts of subsequent year $t + 1$.

4.2 Measuring economic activity

In order to measure real economic activity, given the documented unreliability of real-time estimates on national accounts, both the output gap and survey type of data were utilised. In constructing the output gap variable, the industrial production index (excluding construction) was used in favour of GDP figures, while estimating potential output, the filter method of Hodrick and Prescott (1997) was employed. As it is accustomed when working with monthly time-series, the smoothing parameter on the filter was set to 14400. In the case of estimating potential output using ex-post realised values is straight-forward, while in order to mimic the real-time data availability of the Governing Council, it becomes more difficult. Firstly, in order to overcome this problem, the sample period was extended until 1994, using pre-ECB data before the start of EMU, and secondly, by rolling the sample every month, the estimates for every month were constructed using the preceding five years. The reason for this approach is simple, given that is to a certain degree unrealistic, to imply that the Governing Council at the present time are still obtaining their estimates of potential output on data from 1994.[20] As an example of how it was calculated, without taking into account that industrial production index usually has a publication lag of three months, estimate of potential output for May 2010 was based on the period May 2005 until May 2010.

As survey type of information, which is considered forward-looking, in order to capture the business cycle movements in the euro area the ESIN, EuroCOIN and forecasts of GDP growth published by the Consensus Economics were selected. The ESIN is a weighted mixture of an industrial, consumer, construction and a retail trade confidence indicator. It is published monthly by the European Commission - Economic and Financial Affairs with the intention to measure into a single cyclical composite or confidence indicator the business tendency surveys. In order to estimate the output gap from this measure, after determining the publication lag to one month, the ESIN was calculated as the percentage deviation from its mean. Also for the EuroCOIN the publication lag has been determined to one month, even though it is available on a monthly basis with current period realisations, for the reason that it is published at the end of the month, thus, after the Governing Council decision. It is a monthly "smoothed" measure of quarter-on-quarter GDP growth

[20] For more information on this approach see Belke and Klose (2009)

constructed by collecting large datasets of statistics, such as stock markets and financial data, surveys and demand indicators, and furthermore extracting from them the information relevant to forecasts future GDP.[21] Since these two indicators are strongly correlated, a principal component analysis has been applied, where the first component was used as to measure the response to both of them. The last included measure of economic activity takes the form of one-year-ahead forecasts of GDP growth published by the Consensus Economics. As described in the previous section in calculating inflation, the same method is also employed in calculating the point estimate for GDP growth forecasts. Following Gorter et al. (2007) in constructing the output gap from this variable, the trend potential output growth, as ECB often indicated that it is in the range of 2-2.5% per annum (ECB, 2000), the mid-point has been subtracted from the GDP growth estimate.

4.3 Other variables

As additional variables, given the important role assigned to money in the monetary policy strategy of ECB, the growth in monetary aggregates was considered. More specifically, as ECB decided at 4.5% per annum the reference value for M3 growth, the variable has been calculated as subtracting from the annual growth in M3 its target value. The choice could be further motivated on the fact that regularly money and credit growth are reviewed in the Monthly Bulletins, where also it could be observed that a more important part is played by the three-month moving average of the annual growth in M3. As such both variables are used and compared within the current study. The publication lag has been determined at two months for the former variable, while for the preferred form at three months. Besides these economic indicators, the Governing Council might react to exchange rate developments, given that it could affect inflation due to domestic prices of imported goods, whether or not used as inputs for the final goods, or through the goods produced within the euro area, as their competitiveness on international markets, in terms of their prices, affects demand. For those reasons, the annual growth rate in nominal effective exchange rate, CPI deflated, Euro area-17 countries vis-à-vis a group of 40 trading partners was utilized.

[21] For more information regarding it construction see http://eurocoin.cepr.org/

5 Results

This chapter will include a description of the econometric analysis and the final results. First of all, the in-sample estimates of the reaction functions, containing data prior the credit crisis will be discussed, and subsequently, the whole sample period estimates will be disclosed and compared with the previous findings. This will determine how, and if, the Governing Council interest rate setting behaviour was affected by the financial turmoil. Furthermore, the out-of-sample estimates will answer if the reaction functions estimated only with data prior the crises could better approximate the changes in the interest rates, than those which utilise the whole sample period. Ultimately and more importantly, the current section will determine in the course of the entire analysis, what type of macroeconomic information is actually influencing the Governing Council, and if standard Taylor rule type macroeconomic variables are sufficient to explain their interest setting behaviour.

5.1 In sample estimations

Table 1 presents the empirical findings based on the estimates of the probit model for the period January 1999 to January 2008. The first column exhibit the coefficients of a standard Taylor rule, where inflation was measured by the year-on-year increase in HICP, and economic activity by constructing the output gap from industrial production index. What could be observed is that the estimate of economic activity is significant and positive, thus denoting that an increase in the figure would raise the possibility of an increase in the policy interest rate. On the other hand, inflation measured by HICP turned out to be insignificant. In the next two columns, 2 and 3, in addition to the above mentioned variables, the M3 gap (i.e. the difference between the growth in M3 and its reference value), and subsequently, the Governing Council's favoured form of M3 growth were utilised. No major change could be observed with respect to the estimates of inflation and economic activity, while the estimates of the growth in monetary aggregates, none seems to have played a role, as they turned out to be insignificant. Moreover, in all three columns Pseudo-R^2 is too low to be able to explain the interest setting process of the Governing Council. Another important finding, with which the first part of the reported findings will end, is that the lagged policy rate is insignificant in all cases.

Continuing with the subsequent four reactions functions, columns 4 to 7, the important results are as follows. Firstly, in all cases Component is highly significant and positive, thus survey type of information based on current business and confidence indicators, contributes considerably more than traditional measures of economic activity to the decisions of the Governing Council in setting

the policy interest rate. Secondly, although in some cases only marginally significant, the measure of inflation in all situations is positive. Therefore, this would indicate, compared to the estimates from the previous three columns, that higher contemporaneous measures of inflation would increase the probability of a raise in the next policy rate change. Thirdly, lagged policy rate is always statistically significant and negative, which might be regarded as a sign of interest rate smoothing. Also this could be interpreted, as Gerlach (2007) is underlining, that the Governing Council prefers to wait for a period of time before changing the interest rate, and when it does, the change that has been made to be enough, in order to not necessitate for a further change in the immediate period. Fourthly, both measures of the growth in monetary aggregates and the exchange rate are significant. Moreover, comparing the estimates of M3 growth with the previous ones, an increase in figures could be observed, besides the fact that now both are denoting significance at ten percent level. Also worth mentioning is the improved value in Pseudo R^2, indicating that the fit of the variables is much better than in the case of using standard output gap measures.

In columns 8 to 10, the results displays the scenarios when the Governing Council, instead of utilising contemporaneous measures of inflation, forecasts of the underlying variable are favoured. In the estimates of economic activity, measured again by Component, a slightly lower value could be observed, yet highly statistically significant in all cases. And as expected, the estimates of inflation have much higher values than in the previous conditions, although in some situations the significance level remained just marginally. This is noticeably is in column 10, where in addition to the measures of inflation and economic activity, also the exchange rate and M3 gap were used. Moreover, only in that case the measure of growth in monetary aggregates seems to have affected the Governing Council decisions, as it became highly significant, comparing to column 9, where the estimate of 3 month moving average of M3 turned insignificant.

Furthermore, estimating the reaction function utilising only forecasts of inflation and economic activity, the results are presented in columns 11 to 14. A remarkable result from the very beginning could be seen, given that all estimates are highly significant and have the expected signs. Moreover, the forward-looking behaviour of the Governing Council is detected, as these values are much higher than in the previous cases, indicating for instance that an increase in expected inflation would raise much more the probability of monetary tightening, than in the case when contemporaneous realizations of inflation are increasing. This would indicate not only that the interest setting process of the Governing Council is forward-looking, given the higher coefficients of expected inflation and economic activity, but also that the variables of the growth in monetary aggregates and exchange

Table 1 – In-sample estimates of ECB reaction function for period Jan 1999 – Jan 2008.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Lagged MRO	-0.06	-0.06	-0.05	-0.81***	-0.91***	-0.90***	-0.98***	-0.86***	-0.84***	-1.08***	-1.25***	-1.76***	-1.75***	-1.79***
	(0.15)	(0.15)	(0.16)	(0.26)	(0.29)	(0.28)	(0.31)	(0.27)	(0.27)	(0.32)	(0.29)	(0.41)	(0.41)	(0.46)
HICP	-0.34	-0.35	-0.34	0.70*	0.83**	0.87**	0.76*							
	(0.31)	(0.31)	(0.31)	(0.39)	(0.42)	(0.43)	(0.46)							
Forecasts of Inflation								1.59**	1.47*	1.83**	2.16***	2.10***	2.17***	2.26***
								(0.70)	(0.77)	(0.82)	(0.68)	(0.78)	(0.82)	(0.85)
IP Gap	0.30***	0.31***	0.30***											
	(0.10)	(0.10)	(0.10)											
Component				1.60***	1.79***	1.79***	1.57***	1.61***	1.64***	1.56***				
				(0.33)	(0.38)	(0.38)	(0.43)	(0.33)	(0.34)	(0.40)				
Forecasts of GDP growth											2.23***	3.37***	3.39***	2.99***
											(0.44)	(0.68)	(0.67)	(0.77)
M3 Gap		0.07			0.17*		0.37***			0.27***		0.43***		0.52***
		(0.07)			(0.10)		(0.14)			(0.13)		(0.13)		(0.15)
M3 (3month ma)			0.09			0.20*			0.11				0.47***	
			(0.08)			(0.10)			(0.10)				(0.14)	
Exchange rate							-0.10**			-0.11***				-0.09**
							(0.04)			(0.04)				(0.04)
Threshold														
Lower limit	-2.52***	-2.35***	-1.88	-2.78***	-2.48***	-1.47	-1.36	-1.59	-1.04	-1.98	-2.83**	-4.38***	-2.08***	-4.25***
	(0.72)	(0.74)	(0.89)	(0.92)	(0.96)	(1.12)	(1.18)	(1.18)	(1.28)	(1.29)	(1.14)	(1.43)	(1.32)	(1.50)
Upper limit	0.24	0.42	0.91	1.54*	2.25**	3.29***	4.11***	2.94**	3.59***	3.73**	0.78	0.15	2.54*	0.90
	(0.66)	(0.69)	(0.87)	(0.81)	(0.96)	(1.27)	(1.46)	(1.23)	(1.39)	(1.45)	(1.06)	(1.20)	(1.32)	(1.29)
Pseudo-R2	0.08	0.08	0.09	0.34	0.36	0.37	0.41	0.36	0.36	0.42	0.27	0.37	0.38	0.41

Notes: Standard errors in parentheses. Estimation method is Maximum Likelihood – Ordered Probit (Quadratic hill climbing). ***, **, * denote significance at 1 percent, 5 percent and 10 percent level, respectively. The dependent variable in all cases is the directional change in ECB policy interest rate. Pseudo-R^2 is offering a measure of the goodness of fit.

rate are considerably important. In addition, looking at both measures of M3, the coefficients are almost double than in the previous circumstances, while the coefficient on exchange rate, still have an increasing effect on Pseudo R^2. At the same time, as the coefficient of nominal exchange rate is negative, which is increasing the probability of an interest rate cut, this would imply that the Governing Council reacts to a depreciation of the euro.

In summarizing the findings of Table 1, the Governing Council appears to use a large set of macroeconomic information when it decides on the monetary policy stance for the euro area. Therefore, merely relying on traditional Taylor rule variables, the interest setting behaviour could not be captured. Instead, by making use of survey type information, the growth in monetary aggregates and exchange rate a clearer picture of the whole process could be attained. Moreover, the forward-looking behaviour of the Governing Council is detected, given the highest values on the estimates of inflation and economic activity, for the interest rate reaction functions which are employing forecasts, rather than contemporaneous realisations, of the underlying variables.

Looking at Table 2, which expands the sample period under consideration until October 2010, thus, capturing the financial turmoil, a completely different image could be observed. Comparing the estimates with the previous ones, the findings are as follows. In the first three columns, where traditional Taylor rule measures of economic activity have been utilised, all estimates on the output gaps have smaller values, besides the fact that the one in the first column became insignificant. This could highlight once more that the Governing Council does not utilise as a measures of economic activity the output gaps, given their unreliability in real-time and estimation problems. Turning to the estimates of inflation, although the negative values are still present, in columns 2 and 3 they became marginally significant. Furthermore, a considerable increase in both estimates of the growth in monetary aggregates could be observed, on top of becoming highly significant. This would suggest that during the financial turmoil the Governing Council responded more to M3 growth, since the values are much larger than in the previous situations, indicating that now an increase in the figure would add more to the probability of a raise in the policy interest rate.

Turning to the following seven columns, 4 to 10, where economic activity was measured by survey type of information, only in the seventh column inflation, measured by HICP, remained significantly different from zero, yet the coefficient became as well negative. Moreover, examining the estimates

Table 2 – In-sample estimates of ECB reaction function for period Jan 1999 – Oct 2010.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Lagged MRO	0.09	0.02	0.03	-0.09	-0.23	-0.24	-0.32*	-0.16	-0.28*	-0.36**	-0.21	-0.30**	-0.32**	-0.38**
	(0.14)	(0.14)	(0.14)	(0.14)	(0.15)	(0.16)	(0.17)	(0.14)	(0.15)	(0.17)	(0.14)	(0.15)	(0.15)	(0.16)
HICP	-0.11	-0.39*	-0.42**	-0.06	-0.27	-0.29	-0.35*							
	(0.18)	(0.21)	(0.21)	(0.16)	(0.18)	(0.18)	(0.19)							
Forecasts of Inflation								0.21	-0.37	-0.18	0.32	-0.07	-0.13	0.06
								(0.31)	(0.38)	(0.39)	(0.31)	(0.36)	(0.37)	(0.38)
IP Gap	0.07	0.12**	0.13**											
	(0.04)	(0.05)	(0.05)											
Component				0.43***	0.51***	0.54***	0.52***	0.41***	0.55***	0.46***				
				(0.09)	(0.10)	(0.10)	(0.12)	(0.09)	(0.11)	(0.11)				
Forecasts of GDP growth											0.33***	0.42***	0.45***	0.33*
											(0.12)	(0.12)	(0.13)	(0.13)
M3 Gap		0.15***			0.16***		0.32***			0.25***		0.12**		0.21***
		(0.05)			(0.06)		(0.08)			(0.07)		(0.05)		(0.06)
M3 (3month ma)			0.16***			0.19***			0.19***				0.14**	
			(0.05)			(0.06)			(0.06)				(0.06)	
Exchange rate							-0.08***			-0.07***				-0.08***
							(0.02)			(0.02)				(0.02)
Threshold														
Lower limit	-1.27***	-1.80***	-1.09***	-1.80***	-2.40***	-1.62***	-1.43***	-1.55***	-1.81***	-2.64***	-1.67***	-2.49***	-2.02***	-2.48***
	(0.37)	(0.43)	(0.38)	(0.41)	(0.48)	(0.43)	(0.45)	(0.51)	(0.54)	(0.68)	(0.59)	(0.72)	(0.63)	(0.75)
Upper limit	1.21***	0.80*	1.52***	1.03***	0.65	1.50***	2.14***	1.30**	1.29**	0.72	0.97	0.23	0.72	0.53
	(0.37)	(0.40)	(0.40)	(0.39)	(0.42)	(0.44)	(0.53)	(0.51)	(0.53)	(0.61)	(0.58)	(0.68)	(0.60)	(0.71)
Pseudo-R2	0.01	0.06	0.06	0.13	0.18	0.20	0.26	0.13	0.19	0.23	0.06	0.09	0.10	0.16

Notes: Standard errors in parentheses. Estimation method is Maximum Likelihood – Ordered Probit (Quadratic hill climbing). ***, **, * denote significance at 1 percent, 5 percent and 10 percent level, respectively. The dependent variable in all cases is the directional change in ECB policy interest rate. Pseudo-R^2 is offering a measure of the goodness of fit.

of economic activity, although they remained significant and positive, these are now considerably smaller. Looking at the variables this would indicate that during the credit crises the Governing Council response to both of them was much smaller. More interestingly is that comparable values on the coefficient of M3 growth could be observed also in these circumstances. Another important finding is that the lagged policy rate only in three cases remained significant, on top of a substantial decrease which took place in all values. This contradicts Table 1 findings, or would indicate that the Governing Council changed very much the policy interest rate during the credit crisis. Actually, this happened during the financial turmoil, as the policy rate was lowered nine times in the course of seven months. This is clearly no sign of interest rate smoothing. And given that the Governing Council changed only ten times the policy interest rate during the period January 2002 to January 2008, both findings could have a natural explanation.

The last four columns, 11 to 14, presents the estimates of reaction functions when only the forecasts of inflation and GDP growth are utilized. Also the picture repeats in this case too, as none of the estimates on inflation are now significant and have the expected signs. Moreover, although the estimates of expected GDP growth remained significant and positive, these have dropped very much. The most remarkable contrast is given by the values on Pseudo R^2, which are much smaller than in situations where economic activity was measured by Component. A possible explanation for this fact could be that the Governing Council behaved in a forward-looking manner only until 2008, as emphasized by Belke and Klose (2010), while during the credit crisis the current business and consumer confidence indicators played a much important role.

As an overall impression of Table 2 findings, the interest setting behaviour of the Governing Council has changed noticeably. First of all, inflation is now insignificant in 11 out of 14 cases, and when the estimates are significantly different from zero, their signs became negative. A possible explanation for this fact, given that the considered period included a distinctive situation of price deflation, is that the Governing Council cut the policy interest rate more aggressively, as it disregards deflation much more than inflation above the declared goal. Actually this could be observed given that, as pointed earlier, it was lowered nine times in the course of seven months. Furthermore, although a conclusion such as the interest setting behaviour of the Governing Council might be asymmetric is to a certain degree realistic, given that the policy interest rate was cut much more aggressively, compared to a situation in which a raise occurred, as a result of inflation above the declared goal. Due to the exceptional condition of the credit crises, such a comparison leading to this conclusion could be seen as inappropriate. Moreover, and more importantly, as the values on Pseudo R^2 are

much lower than in Table 1, it seems that the monetary policy stance was not transmitted only through MROs. In fact, this might be observed looking at figure 1, as no major differences could be seen between the overnight interest rates and MROs until mid 2008, while afterwards important divergences are visible, as EONIA dropped considerably below MROs. Surveying the actions of ECB under the credit crisis a number of events could be spotted, which might explain why the discrepancy happened. In fact, ECB was already engaged in policies characterized as "non-standard", when the crisis reached extraordinary heights in mid 2008, the time when it became visible a discrepancy. What is known as "enhanced credit support" clearly has gone well beyond cuts in policy interest rates, as Jean-Claude Trichet underlined[22]. He explained that the monetary policy measures and approaches to crisis management, as to prevent a halt in functioning of the euro area economy, were "unprecedented in nature, scope and magnitude". For instance, non-traditional policy measures such as lessening the conditions under which liquidity was provided to the credit institutions, the 60 Billion euro purchase program of euro-denominated covered bonds[23], or expanding the list of accepted collateral, definitely have had a major impact on money market interest rates, hence, on the monetary policy stance. Therefore, the stance has been more accommodative than the MROs suggested, which could answer as why the estimated coefficients are smaller in Table 2. Another possibility as to explain this occurrence, a subject widely debated among academics, is that the monetary policy was constrained by the lower bound on policy interest rate (Gerlach and Lewis, 2010). Therefore, without such a restriction, the policy makers would have lowered even further the policy interest rate, and as a result, the estimates would have been probable similar to Table 1 findings. Nevertheless, capturing the monetary policy stance of the Governing Council merely looking at MROs is purely a simplification, given the special conditions, which could be made as long as the monetary policy stance is given only through MROs. As such, the estimates of Table 2 must be read with caution, and actually it would be more reliable to base the description of the Governing Council interest setting behaviour on Table 1 findings.

5.2 Out-of-sample estimations

This part explores how well the implied probabilities of the model are correlated with the actual changes that have been made by the Governing Council in the MROs. Firstly, Table 3 will show the values obtained through CP method (i.e. correct predictions) and HM method (i.e. Henriksson and Merton, 1981) for the information sets of the ECB reaction function discussed in Table 1. And

[22] The ECB's "enhanced credit support" is explained in detail by the President of ECB, Jean-Claude Trichet in a keynote address, available at http://www.ecb.int/press/key/date/2009/html/sp090713.en.html
[23] For more information see http://www.ecb.int/press/pr/date/2009/html/pr090604_1.en.html

subsequently, Table 4 findings will answer if the model could still capture the interest rate changes, when the probabilities are based on the coefficients calculated using the whole sample period.

Table 3 – Out-of-sample estimates of ECB reaction function for period Jan 1999 – Jan 2008

	1	2	3	4	5	6	7
CP method	0.79	0.79	0.79	0.80	0.81	0.82	0.81
HM method	0.00	0.00	0.00	0.20	0.23	0.24	0.29
	8	9	10	11	12	13	14
CP method	0.83	0.82	0.80	0.78	0.81	0.81	0.83
HM method	0.25	0.24	0.28	0.11	0.23	0.21	0.36

The first part of Table 3, columns 1 to 3, presents the situations where the information set included traditional Taylor rule macroeconomic variables. As can be noticed, clearly no predictive ability could be achieved, given the zero values obtained from HM method. On the other hand, the high values of CP method resulted because the Governing Council rarely had changed the policy interest rate during the considered period, as a consequence, an outcome of no change in the policy rate has happened in 86 of the 109 meetings. And for the reason that the model under these specifications did not predicted at all a change in the policy interest rate, actually forecasted 86 true outcomes. Therefore, the results obtained with this method do not imply a high accuracy of the model to forecast the changes in the policy interest rate, and actually what is accomplished, is purely recognition of the fact that an outcome of no change has happened many times. In fact, even a naive model which predicts no change in all cases, could have achieved the same value under CP method.

Looking at the following four columns, 4 to 7, where inflation was measured by HICP and economic activity by Component, a great improvement in the values of HM method could be noticed. This would indicate once more, even in predicting the next policy rate decision, that relying on traditional measures of economic activity is ineffective. Moreover, the inclusion of both the growth in monetary aggregates and exchange rate variables substantially increase the accuracy of the forecasts, as can be noticed in column 7. A similar pattern could be observed also in the succeeding three columns, 8 to 10, where instead of HICP, forecasts of inflation are utilised. More interestingly, although as expected, given the detected forward-looking behaviour of the Governing Council, is that the highest values for HM method are obtained when the forecasts of inflation and GDP growth are used. However, without any measures of the growth in M3 and/or exchange rate the value of HM method

of column 11 turned out to be much lower than in the comparable situation of column 8, where also measures of inflation and economic activity were the only variables utilised.

To sum up the findings of Table 3, the forecasting ability is still too low to be able to match the exact timings of the policy interest rate changes, although improvement over traditional Taylor rule macroeconomic variables could be attained by making use of survey type of information, the growth in monetary aggregates and exchange rate. In fact, what could be achieved is a general picture, which captures the overall interest setting behaviour of the Governing Council. As an example, the figure provided below shows the evolution over time of the MROs, along with the implied probabilities corresponding to the information set of column 14. As can be noticed, an increase in the predicted probabilities of a raise in the policy interest rate coincides with the tightening of monetary policy between 1999 and late 2000, as well as in the period late 2005 to mid 2007. In the same line, the period of monetary policy loosening over the period 2001 until late 2003 is associated with an increase in the probabilities of an interest rate cut.

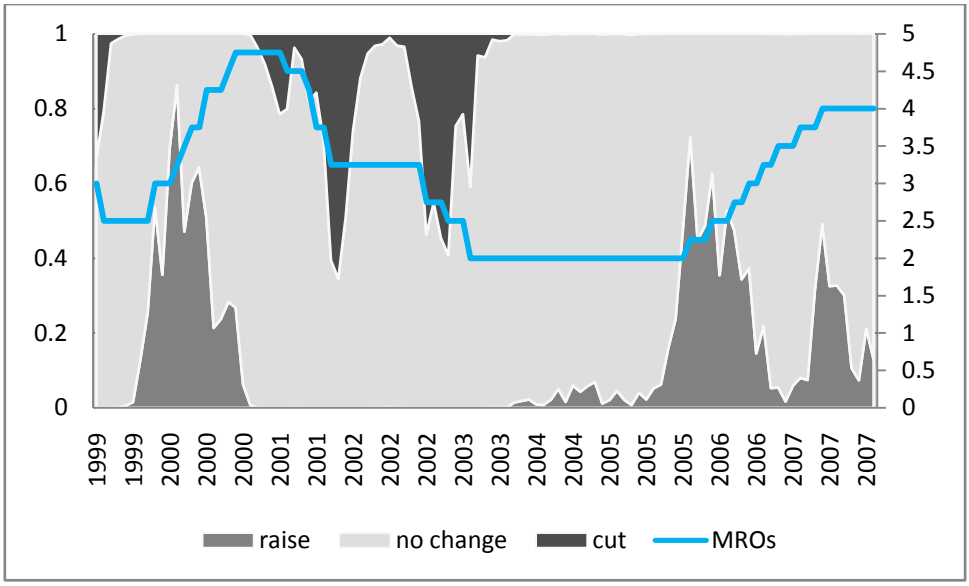

Figure 4 – Implied probabilities of a change in the policy rate corresponding to column 14, Table 3

Moreover, in order to achieve a higher degree of predictive ability, as recently emphasised by many authors, one needs to include within the information set, in addition to macroeconomic variables, also a wording indicator, which captures the central bank communication (Sturm and De Haan, 2009). Although, as shown in Rosa (2009), where similar values for HM method have been reported, that "ECB statements provides complementary, rather than substitutable, pieces of information with

respect to macroeconomic variables" in predicting the next policy rate change. Hence, as a possible explanation for the low ability of the model to forecast the changes in the interest rate, is given by the fact that the Governing Council may transmit information about the exact timings of an interest rate change, which is essential in this context.

Table 4 – Out-of-sample estimates of ECB reaction function for period Jan 1999 – Oct 2010

	1	2	3	4	5	6	7
CP method	0.78	0.78	0.78	0.77	0.76	0.76	0.78
HM method	0.00	0.00	0.00	0.05	0.02	0.02	0.00
	8	9	10	11	12	13	14
CP method	0.76	0.75	0.77	0.75	0.75	0.75	0.77
HM method	0.04	-0.02	0.00	-0.02	-0.02	-0.02	-0.01

Table 4 presents the results covering the whole sample period. All the values on both methods have lowered so much, without having relevance on what types of macroeconomic variables are used, that it can be concluded that no forecasting ability could be achieved. Moreover, in some cases the estimates actually decrease the accuracy of the forecasts below of a naive model, as the HM method values became negative. This is not surprising, given the extreme macroeconomic conditions of the financial turmoil that have lowered the coefficients, with which the probabilities of an interest rate cut, raise or no change are calculated. In support of this, the figure below provides the probabilities.

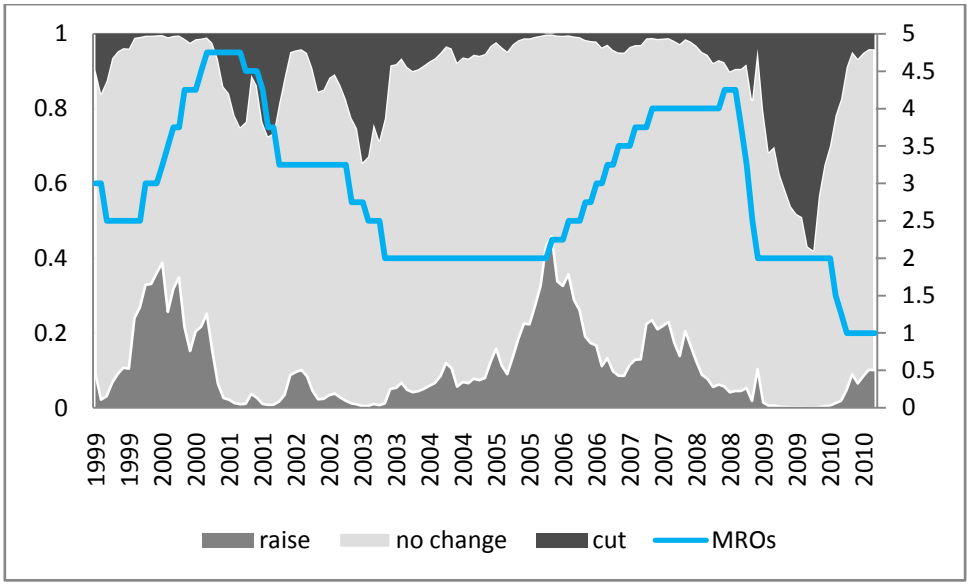

Figure 5 – Implied probabilities of a change in the policy rate corresponding to column 14, Table 4

6 Conclusions

This paper provides an important empirical analysis of the interest rate reaction function of ECB under several specifications. Firstly, in order to determine which information set could better capture the ECB's interest setting behaviour, a comparison has been made between standard Taylor rule macroeconomic variables and survey type data, the growth in monetary aggregates and exchange rate. And secondly, dividing the period under consideration in prior to and after the financial turmoil, the effects of the credit crisis on ECB's reaction function have been studied. The main findings are as follows.

Several conclusions could be drawn with regards to the choice of the information set. On one hand, standard output gap measures of economic activity constructed utilising industrial production index, provides a poor description of the interest setting behaviour of ECB. Instead, by making use of survey type data, such as ESIN and EuroCOIN, a substantial improvement could be observed, for both in-sample and out-of-sample estimations. Moreover, the response of the Governing Council to current measures of inflation was found to be much lower than to forecasts of inflation, as well as it was found comparing current measures of economic activity with forecasts of GDP growth. This is leading to the conclusion that the assessment of outlook in prices of the Governing Council was to a large extent forward-looking, which requires expectations of the underlying variables to be used when a description of their interest setting behaviour is made. This is emphasised even more in the out-of-sample estimations, because such specification provides an increasing predictive ability of the model in forecasting the changes in the policy interest rate. Furthermore, the Governing Council reacted to measures of the growth in monetary aggregates and exchange rate, as both are statistically significant in the estimated reaction function. This underlines the required utilisation of a large set of information, which includes these essential variables, in addition of measures of inflation and economic activity, when predicting the changes in the policy interest rate. However, even in those cases, the model has great difficulty in forecasting the exact timings of the changes in the policy interest rate.

Looking at the estimates constructed utilising data which includes the financial turmoil, a totally different picture could be observed. First of all, the coefficients of inflation became insignificant in most of the cases, while the measures of economic activity estimates have lowered considerably. Furthermore, compared to the estimates of the pre-credit crisis, current business and confidence indicators played a much important role than expectation of GDP growth. This could indicate that the Governing Council has stopped behaving in a forward-looking manner after the start of the

financial turmoil. More interestingly, is that the coefficients of the growth in monetary aggregates and exchange rate remained similar to those of the pre-credit crisis period, and actually, the formers slightly increased. Comparing the out-of-sample estimates with the previous findings, in this case no predictive ability of the model could be accomplished. Finally, no sign of interest rate smoothing could be found on the estimated reaction function in this case, compared to the period before the financial turmoil, where large and negative coefficients were detected on the lagged policy interest rate.

Two possible explications could be given as why such large differences were found between the estimates of the two studied periods. On one hand, the Governing Council might have been constrained by the zero lower bound on policy rate. Therefore, without such a restriction, the policy makers would have lowered even further the rates on MROs, which probable would have leaded to similar estimates between the two periods. And on the other hand, strongly related to the previous point, is due to the differences which occurred between the policy interest rate and the money market interest rates. As such, given that ECB engaged in non-traditional monetary policy measures after the start of the financial turmoil, actually made its stance more accommodative that suggested by the MROs. Hence, estimating the reaction function in such manner, only a part of ECB monetary policy was captured.

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