A Regime Switching Model for the European Central Bank*

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First version: September 2010
Revised: January 2012

Abstract

This paper estimates a regime switching Taylor Rule for the European Central Bank (ECB) in order to investigate some potential nonlinearities in the forward-looking policy reaction function within a real-time framework. In order to compare observed and predicted policy behavior, the paper estimates Actual and Perceived regime switching Taylor Rules for the ECB. The former is based on the refi rate set by the Governing Council while the latter relies on the professional point forecasts of the refi rate performed by a large investment bank before the upcoming policy rate decision. The empirical evidence shows that the Central Bank's main policy rate has switched between two regimes: in the first one the Taylor Principle is satisfied and the ECB stabilizes the economic outlook, while in the second regime the Central Bank cuts rates more aggressively and puts a higher emphasis on stabilizing real output growth expectations. Second, the results point out that the professional forecasters have broadly well predicted the actual policy regimes. The estimation results are also robust to using consensus forecasts of inflation and real output growth. The empirical evidence from the augmented Taylor Rules shows that the Central Bank has most likely not responded to the growth rates of M3 and the nominal effective exchange rate and the estimated regimes are robust to including these additional variables in the regressions. Finally, after the bankruptcy of Lehman Brothers the policy rate has switched to a crisis regime as the ECB has focused on preventing a further decline in economic activity and on securing the stability of the financial system.

JEL Classification: C24, E52, E58

Keywords: European Central Bank, monetary policy predictability, nonlinear policy reaction function, real-time forecasts, Markov regime switching.

*The author is particularly grateful to Henri Loubergé, Charles Wyplosz, Ulrich Kohli, Jean-Marc Natal, Alessandro Missale, the colleagues from the Department of Economics as well as the participants of the Young Researchers Seminar of the University of Geneva for their valuable comments and insights.

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1 Introduction

In a previous paper I have investigated the predictability of ECB's monetary policy by the professional forecasters of a large investment bank within a forward-looking Taylor Rule framework.[1] In that paper the dynamic stability of the response coefficients of the Taylor Rules has been analyzed within rolling and recursive window regressions. The results have shown a swift change in the coefficient estimates of the policy rules occurring since the broadening of the financial crisis in October 2008. At that moment, the ECB has sharply reversed its policy stance to foster liquidity provision on the interbank lending market, as well as to offset a further decline in the economic outlook. This finding points to some possible nonlinearities in the policy reaction functions. Indeed, the Central Bank might have responded in a different way to economic fundamentals depending on the state of the economy, being a financial crisis, an economic downturn or an expansion. Besides, the ECB might also have responded to other economic fundamentals when setting the policy rate. In order to investigate these issues more in-depth, the goal of this paper is to examine some potential nonlinearities in the Central Bank's responsiveness to economic fundamentals within a Markov Regime Switching model for the Actual and Perceived Taylor Rules (MRS ATR and PTR).

The use of regime switching models has been introduced in macroeconomics by Quandt (1972), Goldfeld and Quandt (1973) and has been further investigated by Mankiw, Miron and Weil (1987). The latter study the effect of the founding of the Federal Reserve on the stochastic process for the short term interest rate. They have found a sharp switch of the interest rate to a new regime occurring at the inception of the Federal Reserve in 1914. The authors show that the transition has been sharp rather than gradual and has altered the stochastic process for the long term interest rate as well, consistently with the expectations theory of the term structure of interest rates. Furthermore, in a seminal paper Hamilton (1989) has proposed a regime switching model for the U.S. business cycle. He has shown that the MRS framework provides an alternative objective method for measuring U.S. post-war business cycles that fits accurately the NBER's official measures. Garcia and Perron (1996) consider a three regimes model for the ex-post real interest rate in the United States and find that it has different means and variances over specific time periods. As regards monetary policy, the empirical literature considers two approaches for modeling regime switching policy reaction functions.

The first approach suggests a gradual regime switching model which assumes that the transition between regimes takes place progressively and is driven by a specific variable with respect to some threshold value. In this framework the researchers estimate a Logistic Smooth Transition Regression (LSTR) as in Alcidi, Flamini and Fracasso (2005). The latter have found that a linear Taylor Rule for the U.S. Federal Reserve might have hidden finer policy regimes in the period from 1988 to 2004. They have detected three policy regimes distinguishing between a general, a crash and a Zero Lower Bound (ZLB) regimes. The authors have also emphasized that the linear Taylor Rule actually provides a weighted average of the policy regimes in place during the estimation period. Finally, at the research frontier on this topic, Gerlach (2010), Gerlach and Lewis (2010) have estimated a gradual regime switching model for the European Central Bank within a logistic smoothed transition approach. They have found that the ECB's behavior has changed after the bankruptcy of Lehman Brothers in September 2008 since the Central Bank has adjusted its policy rate much more aggressively than before. Their findings are also consistent with one strand of the literature that postulates that the Central Bank cuts rates more strongly in the vicinity of the ZLB.[2]

[1] Markov N. (2009), "Actual versus Perceived Taylor Rules. How Predictable is the European Central Bank?"

[2] See for instance Reifschneider and Williams (2000) among others.

The second approach is based on a Markov Regime Switching policy framework. This methodology is more general as it allows for discrete changes of regimes which do not depend on any specific transition variable. The MRS models assume an abrupt discrete switch that takes place between some unobservable states rather than considering a gradual transition between regimes. There are several authors who have followed the latter approach as Assenmacher-Wesche (2006). The latter has estimated Central Banks' preferences from time-varying reaction functions for the U.S., U.K. and Germany within a two regimes MRS model. She has found that monetary policy in these countries features a low and a high inflationary regimes and that switching in the residuals' variance turns out to be important for the model's fit. Furthermore, the results indicate that the Deutsche Bundesbank has assigned a higher weight to inflation compared to the Federal Reserve and the main difference in monetary policies is driven by different preferences for interest rate smoothing. In addition, Owyang and Ramey (2004) estimate a MRS model for the U.S. over the period 1965-1999. Their estimates point to the presence of a "dove" and a "hawk" regimes in monetary policy. The researchers report evidence that the regime switches have also Granger caused both NBER's dating of recessions and Romer dates. Sims and Zha (2006) have investigated regime switches in the U.S. monetary policy over the period 1959-2003. Their best model features only a switching in the residuals' variance while among the coefficient switching models the best fit is given by a four regimes MRS model. More recently, Perruchoud (2009) has estimated a MRS forward-looking Taylor Rule for Switzerland over the period 1975-2007. He has found that Swiss monetary policy is described by a smooth and an active regimes. The latter involves a strong reaction of the Swiss National Bank to counteract large deviations of the exchange rate from its trend.

One should note that an alternative approach to the regime switching modeling would be to split the sample in different subsamples and estimate a model with breaks in the case of known break dates, or to estimate them endogenously.[3] In contrast with this method, the MRS model features much greater flexibility in dealing with nonlinearities since it estimates the regime switches using all available data. Moreover, it also differs from the LSTR specification in the sense that it is a more general framework to detect regime shifts without defining a priori any transition variable that drives the switch between regimes. Besides, the MRS model assumes that the regime shift occurs instantaneously as one would expect in a period of economic turmoil for instance. Therefore, in order to keep the model as flexible and general as possible in detecting all potential regime switches in the ECB policy rate, I have opted for the MRS approach in modeling the nonlinearity of the reaction function.

In that spirit, the paper contributes to the aforementioned literature on MRS models in three aspects. First, it analyzes potential nonlinearities in the European monetary policy at the frequency of the ECB Governing Council meetings from April 2000 until June 2010. Second, in the theoretical specification and in the empirical investigation I specify Actual and Perceived MRS Taylor Rules for the ECB. The latter is based on the professional point forecasts from a large investment bank of the key policy rate (the refi rate) for the upcoming Governing Council interest rate decision, while the former is based on the actual refi rate set by the Council at the corresponding policy meeting. Such a comparison will unveil whether the economists have foreseen the nonlinearity of the ECB Taylor Rule and have accurately predicted the regime switches of the actual refi rate. Third, the empirical evidence sheds more light on understanding the behavior of the ECB during the recent financial crisis.

The estimation results point to several major findings. First, the MRS model has identified two regimes for the European monetary policy: in the first one the Taylor Principle is satisfied and the policy rate exhibits a high level of inertia, while in the second regime

[3] In the latter case the researcher could follow the approach of Zivot and Andrews (1992) for instance.

the Central Bank puts a higher emphasis on the economic outlook downplaying the stabilization of inflation expectations. Second, the professional forecasters have broadly well predicted the policy regimes, as well as the timing of the switches. The augmented Taylor Rules point out that the Central Bank has most likely not responded to the growth rates of M3 and to the nominal effective exchange rate when setting the policy rate. In addition, the estimated coefficients are sensitive to the measure of inflation and real output growth expectations used in the regressions while the estimated regimes remain qualitatively unaltered. The empirical evidence also suggests that there might be a third regime in the Central Bank's responsiveness to economic fundamentals. The latter tends to occur in periods of monetary policy tightening but is sometimes difficult to disentangle from the presence of the second regime.

The structure of the paper is the following. Section 2 outlines the theoretical model, while the data and the methodological approach are described in section 3. The main empirical results are reported in section 4, while section 5 provides a sensitivity analysis of the baseline results using consensus data, an alternative forecast horizon and some additional variables. The extension to a three regimes switching model is presented in section 6 and the final part of the paper concludes on the empirical findings.

2 The Model

In line with most of the recent literature on Central Bank policy reaction functions, I estimate a forward-looking Taylor Rule which takes the following form[4]:

$$\bar{i}_{t+1} = r^* + \pi^* + \beta_\pi E_t \{\pi_{t+k} - \pi^* | \Omega_t\} + \beta_y E_t \{y_{t+k} - y^* | \Omega_t\} + \eta_{t+1} \tag{1}$$

where $\bar{i}_{t+1}$ denotes the Central Bank's target for the policy interest rate in period $t+1$, r^* and π^* are the equilibrium real interest rate and the inflation objective respectively. $E_t \{\pi_{t+k} - \pi^* | \Omega_t\}$ and $E_t \{y_{t+k} - y^* | \Omega_t\}$ are the inflation and real output growth expectations respectively formed in period t for a horizon $t+k$, in deviation from the inflation objective π^* and the trend real output growth rate y^*. Ω_t denotes the available information set in period t and η_{t+1} is a stochastic disturbance term. In order to account for the fact that Central Banks tend to adjust the policy rate gradually to the target level, I introduce the following partial adjustment mechanism for the policy rate:

$$i_{t+1} = \rho i_t + (1-\rho)\bar{i}_{t+1} + \xi_{t+1} \tag{2}$$

where i_{t+1} is the observed interest rate in period $t+1$, ρ is the interest rate smoothing parameter and ξ_{t+1} is a stochastic disturbance. This equation points out that the Central Bank implements a fraction $(1-\rho)$ of the desired policy rate target at each meeting of the policy committee. Combining equations (1) and (2) yields the final specification to be estimated:

$$i_{t+1} = \rho i_t + (1-\rho)[\alpha + \beta_\pi E_t \{\pi_{t+k} | \Omega_t\} + \beta_y E_t \{y_{t+k} | \Omega_t\}] + \epsilon_{t+1} \tag{3}$$

where $\alpha = r^* + \pi^*(1-\beta_\pi) - y^*\beta_y$.

Furthermore, in order to consider some potential nonlinearities in the forward-looking Taylor Rule, I estimate a two regimes first order Markov Regime Switching model (MRS) for the policy rate in which the coefficients can switch from one regime to another with

[4]The modeling approach is in line with the monetary policy rules estimated in Clarida, Galí and Gertler (1998) and (2000) for instance. The difference is that in this setting the Central Bank responds to the growth rate of real GDP in deviation from the growth rate of potential GDP instead to the output gap. Given the relatively short period since the inception of the ECB it is reasonable to assume that the potential GDP has remained constant.

some probability estimated from the data. Hence, by relaxing the linearity assumption the MRS model should permit to unveil whether the European monetary policy could be described by a Taylor Rule whose coefficient estimates change along with the state of the economy. In addition, given the swift reversal of the single monetary policy stance that has occurred on 8 October 2008, this model will permit to reveal whether and possibly how the ECB's behavior has changed at the turning point of the financial crisis. Therefore, it will show in which manner the Taylor Rule has to be specified in order to more accurately describe the monetary policy stance in normal and in crisis periods.

Based on equation (3), I estimate an Actual regime switching Taylor Rule which takes the following form:

$$i_{t+1} = \rho_{S_{t+1}} i_t + (1 - \rho_{S_{t+1}})[\alpha_{S_{t+1}} + \beta_{\pi_{S_{t+1}}} E_t \{\pi_{t+k}|\Omega_t\} + \beta_{y_{S_{t+1}}} E_t \{y_{t+k}|\Omega_t\}] + \epsilon_{1t+1} \quad (4)$$

where i_{t+1} denotes the refi rate set by the ECB Governing Council in period $t+1$.

I also estimate a Perceived regime switching Taylor Rule based on the professional point forecasts of the refi rate $E_t \{i_{t+1}\}$ one week ahead of the upcoming policy rate decision:

$$E_t \{i_{t+1}\} = \rho_{S_{t+1}} i_t + (1 - \rho_{S_{t+1}})[\alpha_{S_{t+1}} + \beta_{\pi_{S_{t+1}}} E_t \{\pi_{t+k}|\Omega_t\} + \beta_{y_{S_{t+1}}} E_t \{y_{t+k}|\Omega_t\}] + \epsilon_{2t} \quad (5)$$

where ϵ_{1t+1} is i.i.d $N(0, \sigma^2_{\epsilon_1})$, ϵ_{2t+1} is i.i.d $N(0, \sigma^2_{\epsilon_2})$.
The regime-dependent Actual Taylor Rule becomes the following:

$$i_{t+1} = \rho_{S_{t+1}} i_t + \gamma'_{S_{t+1}} x_t + \epsilon_{1t+1} \quad (6)$$

The regime switching Perceived Taylor Rule can be written in a similar way:

$$E_t \{i_{t+1}\} = \rho_{S_{t+1}} i_t + \gamma'_{S_{t+1}} x_t + \epsilon_{2t} \quad (7)$$

where

$$x_t = [1 \quad E_t \{\pi_{t+k}|\Omega_t\} \quad E_t \{y_{t+k}|\Omega_t\}]' \quad (8)$$

$$\gamma_{S_{t+1}} = [(1 - \rho_{S_{t+1}})\alpha_{S_{t+1}} \quad (1 - \rho_{S_{t+1}})\beta_{\pi_{S_{t+1}}} \quad (1 - \rho_{S_{t+1}})\beta_{y_{S_{t+1}}}]' \quad (9)$$

The parameters $\gamma_{S_{t+1}}$ are assumed to be driven by two regimes depending on the unobservable latent variable S_{t+1}. The latter takes the value 0 or 1 for the first and the second regimes correspondingly:

$$\rho_{S_{t+1}} = \rho_1(1 - S_{t+1}) + \rho_2 S_{t+1} \quad (10)$$

$$\beta_{\pi_{S_{t+1}}} = \beta_{\pi_1}(1 - S_{t+1}) + \beta_{\pi_2} S_{t+1} \quad (11)$$

$$\beta_{y_{S_{t+1}}} = \beta_{y_1}(1 - S_{t+1}) + \beta_{y_2} S_{t+1} \quad (12)$$

$$\alpha_{S_{t+1}} = \alpha_1(1 - S_{t+1}) + \alpha_2 S_{t+1} \quad (13)$$

The dummy variable S_{t+1} is assumed to be driven by the Markov transition probabilities which can be written as follows:

$$p_{ij} = p(S_{t+1} = j|S_t = i), \qquad i, j = 1, 2 \quad (14)$$

$$\Pi = \begin{bmatrix} \pi_{11} & \pi_{21} \\ \pi_{12} & \pi_{22} \end{bmatrix}$$

where Π denotes the Markov transition probabilities matrix and the rows refer to regimes 1 and 2 respectively.[5]

3 Data and methodology

The data set contains real-time point forecasts of inflation and real GDP growth for the euro area reported by the economists of a large investment bank in their weekly economic research publications.[6] Since the market participants do not report forecasts of the output gap I use the projections of real GDP growth in the regressions.[7] In addition, the professional forecasters of the bank also report the main point forecast of the refi rate for the upcoming interest rate decision of the ECB Governing Council. The forecasts are made in general one week before the corresponding monetary policy meeting and span the period from April 2000 until June 2010. The frequency of the observations thus corresponds to the meetings of the Governing Council of the ECB which are in general monthly.[8] Data on the key policy interest rate are taken from the official website of the ECB. Given that the weekly reports contain the economists' expectations about the future policy rate, this framework permits to assess the predictability of the European monetary policy within the regime switching Actual and Perceived Taylor Rules.

Regarding the forecasts of economic fundamentals, the economists report their main point projection of inflation and real GDP growth for the current year and the year ahead. As the latter are directly observed by the forecasters and the ECB and are used to predict the refi rate these variables are considered as exogenous. This assumption is corroborated by the formal difference-in-Sargan statistics which do not find evidence against the null hypothesis of exogeneity. A detailed description of the data and some summary statistics are provided in tables A.1 and A.2 in the appendix. The average inflation expectations for the year ahead are 1.788% and 1.790% for the investment bank economists and the consensus forecasters respectively and they are fully consistent with the ECB's inflation objective. Tables A.3 and A.4 report the unit root and stationarity tests of the series used in the estimations. The Augmented Dickey-Fuller (ADF) and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test statistics point out that in general the variables are stationary. However, as found in the first chapter some of the Phillips-Perron (PP) tests do not show evidence against the null hypothesis of unit root for some of the series, in particular for the actual and forecasted refi rates and for the GDP growth forecasts. This result is probably due to the low power of the test statistics in small samples and to the magnitude of the

[5] Each row indicates the probability to remain in the corresponding regime as well as the probability to switch to another regime. As the probabilities reported in each row represent all possible outcomes within each regime they have to sum to one.

[6] I have built-up the database from their weekly reports made in general one week before the upcoming monetary policy meeting of the ECB. The forecasts are provided in real-time and thus are not subject to the Orphanides' critique (2001).

[7] This approach is consistent with the speed limit policy described by Walsh (2003). The latter has emphasized that a policy rule in which the Central Bank responds to the change in the output gap delivers the optimal pre-commitment policy outcome. This policy is welfare improving especially in the case of imperfect observation of the output gap. In the present setting I have assumed a constant level of potential output given the relatively short time period.

[8] The Governing Council has taken monetary policy decisions twice a month until October 2001. However, as shown in Markov (2009) accounting for the higher frequency of the meetings before October 2001 does not seem to be important for the interest rate setting policy. Besides, the regime switching estimates do not show evidence for a change in the Taylor Rules related to the frequency of the monetary policy meetings.

economic contraction during the recent financial crisis. The latter is explicitly accounted for in the regime switching specification. Based on the methodology of Gorter, Jacobs and de Haan (2008) I use two approaches in constructing the expectations of inflation and real output growth that are used in the empirical analysis.

In a first approach to modeling the expectations of inflation and real output growth I use for each period t the inflation and real GDP growth forecasts for the year ahead. The attractiveness of this methodology is that it is entirely forward-looking since I consider the forecasters' expectations for the year ahead. It is also in line with the method used in Poplawski-Ribeiro and Rülke (2010) in their investigation of the impact of the Stability and Growth Pact on the forecast accuracy of the public budget deficit in the euro area by the market participants. This approach could also better reflect the observed long and variable lags in the monetary policy transmission process.

The second methodology considers a fixed forecast horizon of one year which is computed using the following formula:

$$\bar{x}_{y,h} = \frac{361-h}{360} x_{y,h} + \frac{h-1}{360} x_{y+1,h}$$

where $x_{y,h}$ is any of the current year (y) forecasts of the macroeconomic variables reported on day h and $x_{y+1,h}$ stands for the year ahead ($y+1$) projections reported on the same day. The indices y and h take respectively the values $y = 2000, \ldots, 2010$ and $h = 1, \ldots, 360$ assuming 360 days within a year which is a standard assumption for financial markets participants.

The advantage of this approach is that one obtains a fixed horizon of one year for the inflation and real GDP growth forecasts. However, there are also some drawbacks related to this methodology. First, the variables computed are not entirely forward-looking because I consider the expectations of the series for the current year in their computation. Second, by applying this formula we cannot assign a specific forecasting horizon to the variables computed because they encompass any period that is between the current year and the year ahead. Moreover, given that these variables are constructed from the economists' reports they may not correspond well to the way the economists form their expectations of macroeconomic variables. Conversely, the year ahead forecasts are directly reported by the economists and are observed by the Central Bank in real-time, and hence are more likely to correspond to the expectations formation process of the private sector about macroeconomic fundamentals compared to the expectations variables obtained with the second approach.

Finally, in the empirical part of the paper the first methodology yields better results which points out that the year ahead forecasts of the variables provide a good measure for the forward-looking expectations of inflation and output growth of the investment bank's economists and the consensus forecasters. The one-year fixed horizon forecasts obtained with the second approach are less likely to reflect the expectations formation process of the professional forecasters as they yield less satisfactory results and do not imply a preemptive behavior of the Central Bank.

The estimation approach closely follows the methodology developed in the seminal paper of Hamilton (1989), which is also explained in Hamilton (2005) and is derived in Kim and Nelson (1999). In the first paper, Hamilton develops a classical method for estimating regime switching models which is based on an Iterative Maximum Likelihood Estimation (I-MLE). This methodology provides the best unbiased estimator for linear and nonlinear regressions with identically and independently distributed error terms. It is important to emphasize that in Markov switching models the GMM approach is not feasible because of the presence of the unobservable latent variable S_{t+1}. Therefore, all regressions are performed with the I-MLE algorithm of Hamilton. To control for a potential endogeneity that could arise when including the lagged dependent variable as a regressor,

I have performed Portmanteau and BDS white noise tests as well as LM tests for serial correlation of the residuals. The test statistics point out that there is no evidence against the absence of autocorrelation in the residuals and the latter can be considered as white noise processes.

The estimation algorithm derived below is based on the methodology exposed in Kim and Nelson (1999). The Actual Taylor Rule of equation (6) can be written in the following more compact form[9]:

$$i_{t+1} = \Theta'_{S_{t+1}} z_t + \epsilon_{1t+1}, \qquad t = 1, 2, ..., T \tag{15}$$

where

$$\Theta_{S_{t+1}} = \begin{bmatrix} \rho_{S_{t+1}} \\ \gamma'_{S_{t+1}} \end{bmatrix}, z_t = \begin{bmatrix} i_t \\ x_t \end{bmatrix} \tag{16}$$

and

ϵ_{1t+1} is $i.i.d\ N(0, \sigma^2_{\epsilon_1})$

First, in order to start the optimization algorithm one has to consider the joint density function of i_{t+1} and the unobserved state S_{t+1}:

$$f(i_{t+1}, S_{t+1}|\Psi_t) = f(i_{t+1}|S_{t+1}, \Psi_t) f(S_{t+1}|\Psi_t) \tag{17}$$

where Ψ_t refers to the available information set at time t. The marginal density function of i_{t+1} is then obtained in the following way:

$$\begin{aligned} f(i_{t+1}|\Psi_t) &= \sum_{S_{t+1}=0}^{1} f(i_{t+1}, S_{t+1}|\Psi_t) \\ &= \sum_{S_{t+1}=0}^{1} f(i_{t+1}|S_{t+1}, \Psi_t) f(S_{t+1}|\Psi_t) \\ &= f(i_{t+1}|S_{t+1} = 0, \Psi_t) Pr[S_{t+1} = 0|\Psi_t] + f(i_{t+1}|S_{t+1} = 1, \Psi_t) Pr[S_{t+1} = 1|\Psi_t] \end{aligned} \tag{18}$$

The associated log likelihood function is a weighted average of the density functions in the two regimes and takes the following form:

$$LogLik = \sum_{t=1}^{T} Log\Big[\sum_{j=0}^{1} f(i_{t+1}|S_{t+1}, \Psi_t) Pr[S_{t+1} = j|\Psi_t]\Big] \tag{19}$$

The weights are given by the transition probabilities and can be written as follows:

$$\begin{aligned} Pr[S_{t+1} = j|\Psi_t] &= \sum_{i=0}^{1} Pr[S_{t+1} = j, S_t = i|\Psi_t] \\ &= \sum_{i=0}^{1} Pr[S_{t+1} = j|S_t = i] Pr[S_t = i|\Psi_t] \end{aligned} \tag{20}$$

where $Pr[S_{t+1} = j|S_t = i]$ denotes the states' transition probabilities. At the end of each period $t+1$, i_{t+1} is observed and one has to apply an iterative filter to update the filtered probabilities:

[9] The same algorithm can be applied to the Perceived Taylor Rule in a straightforward way.

$$Pr[S_{t+1} = j|\Psi_{t+1}] = Pr[S_{t+1} = j|\Psi_t, i_{t+1}] = \frac{f(S_{t+1} = j, i_{t+1}|\Psi_t)}{f(i_{t+1}|\Psi_t)} \tag{21}$$
$$= \frac{f(i_{t+1}|S_{t+1} = j, \Psi_t)Pr[S_{t+1} = j|\Psi_t]}{\sum_{j=0}^{1} f(i_{t+1}|S_{t+1} = j, \Psi_t)Pr[S_{t+1} = j|\Psi_t]}$$

This approach can also be used to compute the smoothed regime probabilities (using all available information up to the final observation T):

$$Pr[S_{t+1} = j|\Psi_t], \qquad t = 1, 2, ..., T \tag{22}$$

To start the filter in the first period one can use the unconditional states' probabilities for the first and the second regimes respectively:

$$\pi_1 = Pr[S_1 = 0|\Psi_0] = \frac{1-p}{2-p-q}, \qquad \pi_2 = Pr[S_1 = 1|\Psi_0] = \frac{1-q}{2-p-q} \tag{23}$$

where p and q are the unconstrained parameters.
Using the described methodology the following section presents the estimation results for the Actual and Perceived MRS TR.[10]

4 Empirical evidence

The goal of the MRS TR specification is to uncover whether the standard forward-looking policy reaction function hides any finer monetary policy regimes that could not have been detected by a linear policy rule. Moreover, a comparison between the Actual and Perceived Taylor Rules will reveal whether the investment bank's economists have accurately predicted the magnitude and the timing of the actual regime switches of the ECB's main policy rate. In the following subsection, I first present the estimation results for the Actual Taylor Rule using the inflation and real output growth forecasts for the year ahead.[11]

4.1 Actual regime switching Taylor Rule

In a first approach, I estimate a baseline model which allows for a switching in the model's coefficients across two possible regimes. The model features regime shifts in the policy inertia, inflation and real GDP growth coefficients.[12] Indeed, in a general framework one can rationally assume that the Central Bank's responsiveness to key macroeconomic fundamentals, such as inflation and real output growth, might depend on the state of the euro area economy. The ECB might be more inclined to implement a more hawkish monetary policy in a highly inflationary environment consistently with its policy mandate, and to behave more dovishly in a state of economic downturn or in an economic crisis.

[10] All estimations are derived from numerical optimization that has been implemented in Matlab R2010a and are based on the estimation algorithm developed by Perlin M. (2009).

[11] The favorite specifications contain the real-time professional forecasts of inflation and real output growth for the year ahead instead of the one-year horizon forecasts computed with the second approach. Indeed, the former yield more satisfactory results compared to the latter. However, in section 5, I also present the estimation results using the alternative one-year horizon forecasts.

[12] The models do not feature a switching in the constant term because it does not produce satisfactory results and there is evidence that the constant has not switched across regimes in the more general specification.

The MRS model in this paper assumes that the transition probabilities of the regimes are governed by a first order Markov chain process and are also reported along with the coefficient estimates. Table 1 reports the estimation results for the Actual Taylor Rule.

Table 1: Actual MRS Taylor Rule, Baseline Model (BM)

	Regime 1	Regime 2
$\rho_{s_{t+1}}$	0.9859***	0.9300***
	(0.0050)	(0.0190)
$\gamma_{\pi_{s_{t+1}}}$	0.0315***	-0.1864***
	(0.0040)	(0.0377)
$\gamma_{y_{s_{t+1}}}$	0.0052***	0.0441***
	(0.0001)	(0.0010)
γ_c	-0.0000	
	(0.0000)	
σ_ϵ	0.0009***	
	(2.350e-05)	
$P[S_{t+1} = i \mid S_t = 1]$	0.9484***	0.0516***
	(0.1393)	(0.0015)
$P[S_{t+1} = i \mid S_t = 2]$	0.5831***	0.4169***
	(0.1123)	(0.0521)
Observations	141	
Log-likelihood	749.329	

Note: The table displays the short-run coefficients. $\rho_{s_{t+1}}$, $\gamma_{\pi_{s_{t+1}}}$, $\gamma_{y_{s_{t+1}}}$, γ_c denote the policy inertia, inflation and output growth expectations coefficients respectively and the constant term. Estimates in the middle of the columns refer to parameters that do not switch across regimes. Iterative MLE, HAC standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

From the results of table 1 one can observe the emergence of two different policy regimes with statistically significant parameter estimates. In the first one monetary policy is quite inertial and the ECB raises the refi rate in the event of an increase in the inflation and real output growth forecasts. Conversely, in the second one the policy stance becomes more aggressive as the Central Bank implements a larger fraction of the desired policy rate in each period. Besides, while the ECB responds positively to the economic outlook, the coefficient estimate on inflation expectations is negative in the second regime. The increasing aggressiveness of the Central Bank in the crisis regime is in line with the findings reported in the literature as in Belke and Klose (2010), Gerlach and Lewis (2010) and Mishkin (2009) for instance. As regards the estimated transition probabilities, one can see that the first regime is particularly persistent compared to the smaller probability of occurrence of the second regime. The average duration of the former is about 19.38 policy meetings while the latter lasts on average 1.71 meetings. Furthermore, there is a much higher probability of transiting into regime 1 conditional on being in the second regime compared to the lower probability of entering the second regime conditional on being in the first one. Indeed, once the policy rate has entered the second regime it has a greater chance to transit back again to the first one. The long-run response coefficients of the model, $\beta_{\pi_{S_{t+1}}}$ and $\beta_{y_{S_{t+1}}}$, as well as some relevant statistics are reported in table 2.

Table 2: Actual MRS Taylor Rule, BM long-run parameters

	Regime 1	Regime 2
$\rho_{s_{t+1}}$	0.9859***	0.9300***
	(0.0050)	(0.0190)
$\beta_{\pi_{s_{t+1}}}$	2.2400**	-2.6631***
	(1.0744)	(0.1951)
$\beta_{y_{s_{t+1}}}$	0.3688***	0.6304***
	(0.1378)	(0.1577)
Observations	141	
LL MRS model	749.329	
LL linear model	729.030	
LR test	40.598***	
AIC MRS model	-1474.659	
BIC MRS model	-1439.274	
AIC linear model	-1448.060	
BIC linear model	-1433.316	
RMSE MRS model	0.000899	
RMSE linear model	0.001375	

Note: The table displays the implied long-run coefficients. $\rho_{s_{t+1}}$, $\beta_{\pi_{s_{t+1}}}$, $\beta_{y_{s_{t+1}}}$ denote the policy inertia, inflation and output growth expectations coefficients respectively. Estimates in the middle of the columns refer to parameters that do not switch across regimes. Standard errors are computed with the Delta method and are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

As table 2 shows the estimated long-run coefficients are statistically significant in both regimes. In the first one, the refi rate is particularly inertial and the Central Bank implements a stabilizing policy for both the inflation and real output growth expectations.[13] As pointed out before, in the second regime monetary policy becomes more aggressive and it seems that the Central Bank does not prioritize the stabilization of inflation expectations since the estimated coefficient is negative. On the contrary, its policy is geared towards stabilizing the economic outlook as reflected in the increasing output growth forecasts responsiveness coefficient.

In order to corroborate the economic intuition about the estimated regimes it is important to test explicitly for the number of regimes against the null hypothesis of one regime estimated with a linear model. However, the testing procedure is complicated by the fact that there is a problem of nuisance parameters as the transition probabilities are not identified under the null hypothesis of linearity.[14] To overcome this problem I follow the approach of Assenmacher-Wesche (2006), Tillmann (2003) and Jeanne and Masson (2000). Hence, in performing the Likelihood Ratio (LR) test for the number of regimes the test statistic is compared to a $\chi^2(d+n)$ distribution where d corresponds to the number of restrictions tested and n indicates the number of unidentified nuisance parameters under the null hypothesis.[15] In the empirical literature it is commonly acknowledged that this is a rather conservative approach in testing the number of regimes as the test statistic fails

[13] For an inflation stabilizing regime $\beta_{\pi_{S_{t+1}}}$ should be higher than one according to the Taylor Principle, while $\beta_{y_{S_{t+1}}}$ should be positive to observe a stabilizing policy for the economic outlook.

[14] This problem is extensively documented in Garcia (1998), Hamilton (1994), Hansen (1992) and (1996) for instance.

[15] The LR test statistic is computed in the following way:

$$LR = 2[LL(\gamma|Y) - LL(\gamma^*|Y)] \tag{24}$$

where $LL(\gamma^*|Y)$ denotes the value of the log-likelihood function obtained in the constrained linear model.

to reject the null hypothesis of linearity too often when the latter is actually false (a type two error).

Table 2 indicates that the LR statistic is highly statistically significant and corroborates the presence of two regimes in the estimated monetary policy rule. Furthermore, a comparison of the AIC and BIC information criteria between the MRS and the linear models points out that the regime switching specification is also preferred from a model selection perspective. Finally, in line with the previous evidence it is also important to emphasize that the model performance is much better when using a regime switching specification rather than a linear model. Indeed, an inspection of the Root Mean Squared Error (RMSE) of the models indicates that the nonlinear specification should be preferred to the linear one as the former more accurately predicts the actual policy rate of the ECB within the sample.

In addition, one could also test for a higher number of regimes. Section 6 reports the estimation results from a three regimes model along with the LR test statistic. However, it should be noted that it seems rather implausible that a higher order of policy regimes has prevailed given the relatively short time span that has elapsed since the inception of the ECB. Even though there is some statistical evidence for a three regimes model the baseline specification features two regimes which are also more in line with the economic intuition.

In order to provide an economic interpretation of the policy behavior of the Central Bank in the estimated regimes one should examine the estimated filtered regime probabilities along with the refi rate set by the ECB and the one forecasted by the economists of the investment bank. These variables are displayed in figure 1.[16]

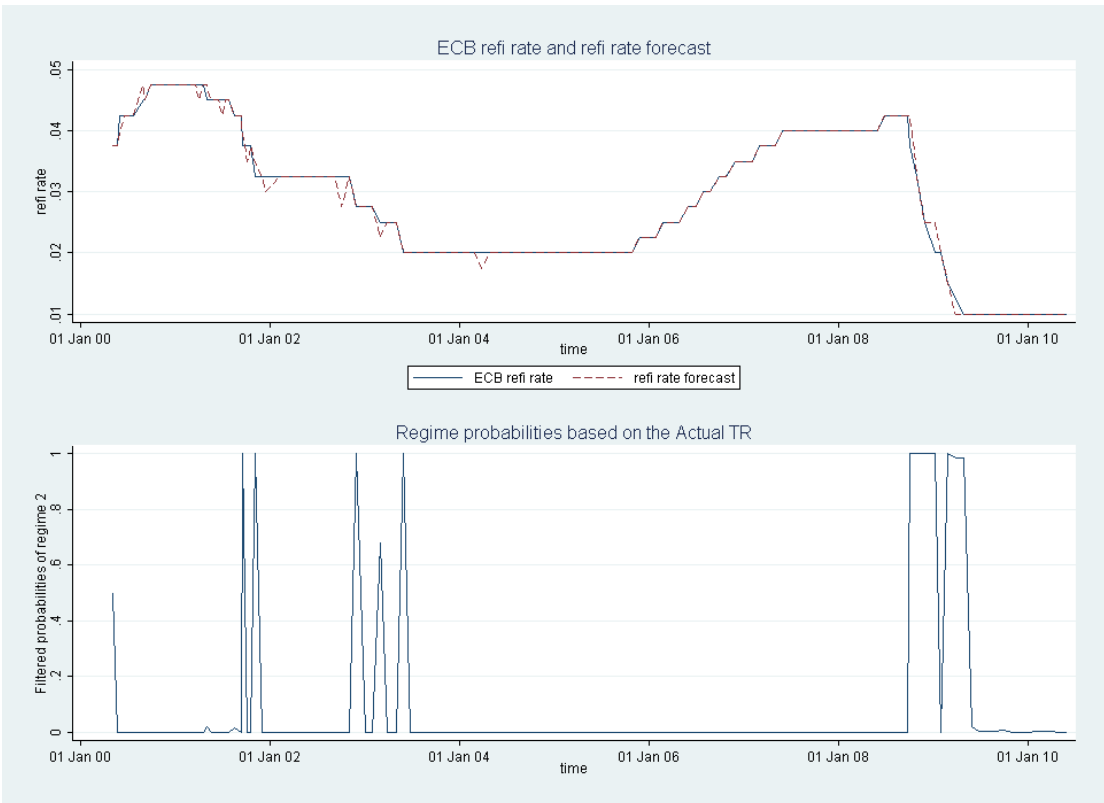

Figure 1: Actual filtered probabilities, baseline model

[16] I report the filtered probabilities instead of the smoothed ones because the former are estimated using only currently available information instead of considering all observations. This approach is more consistent with the real-time spirit of the paper. The results are qualitatively very similar when using the estimated smoothed probabilities.

Figure 1 shows that there have been several switches of the actual refi rate set by the ECB between the estimated regimes. With a view to providing an economic interpretation to the regime switches one should compare the actual filtered probabilities with the refi rate that has been effectively set by the ECB Governing Council. In that perspective one can see that regime 1 tends to occur both in periods of monetary policy easing and tightening, whereas regime 2 takes place only in periods that feature swift interest rate cuts. Therefore, periods of sharp reduction in the main policy rate are characterized by a change in the policy inertia, inflation and real output growth responsiveness of the Central Bank. Moreover, a switch to the second regime seems to occur during economic downturns that often require sharp interest rate cuts, as in the period from 2001 to 2003, and in particular during the recent financial crisis from October 2008 until the first half of 2009.[17]

The empirical evidence thus suggests that regime 1 could be attributed to a policy stance that takes place in normal (non crisis) periods, while regime 2 points to a crisis behavior on the part of the Central Bank which occurs in times of economic turmoils. In fact, in the latter the ECB's responsiveness to economic fundamentals changes sharply: the Central Bank adjusts faster the refi rate and focuses on stabilizing the economic outlook rather than inflation expectations.

In the following subsection I present the estimation results for the Perceived regime switching Taylor Rule. The latter is based on the economists' point forecasts of the refi rate for the upcoming monetary policy meeting using the inflation and real output growth forecasts for the year ahead in real-time.

4.2 Perceived regime switching Taylor Rule

The estimation of the regime switching Taylor Rule for the professional forecasters permits to unveil whether the latter have accurately predicted the actual policy regimes of the Central Bank. As with the Actual ECB Taylor Rule, I have adopted a general approach in the estimation procedure by allowing all policy responsiveness coefficients to switch across regimes. The transition probabilities are reported along with the coefficient estimates of the model as previously highlighted.

The estimated coefficients presented in table 3 firmly corroborate the previous results obtained for the Actual Taylor Rule. Indeed, in regime 1 the ECB reacts positively and significantly to the inflation and real output growth forecasts, while in regime 2 it focuses on stabilizing the real output growth expectations and implements a less inertial policy. In light of the transition probabilities, the first regime appears to be highly persistent compared to the smaller probability of occurrence of regime 2.

Indeed, the average duration of the former is 20.04 policy meetings, while the latter is much short-lived as it lasts on average 1.42 meetings of the Governing Council. In addition, similarly to the results obtained for the Actual Taylor Rule, there is a much higher probability of transiting back into the first regime conditional on being in the second one than to enter the second regime conditional on being in the first one. The long-run response coefficients of the model, $\beta_{\pi_{S_{t+1}}}$ and $\beta_{y_{S_{t+1}}}$, as well as some relevant statistics are reported in table 4.

[17] It is important to emphasize, that in the 2001-2003 monetary policy easing the refi rate has been cut by 275 basis points, while in the 2008-2009 series of interest rate cuts it has been reduced by 325 basis points. While in terms of magnitude the reduction of the refi rate is of a similar order, the latter interest rate cuts have lasted only 8 months.

Table 3: Perceived MRS TR, Baseline Model (BM)

	Regime 1	Regime 2
$\rho_{s_{t+1}}$	0.9737***	0.8900***
	(0.0053)	(0.0166)
$\gamma_{\pi_{s_{t+1}}}$	0.0360***	-0.1430***
	(0.0023)	(0.0033)
$\gamma_{y_{s_{t+1}}}$	0.0158***	0.0249***
	(0.0014)	(0.0011)
γ_c	0.0000	
	(0.0000)	
σ_ϵ	0.0010***	
	(3.297e-05)	
$P[S_{t+1} = i \mid S_t = 1]$	0.9501***	0.0499***
	(0.0177)	(0.0022)
$P[S_{t+1} = i \mid S_t = 2]$	0.7039***	0.2961***
	(0.0128)	(0.0149)
Observations	141	
Log-likelihood	736.512	

Note: The table displays the short-run coefficients. $\rho_{s_{t+1}}$, $\gamma_{\pi_{s_{t+1}}}$, $\gamma_{y_{s_{t+1}}}$, γ_c denote the policy inertia, inflation and output growth expectations coefficients respectively and the constant term. Estimates in the middle of the columns refer to parameters that do not switch across regimes. Iterative MLE, HAC standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Perceived MRS Taylor Rule, BM long-run parameters

	Regime 1	Regime 2
$\rho_{s_{t+1}}$	0.9737***	0.8900***
	(0.0053)	(0.0166)
$\beta_{\pi_{s_{t+1}}}$	1.3683***	-1.3002***
	(0.3408)	(0.1694)
$\beta_{y_{s_{t+1}}}$	0.6002***	0.2261***
	(0.1661)	(0.0439)
Observations	141	
LL MRS model	736.512	
LL linear model	730.705	
LR test	11.614	
AIC MRS model	-1449.023	
BIC MRS model	-1413.638	
AIC linear model	-1451.411	
BIC linear model	-1436.667	
RMSE MRS model	0.001011	
RMSE linear model	0.001359	

Note: The table displays the implied long-run coefficients. $\rho_{s_{t+1}}$, $\beta_{\pi_{s_{t+1}}}$, $\beta_{y_{s_{t+1}}}$ denote the policy inertia, inflation and output growth expectations coefficients respectively. Estimates in the middle of the columns refer to parameters that do not switch across regimes. Standard errors are computed with the Delta method and are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

The empirical evidence points to the presence of two regimes for the perceived policy reaction function as well. In both regimes the estimated coefficients are significant and

corroborate the results previously found for the actual policy rule. However, the LR test statistic does not show evidence against the restricted linear model. This result is possibly attributed to the particularly conservative approach adopted when computing the LR test statistic. The latter often fails to reject the null hypothesis of linearity even when it is actually false. In terms of the AIC information criterion the difference between the MRS and the linear models is very small, while the BIC criterion suggests that the linear model is more likely to be preferred from the perspective of model selection. Nevertheless, it is better to estimate a regime switching model in order to more accurately predict the policy rate as indicated by the lower RMSE of the MRS model compared to the higher RMSE of the linear specification.

The estimation results point out that the professional forecasters have quite accurately foreseen the Actual regime switching Taylor Rule. Indeed, based on the Perceived Taylor Rule regime 1 features a particularly inertial policy rate and monetary policy exerts a stabilizing effect both on inflation expectations and on the output growth forecasts. Notice that the estimated coefficients in the first regime are well in line with the empirical findings in the literature. Besides, the economists have perceived the ECB to put a higher emphasis on the economic outlook relative to inflation stabilization when switching to the second regime, consistently with the evidence for the actual policy rule. It is also important to highlight that, even though the inflation coefficient estimate is negative in the second regime for both the Actual and Perceived Taylor Rules, monetary policy is not necessarily destabilizing for inflation because of the short average duration of this regime and the fact that the algorithm maximizes the joint probability distribution of the policy rates and the regimes. Figure 2 displays the filtered probabilities of the second regime for the Perceived Taylor Rule.

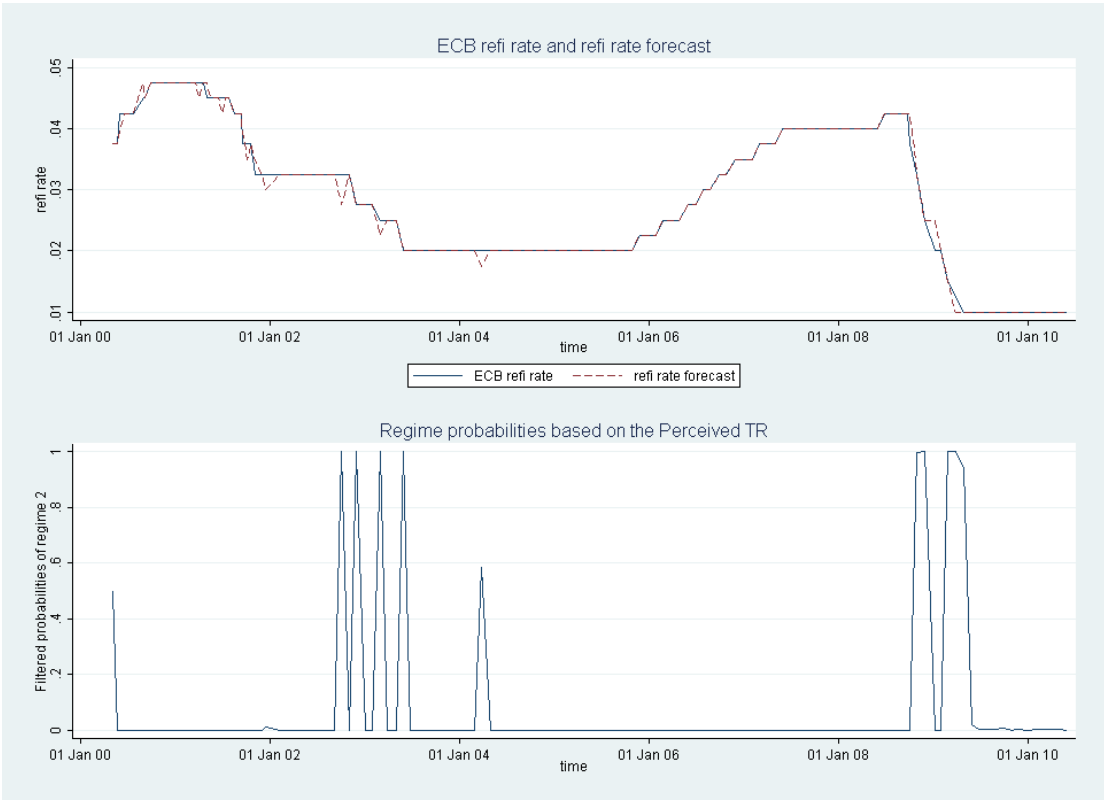

Figure 2: Perceived filtered probabilities, baseline model

The perceived filtered probabilities provide evidence for the accurate perceptions of the professional forecasters about the actual regime switches of the main policy rate estimated

with the actual policy rule. Indeed, the timing of the perceived regime switches is broadly well aligned with the actual dates of the regime shifts. As pointed out earlier, the first regime occurs both in periods of monetary policy easing and tightening, while the second one appears in times of economic downturns that require swift interest rate cuts. The economists have accurately perceived the switch to the second regime in the 2001-2003 policy easing, as well as more recently during the broadening of the financial crisis since October 2008 until the first half of 2009. However, there is a slight difference compared to the actual regime shifts because the economists have not foreseen the initial stage of the series of policy rate cuts that has started in the second half of 2001. Besides, the professional forecasters have also expected a higher probability of a switch to the second regime in March 2004 that has not been estimated with the actual policy reaction function. Indeed, this perception is related to the forecast of a policy rate cut for the 1st April 2004 meeting of the Governing Council which actually has not materialized. The next subsection presents a more detailed analysis of the timing of the regime switches based on a comparison between the actual and perceived filtered probabilities.

4.3 Actual and Perceived filtered probabilities

This subsection offers a detailed analysis of the actual and perceived filtered probabilities of the estimated regimes. The goal is to assess the accuracy of the professional economists' predictions of the actual filtered regime probabilities and to shed more light on understanding the driving factors of the regime switches during the first decade of single European monetary policy. Figure 3 displays the estimated filtered probabilities.

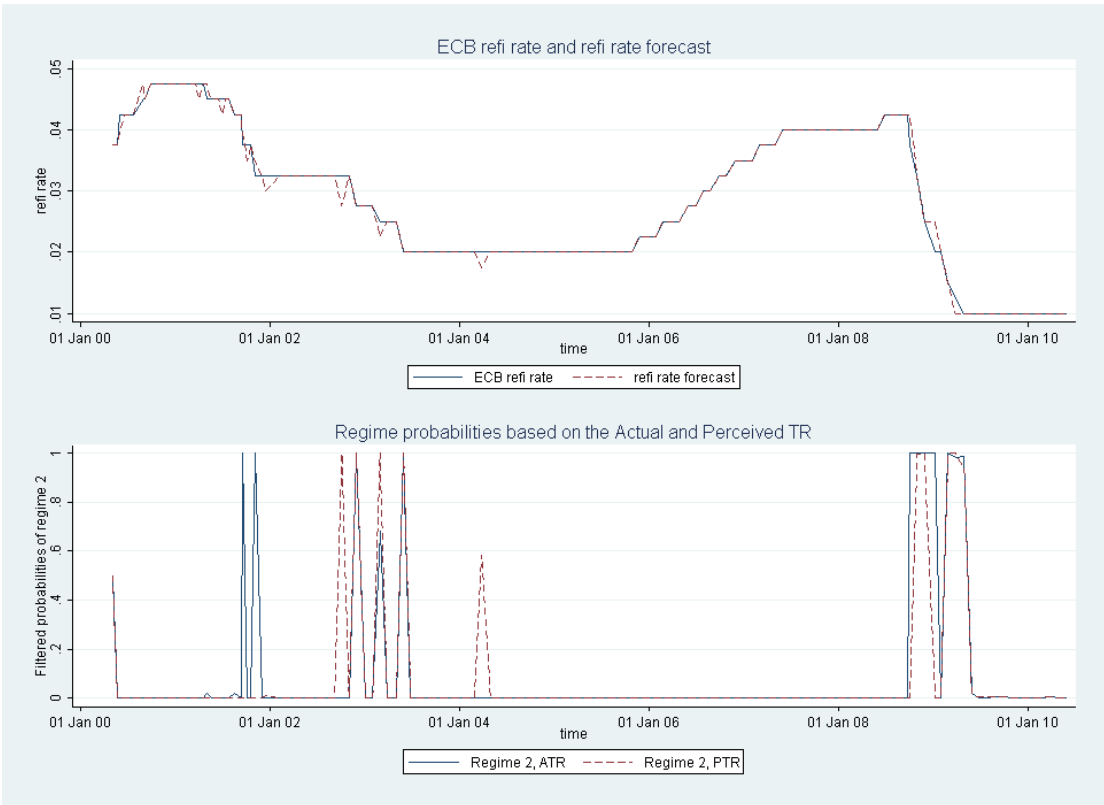

Figure 3: Actual and perceived filtered probabilities, baseline model

As previously reported, it is compelling to notice that the professional forecasters have quite accurately predicted the actual regime switches of the ECB over the last decade. However, as regards the 2001-2003 interest rate cuts a closer inspection of figure 3 reveals

that there have been some misalignments between the actual and perceived filtered probabilities. The first one occurs with the sharp 50 basis points reduction of the key policy rate that the ECB has implemented in September 2001. Indeed, the economists have not expected the exact magnitude of that rate cut as well as the subsequent switch of the refi rate to the second regime. The second mismatch appears in November 2001 when the professional forecasters have not expected the switch of the policy rate to the second regime that has occurred following the 50 basis points cut of the refi rate. Then, in October 2002, as well as in March 2004, the refi rate point forecast has switched to the second regime as the economists have expected further policy rate cuts that actually have not materialized.

Concerning the recent financial crisis, one can notice that until 8 October 2008 the actual and forecasted policy rates have remained in the first regime. Then, after the sharp reduction of the refi rate that has been implemented on the same day, the actual policy rate has switched to the second crisis regime. As regards the forecasted policy rate the observed pattern is broadly identical with some exceptions. The latter has switched to the second regime only at the following monetary policy meeting in November 2008, probably because the economists have not expected the sharp refi rate cut. Regarding the actual policy rate it has remained in the second regime until January 2009 and then has switched back to the first policy regime in February 2009. Turning to the perceived policy rule, the refi rate point forecast has remained in the second regime until December 2008 and then has switched back again to the first inflation stabilizing regime as the professional forecasters have not expected the 50 basis points rate cut occurring in January 2009. Then, as the ECB has resumed the interest rate cuts in the first half of 2009, the actual as well as the forecasted policy rates have switched back again to the second regime in March 2009 and have stayed there until May 2009. Since June 2009 both Taylor Rules have switched back to the first regime and have firmly remained there until June 2010 which is the final observation in the data set.[18]

Therefore, a closer analysis of the recent financial crisis reveals that while there have been broadly similar perceptions of the economists about the actual regime switches, it seems that the professional forecasters have exhibited a delayed perception of the actual timing of the ECB regime switches. This finding may be attributed to some gradual learning process about the actual monetary policy stance that has taken place especially in such a period of financial turbulence. Finally, in the period studied the switching to the crisis regime usually takes place once a sharp reduction of the main policy rate of about 50 to 75 basis points is either observed or/and expected. Furthermore, the empirical results obtained with the regime switching specification partly corroborate the findings of Gerlach and Lewis (2010). The authors model the ECB interest rate policy in the vicinity of the Zero Lower Bound within a logistic smooth transition regression. They have found that the best model for the ECB's key policy rate in the crisis regime is an AR(1) process for the interest rate. Indeed, in a period of economic downturn the ECB might respond less to economic fundamentals and could be more inclined to sharply cut the policy rate to secure the stability of the euro area financial system. Consistently with their results, I find that in a crisis period the Central Bank enters a second policy regime and cuts rates faster compared to a normal period. However, in contrast with their evidence, in the second regime the Central Bank still responds, but in a differentiated way to key macroeconomic fundamentals. The difference in the ECB's responsiveness between the 2000-2001 crisis and the 2007-2009 economic downturn lies in the duration of the crisis regime. In fact, while during the 2001-2003 cycle of policy rate cuts the second regime has occurred sporadically during very short periods, in the 2008-2009 series of interest rate cuts the refi rate has

[18] It is interesting to notice that the switch back to the normal policy regime has occurred in the same quarter as the end of the recession in the euro area as announced by the Euro Area Business Cycle Dating Committee. Possibly, as economic fundamentals have improved the ECB has prioritized its long-run price stability goal.

remained longer in the crisis regime. This evidence reflects the pronounced severity of the recent turmoil compared to the earlier crisis.

4.4 Actual and Perceived fitted policy rates

In this subsection I present the graphs of the fitted policy rates obtained with the estimated Actual and Perceived regime switching Taylor Rules. This analysis is important as it permits to better understand whether a nonlinear specification of the Taylor Rule fits more closely the actual policy rate.[19] The goal of this subsection is to provide a graphical analysis of the estimation results and to highlight the advantage of using a regime switching approach compared to a linear model in performing the in-sample predictions of the policy rate. Furthermore, the analysis should unveil whether there is any difference in the implied policy rate targets when using a nonlinear specification compared to the policy rate target predicted from a linear model.[20]

I first start the analysis by comparing the actual and perceived fitted policy rates based on the previous estimations. The graphs are displayed in figures A.1 and A.2 respectively in the appendix. As expected, for both Taylor Rules the model's fit is clearly better when considering a regime switching specification compared to the fit from a linear model. Indeed, the figures point out that for both Taylor Rules the in-sample predicted interest rates follow more closely the actual and forecasted policy rates when considering the MRS specification rather than a linear model.

Therefore, accounting for different monetary policy regimes seems to provide an important improvement of the model specification as it permits to more accurately predict the Central Bank's key policy rate within the sample. Moreover, I also display the implied refi rate targets for both policy rules in figure 4 and compare them to the policy rate targets estimated from a linear model. In order to provide an economic intuition for the results I also present a graph of the inflation and real output growth forecasts used in the regressions in figure 5.

First, based on the results from the Actual Taylor Rule one can see that accounting for regime switches in the ECB's monetary policy results in a different implied target rate compared to the one estimated with a linear model. Indeed, within a normal policy regime the policy rate target predicted from the regime switching specification exceeds in general the one inferred from the linear model. In particular, the graph suggests that the ECB's refi rate has remained at a too low level for an extended period of time from June 2003 until December 2005. During this period the refi rate has been maintained at the level of 2%. Based on the MRS model the Central Bank should have started raising the main policy rate much earlier than in December 2005 and should have kept the refi rate at a higher level until the first half of 2008. The implied target rate from the linear model also points in the same direction even though it suggests that the refi rate should have been maintained at a lower level than the one predicted with the MRS specification.

Second, one can clearly see from figure 4 that within a crisis regime the Central Bank cuts swiftly the policy rate and the implied target rate falls down sharply and reaches the Zero Lower Bound quite often. This evidence raises the question about what are the driving factors of the change in regime in the single European monetary policy.

[19] Actually, this issue has been investigated more formally in the previous subsection when comparing the RMSE of the MRS and the linear models.

[20] The implied policy rate target corresponds to the fitted policy rate of equation 1. It is obtained by dividing the estimated short-run model coefficients by one minus the lagged refi rate within the corresponding policy regime. More precisely, I compute the expected refi rate target since the coefficient estimates are weighted by the probability of being in the different regimes. The results are almost identical when considering that the policy rate is in a particular regime according to a specific threshold value for the filtered probabilities.

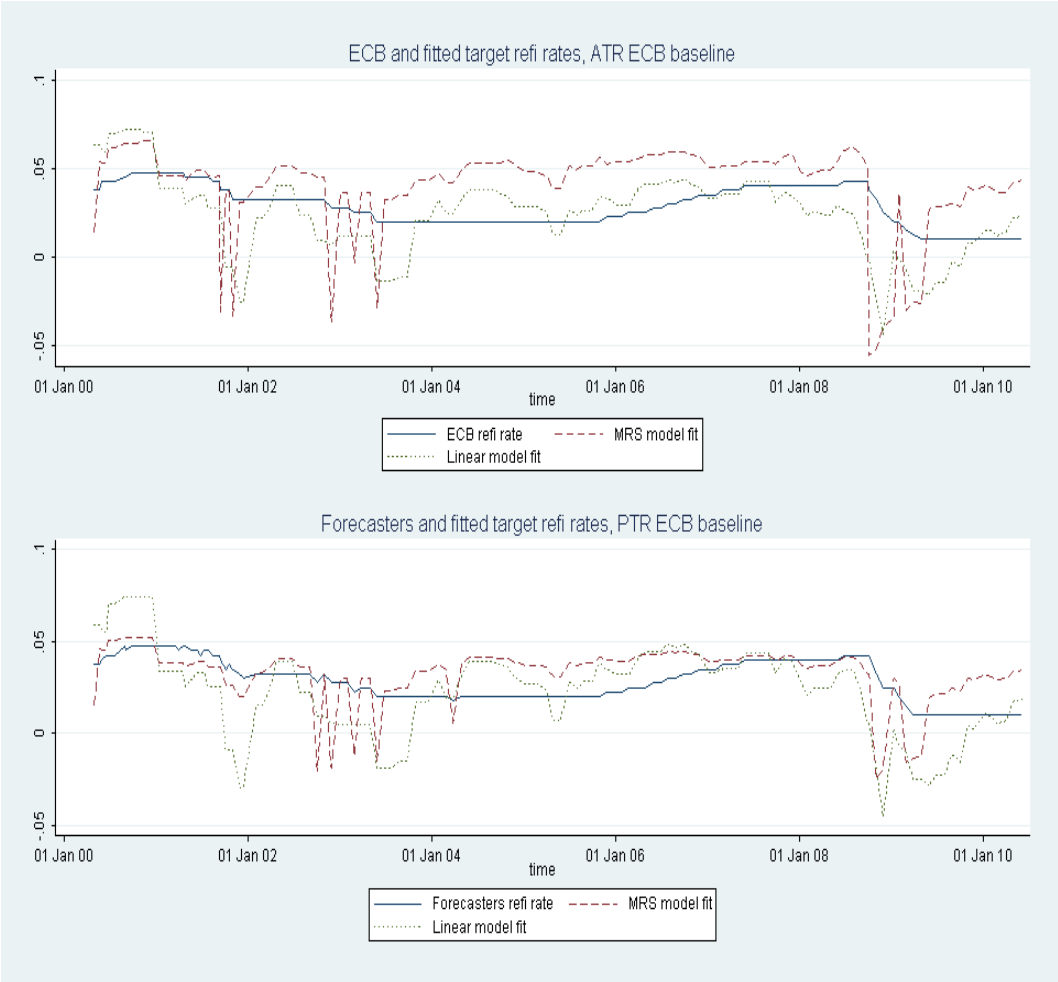

Figure 4: Actual and perceived fitted target rates, baseline model

Figure 5: Inflation and real GDP growth forecasts, baseline model

An inspection of figure 5 indicates that what drives mostly the switch from the normal to the crisis regime are the expectations of a sharp decline in the forecasts of the economic outlook: each time the main policy rate enters the second regime the graph shows that the

professional forecasters have expected a sharp drop in the real output growth rate.

This result highlights an important finding: in a normal regime the ECB is entirely focused on maintaining price stability as its overriding goal which is in line with its monetary policy mandate enshrined in the Maastricht Treaty. However, each time the economists expect a sharp deterioration of the economic outlook the ECB attempts to avoid a further decline in the expected growth rate of real GDP by entering the second policy regime. In the latter, the Central Bank cuts rates swiftly to boost the euro area economy and it temporarily puts aside its primary goal of price stability. It is also important to highlight that the second regime is not necessarily destabilizing for inflation expectations as it is on average rather short-lived. Finally, notice that according to the predicted policy rate target from the MRS model the ECB should have started increasing its policy rate since the second half of 2009 as the euro area economy has come out of the economic recession in line with the forecasts performed by the Euro Area Business Cycle Dating Committee.

As regards the evidence from the Perceived Taylor Rule the results are broadly in line with the previous findings. Nevertheless, there is an important difference in the magnitude of the predicted target rate especially in the first policy regime. Indeed, in normal periods the perceived policy rule predicts that in general the refi rate target should have been higher than the observed refi rate but to a lesser extent compared to the predictions from the actual reaction function. Consistently with the above results the switch to the crisis regime seems to have been driven primarily by the expectations of a sharp decline in the economic outlook. One can also notice that during the 2001-2003 series of policy rate cuts, as well as throughout the broadening of the financial crisis in 2008 the refi rate target seems to have reached the Zero Lower Bound as reflected in both the MRS and linear model predictions from both Taylor Rules. Finally, in the aftermath of the recent financial crisis the ECB should have started increasing the refi rate since the second half of 2009 as the recession has ended and the Central Bank has entered the first regime. This result is in line with the previous findings for the Actual Taylor Rule.

The empirical results presented in this section are consistent with the theoretical model of Agur and Demertzis (2011). The latter derive the optimal policy rate from a Central Bank loss function that contains a financial stability goal in addition to the objective of output gap stabilization. The authors show that following a negative demand shock a Central Bank that carries on a financial stability goal will implement larger cuts of the policy rate that will be rather short-lived compared to the policy response it would provide in the absence of such an objective. The authors argue that given that the rate cut has a short duration the Central Bank has to behave aggressively and implement large policy rate cuts in order to take into account the need to stabilize the output gap as well. In addition, Agur and Demertzis (2011) also show that if the rate cuts last for a prolonged period of time they may favor a risk taking behavior on the part of the banking sector. Therefore, the more a Central Bank is concerned about securing the stability of the financial system the shorter will be the rate cuts and the sharper their magnitude in order to take account of the other policy objectives.

The paper of Agur and Demertzis (2011) thus provides the theoretical underpinning of the regime switching Taylor Rules for the ECB. Consistently with their results, the second regime is rather short-lived and the Central Bank implements sharp policy rate cuts. The aggressive policy responsiveness of the ECB points out that when entering the crisis regime the Central Bank might be also concerned about the stability of the financial system in addition to stabilizing the economic outlook. Besides, this result suggests the presence of some asymmetry between the policy rate hikes and the rate cuts in the ECB's monetary policy. More precisely, the policy rate hikes of the ECB last longer than the rate cuts as the former occur in periods of economic expansion when the Central Bank is entirely focused on maintaining its price stability objective. Conversely, in periods of economic turmoil the

policy rate enters a crisis regime and the ECB implements large interest rate cuts which are short-lived as indicated by the estimated filtered probabilities. Hence, this evidence might point out that in the second regime the ECB assigns some weight on securing the stability of the euro area financial system when setting the refi rate, while at the same time it accounts for the need to stabilize the economic activity. However, the observed behavior of the ECB contrasts with the optimal policy outlined in Agur and Demertzis (2011) in the sense that when switching back to the first regime the Central Bank maintains the policy rate at a low level for a rather prolonged period of time. Such a policy was implemented after the 2001-2003 series of rate cuts and more recently in the aftermath of the 2007-2009 financial crisis. In order to prevent the build-up of an excessive risk taking behavior in the banking sector, the Central Bank should not keep the policy rate at a too low level for a protracted period of time. Indeed, this proposition is fully in line with the implied refi rate targets estimated from the Actual and Perceived regime switching Taylor Rules which are displayed in figure 4. The latter show that following an economic downturn the policy rate enters a normal regime and the ECB should raise the refi rate to foster its price stability commitment. This policy reversal is necessary for the firm anchoring of the long-run inflationary expectations to a level consistent with the policy objective. The latter is crucial for maintaining the low inflation credibility of the Central Bank in the medium and longer terms.

Furthermore, the empirical results for the regime switching policy rules are consistent with Mishkin (2009). The latter argues that monetary policy should be more aggressive in crisis periods as the Central Bank implements large interest rate cuts. According to the author this policy easing is necessary to alleviate the adverse effects of the financial turmoil on the economy and thus to prevent the emergence of an adverse feedback loop that could engineer a deeper economic contraction. Mishkin also argues that an important shortcoming of this policy is that it could lead to higher inflation expectations which would seriously challenge the price stability commitment of the Central Bank. Therefore, it is of the utmost importance that in the aftermath of financial crises Central Banks do not wait too long before implementing interest rate hikes in order to comply with their policy mandate. This proposition is also in line with the estimated refi rate targets from the regime switching Taylor Rules. Thereof, the more credible the Central Bank's commitment to a low level of inflation the more aggressive and shorter-lived the interest rate cuts in the event of a full-blown crisis and the more effective would be the policy outcome.

In the following section I conduct a sensitivity analysis of the baseline specifications previously estimated. In a first step, I consider the Consensus Economics Forecasts of inflation and real GDP growth in the regressions to infer whether the regimes previously obtained are robust to the forecast variables used. Then, I consider an alternative forecast horizon in the regressions to determine which forecast horizon is more in line with the expectations formation process of the economists. Finally, I estimate some augmented Taylor Rules to understand whether the ECB responds to other economic fundamentals as well. The extended model contains the growth rates of M3 and the nominal effective exchange rate as additional regressors.

5 Robustness analysis

In order to perform a sensitivity analysis of the baseline results, the next subsection presents the estimation results for the actual and perceived policy rules using Consensus Economics Forecasts (CEF) of inflation and real output growth instead of the professional forecasts from the investment bank used in the benchmark regressions. The consensus forecasts data are particularly valuable since they are unrevised and are provided in a real-time setting. In the estimations I use the average of the inflation and real output growth forecasts provided

by the panel of professional forecasters for the euro area.[21]

5.1 Actual and Perceived Taylor Rules with consensus forecasts

In this subsection I conduct a sensitivity analysis of the results obtained with the baseline model by considering the consensus forecasts of inflation and real GDP growth for the euro area and for the year ahead horizon in the regressions. In all estimations I have used the most recently available observations in order to preserve the real-time feature of the model. The estimation results for the Actual Taylor Rule are reported in table 5.

At a first look one can see that the empirical results for the baseline specification are qualitatively unaltered when considering the consensus forecasts of economic fundamentals instead of the professional forecasts from the investment bank. More specifically, the empirical evidence suggests that there are two different regimes for the main policy rate as previously estimated with the baseline model. Hence, in the first regime the Central Bank implements a particularly inertial policy and responds positively and significantly to the inflation and real output growth expectations. Conversely, in the second regime the ECB enters in a crisis mode and implements the desired policy rate faster than in normal times. As previously found the Central Bank puts a higher emphasis on the economic outlook rather than on inflation expectations in the second regime.

Table 5: Actual MRS Taylor Rule, CEF

	Regime 1	Regime 2
$\rho_{s_{t+1}}$	0.9925***	0.9246***
	(0.0038)	(0.0045)
$\gamma_{\pi_{s_{t+1}}}$	0.0245***	-0.1654***
	(0.0026)	(0.0058)
$\gamma_{y_{s_{t+1}}}$	0.0010***	0.0603***
	(0.0001)	(0.0062)
γ_c	-0.0000	
	(0.0000)	
σ_ϵ	0.0009***	
	(6.140e-05)	
$P[S_{t+1} = i \mid S_t = 1]$	0.9463***	0.0537***
	(0.0590)	(0.0051)
$P[S_{t+1} = i \mid S_t = 2]$	0.5908***	0.4092**
	(0.0521)	(0.1750)
Observations	141	
Log-likelihood	748.636	

Note: The table displays the short-run coefficients. $\rho_{s_{t+1}}$, $\gamma_{\pi_{s_{t+1}}}$, $\gamma_{y_{s_{t+1}}}$, γ_c denote the policy inertia, inflation and output growth expectations coefficients respectively and the constant term. Estimates in the middle of the columns refer to parameters that do not switch across regimes. Iterative MLE, HAC standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

[21] The Consensus Economics Forecasts are reported by a large panel of professional forecasters for the current year and the year ahead. The data are provided by the Swiss National Bank and Thomson Reuters Datastream.

Table 6: Actual MRS Taylor Rule, CEF long-run parameters

	Regime 1	Regime 2
$\rho_{s_{t+1}}$	0.9925***	0.9246***
	(0.0038)	(0.0045)
$\beta_{\pi_{s_{t+1}}}$	3.2890*	-2.1930***
	(1.9589)	(0.1709)
$\beta_{y_{s_{t+1}}}$	0.1320*	0.8000***
	(0.0771)	(0.1028)
Observations	141	
LL MRS model	748.636	
LL linear model	726.111	
LR test	45.050***	
AIC MRS model	-1473.271	
BIC MRS model	-1437.886	
AIC linear model	-1442.222	
BIC linear model	-1427.479	
RMSE MRS model	0.000881	
RMSE linear model	0.001404	

Note: The table displays the implied long-run coefficients. $\rho_{s_{t+1}}$, $\beta_{\pi_{s_{t+1}}}$, $\beta_{y_{s_{t+1}}}$ denote the policy inertia, inflation and output growth expectations coefficients respectively. Estimates in the middle of the columns refer to parameters that do not switch across regimes. Standard errors are computed with the Delta method and are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Furthermore, table 5 points out that the transition probabilities are very similar to those obtained with the baseline model. Indeed, regime 1 is particularly persistent featuring an average duration of 18.62 monetary policy meetings while the second regime is rather short-lived since it lasts on average 1.69 meetings. In line with the previous results, there is a much higher probability of transiting to the first regime conditional on being in the second one rather than to enter the crisis regime conditional on being in the normal one. Table 6 displayed above reports the implied long-run model coefficients along with some relevant statistics.

The implied long-run coefficients of the model with the consensus forecasts are broadly in line with the results obtained for the benchmark model. In particular one can see that in the first regime the Taylor Principle is satisfied as the ECB implements a particularly stabilizing policy with respect to inflation expectations. This result is also consistent with the long-run objective of price stability that is embedded in the monetary policy mandate. Without prejudice to this overriding goal the Central Bank also takes into account the need to stabilize the economic outlook as indicated by the significant and positive coefficient estimate of the real output growth forecasts. Second, the ECB focuses primarily on stabilizing the latter rather than inflation expectations when entering the crisis regime thus putting temporarily aside its overriding goal. However, it is important to emphasize that given that the second regime has a short duration, the negative coefficient estimate on inflation expectations does not necessarily imply that the Central Bank implements a destabilizing policy with respect to inflation expectations.

In addition, the LR test statistic shows strong evidence in favor of the regime switching specification compared to the linear model. The AIC and BIC information criteria suggest that the nonlinear model should be preferred to the linear one from a model selection perspective. Finally, the MRS specification permits to more accurately predict the refi rate within the sample as indicated by the smaller RMSE compared to the one of the linear model. This result corroborates the previous findings that the fitted policy rate

follows more closely the actual refi rate within the regime switching specification. In order to check whether the baseline results for the professional forecasters are robust to using consensus data, table 7 reports the empirical evidence for the Perceived Taylor Rule.

Table 7: Perceived MRS Taylor Rule, CEF

	Regime 1	Regime 2
$\rho_{s_{t+1}}$	0.9836***	0.8029***
	(0.0050)	(0.0029)
$\gamma_{\pi_{s_{t+1}}}$	0.0178***	
	(0.0005)	
$\gamma_{y_{s_{t+1}}}$	0.0152***	
	(0.0008)	
γ_c	-0.0000	
	(0.0000)	
σ_ϵ	0.0011***	
	(3.125e-05)	
$P[S_{t+1} = i \mid S_t = 1]$	0.9485***	0.0515***
	(0.0280)	(0.0007)
$P[S_{t+1} = i \mid S_t = 2]$	0.7047***	0.2953***
	(0.0217)	(0.0030)
Observations	141	
Log-likelihood	731.921	

Note: The table displays the short-run coefficients. $\rho_{s_{t+1}}$, $\gamma_{\pi_{s_{t+1}}}$, $\gamma_{y_{s_{t+1}}}$, γ_c denote the policy inertia, inflation and output growth expectations coefficients respectively and the constant term. Estimates in the middle of the columns refer to parameters that do not switch across regimes. Iterative MLE, HAC standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

As regards the Perceived Taylor Rule the regime switching model does not converge well when considering a switching in all policy responsiveness coefficients. The best model is obtained by considering a switching in the policy inertia coefficient only. Nevertheless, the results obtained with this specification are in line with the previous economic intuition about the policy regimes. In light of the results from table 7 one can see that when switching from the first to the crisis regime the perceived policy stance is less inertial. However, the ECB responds positively and significantly to the inflation and real output growth forecasts in both regimes. The estimated transition probabilities are also fully in line with those obtained for the Perceived Taylor Rule in the baseline specification. Thereby, regime 1 is particularly persistent compared to the smaller probability of occurrence of the crisis regime. The average duration of the former is 19.42 policy meetings while the latter lasts 1.42 meetings on average. Table 8 reports the implied long-run coefficient estimates and some relevant statistics.

The estimated long-run coefficients suggest that the Taylor Principle seems to be satisfied in the normal regime. Indeed, in the latter the ECB implements a stabilizing policy with respect to inflation expectations. The Central Bank also takes due account of the need to stabilize the economic activity in the euro area as reflected by the significant and positive real output growth forecasts coefficient. In contrast with these results, in the crisis regime the ECB implements a larger fraction of the desired policy rate as indicated by the smaller policy inertia coefficient. Besides, the Central Bank's long-run responsiveness to both the inflation and real output growth expectations seems to have been dampened and the Taylor Principle is not fulfilled. This evidence is related to the fact that the variables do not switch across regimes and the change in the long-run coefficients is entirely due to

a change in the policy inertia point estimate.

Table 8: Perceived MRS Taylor Rule, CEF long-run parameters

	Regime 1	Regime 2
$\rho_{s_{t+1}}$	0.9836***	0.8029***
	(0.0050)	(0.0029)
$\beta_{\pi_{s_{t+1}}}$	1.0876***	0.0904***
	(0.3521)	(0.0021)
$\beta_{y_{s_{t+1}}}$	0.9256***	0.0769***
	(0.3144)	(0.0040)
Observations	141	
LL MRS model	731.921	
LL linear model	715.022	
LR test	33.798***	
AIC MRS model	-1443.841	
BIC MRS model	-1414.354	
AIC linear model	-1420.045	
BIC linear model	-1405.301	
RMSE MRS model	0.001061	
RMSE linear model	0.001519	

Note: The table displays the implied long-run coefficients. $\rho_{s_{t+1}}$, $\beta_{\pi_{s_{t+1}}}$, $\beta_{y_{s_{t+1}}}$ denote the policy inertia, inflation and output growth expectations coefficients respectively. Estimates in the middle of the columns refer to parameters that do not switch across regimes. Standard errors are computed with the Delta method and are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Moreover, the LR test statistic indicates that there is evidence in favor of a regime switching specification compared to a linear model. Both the AIC and BIC information criteria also point out that the nonlinear specification should be preferred to a linear model. Finally, a comparison of the RMSE between the models points out that the fitted policy rate forecast in the MRS model follows more closely the actual policy rate forecast and should be preferred to a linear specification. The estimated filtered probabilities are displayed in figure 6 below.

It is compelling to notice from the following figure that the actual and perceived filtered probabilities are consistent with the results obtained for the baseline model. Indeed, the estimated regimes and the timing of the switches are identical using either the investment bank forecasts or the consensus data. In line with the previous findings the economists have broadly well predicted the actual regime switches of the Central Bank with some minor exceptions. The regimes are the same as in the previous subsection and the second relates to the 2001-2003 cycle of policy easing, and more recently to the sharp refi rate cuts implemented during the broadening of the financial crisis in 2008. The timing of the regimes points out that when switching to the second regime the ECB temporarily deviates from its primary goal of price stability and attempts to offset a further decline in economic activity. Given that the second regime occurs in periods of crisis or financial turbulence the Central Bank has to react very quickly to the economic downturn by adjusting its policy rate accordingly and by taking all necessary measures to secure the stability of the euro area financial system.

As a concluding remark of this subsection one can clearly state that the baseline results remain qualitatively unaltered from including the consensus forecasts of inflation and real output growth in the regressions. This evidence emphasizes the importance of modeling a regime switching policy reaction function in order to more accurately predict the ECB's

main policy rate. Even though the estimation of the Perceived Taylor Rule with the consensus forecasts does not feature a switching in all policy reaction coefficients, the results obtained corroborate the policy regimes and the economic intuition of the benchmark model.

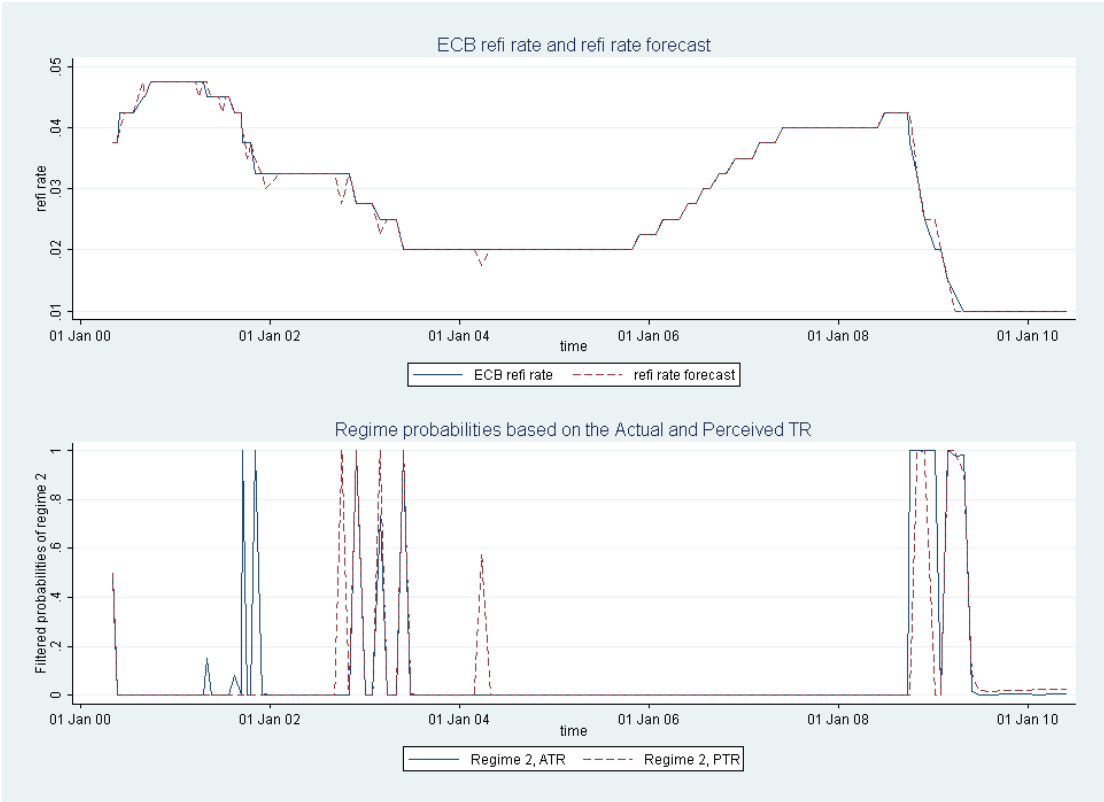

Figure 6: Actual and perceived filtered probabilities, consensus forecasts

In order to check whether the empirical evidence is sensitive to the measure of expectations used in the estimations, the following subsection presents the results obtained with a one-year fixed forecast horizon using the expectations of inflation and real output growth from the investment bank's economists in the regressions.

5.2 Actual and Perceived Taylor Rules with an alternative forecast horizon

In this subsection I present the estimation results for the regime switching policy rules using the inflation and real output growth forecasts with a fixed horizon of one year. It is important to emphasize that while this methodology permits to keep a fixed forecast horizon at each policy meeting the latter is obtained using the forecasts for the current year and the year ahead in computing the expectations. The goal of this approach is to determine whether the fixed forecast horizon corresponds more accurately with the expectations formation process of the economists compared to the previous methodology used in the baseline regressions. The regression results obtained with this approach are less satisfactory compared to the results obtained for the baseline model using the forecasts for the year ahead in the regressions. The estimation procedure does not converge well when allowing for a switching in all policy responsiveness coefficients and the model produces satisfactory results when a switching in the policy inertia and inflation responsiveness coefficients is permitted for the Actual and Perceived Taylor Rules respectively. I first present the empirical evidence for the actual reaction function in table 9.

Table 9: Actual MRS Taylor Rule, Alternative Model (AM)

	Regime 1	Regime 2
$\rho_{s_{t+1}}$	0.9761***	0.8372***
	(0.0035)	(0.0090)
$\gamma_{\pi_{s_{t+1}}}$	0.0156***	
	(0.0012)	
$\gamma_{y_{s_{t+1}}}$	0.0349***	
	(0.0005)	
γ_c	0.0000	
	(0.0000)	
σ_ϵ	0.0009***	
	(1.521e-05)	
$P[S_{t+1} = i \mid S_t = 1]$	0.9483***	0.0517***
	(0.1491)	(0.0097)
$P[S_{t+1} = i \mid S_t = 2]$	0.6194***	0.3806***
	(0.1186)	(0.0134)
Observations	141	
Log-likelihood	752.061	

Note: The table displays the short-run coefficients. $\rho_{s_{t+1}}$, $\gamma_{\pi_{s_{t+1}}}$, $\gamma_{y_{s_{t+1}}}$, γ_c denote the policy inertia, inflation and output growth expectations coefficients respectively and the constant term. Estimates in the middle of the columns refer to parameters that do not switch across regimes. Iterative MLE, HAC standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 10: Actual MRS Taylor Rule, AM long-run parameters

	Regime 1	Regime 2
$\rho_{s_{t+1}}$	0.9761***	0.8372***
	(0.0035)	(0.0090)
$\beta_{\pi_{s_{t+1}}}$	0.6530***	0.0957***
	(0.1390)	(0.0126)
$\beta_{y_{s_{t+1}}}$	1.4629***	0.2143***
	(0.1963)	(0.0093)
Observations	141	
LL MRS model	752.061	
LL linear model	727.479	
LR test	49.164***	
AIC MRS model	-1484.121	
BIC MRS model	-1454.634	
AIC linear model	-1444.959	
BIC linear model	-1430.215	
RMSE MRS model	0.000890419	
RMSE linear model	0.001390119	

Note: The table displays the implied long-run coefficients. $\rho_{s_{t+1}}$, $\beta_{\pi_{s_{t+1}}}$, $\beta_{y_{s_{t+1}}}$ denote the policy inertia, inflation and output growth expectations coefficients respectively. Estimates in the middle of the columns refer to parameters that do not switch across regimes. Standard errors are computed with the Delta method and are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

The results from table 9 highlight the presence of two regimes for the policy inertia coefficient. In the first one monetary policy is quite inertial while in the second regime

the Central Bank implements a larger fraction of the desired policy rate at each monetary policy meeting. Moreover, the ECB seems to respond positively to the inflation and real output growth forecasts and puts a higher emphasis on the latter. Finally, notice that in line with the empirical findings for the baseline specification regime 1 appears to be particularly persistent, contrarily to the smaller probability of occurrence of the second regime. In fact, the crisis regime is a rather infrequent event that occurs with a small conditional probability of the policy rate being in the normal regime. However, once the refi rate gets into the second regime it has a much greater chance to transit back to the first one rather than to remain in the second regime. Hence, the average duration of the former and the latter are respectively 19.34 and 1.61 policy meetings. The long-run response coefficients and the relevant statistics are reported in table 10.

Table 10 points out that the Taylor Principle does not seem to be satisfied in either regime when using a fixed horizon of one year in the estimations. Hence, it might be the case that these forecast variables do not accurately reflect the forward-looking nature of the expectations formation process of the professional forecasters. This evidence could stem from the fact that the one-year forecasts are not entirely forward-looking and do not refer to a specific period between the current year and the year ahead. From this perspective, the forecasts for the year ahead clearly permit greater flexibility in the regime switching modeling of the forward-looking Taylor Rules and are likely to more accurately correspond with the expectations formation process of the professional forecasters. The latter is crucial for understanding the predictability of the European monetary policy within the Taylor Rule framework.

Furthermore, the results from table 10 suggest first that the ECB has assigned a higher weight to stabilizing the real output growth rather than the inflation expectations in both regimes. Besides, when switching from the first to the second regime the Central Bank's policy inertia decreases and the reaction to both the inflation and real output growth forecasts is dampened. This result is close to the findings of Gerlach and Lewis (2010) who report that in a crisis regime the ECB responds very little to economic fundamentals. As regards the test for the two regimes model, the LM statistic points out that there is evidence in favor of the MRS specification compared to the linear model. This result is further corroborated by the AIC and BIC information criteria which indicate that the regime switching policy rule should be preferred from a model selection perspective as well. Finally, a comparison of the RMSE between the models reveals that one should use the nonlinear specification in order to reduce the in-sample prediction error for the main policy rate given the higher RMSE of the linear model. The specification that converges properly for the Perceived Taylor Rule embeds a switching only in the inflation responsiveness coefficient and is reported in table 11.

The following table indicates that there are two policy regimes for the inflation expectations coefficient in the Perceived Taylor Rule using the one-year fixed horizon forecasts in the estimations. In the first regime, the Central Bank responds positively to the inflation and real output growth forecasts putting a higher emphasis on the stabilization of the real output growth expectations as found for the Actual Taylor Rule. In the second regime, the ECB's reaction to inflation expectations sharply changes since the coefficient estimate becomes significantly negative. Besides, it seems that in both regimes the ECB has put a greater emphasis on stabilizing the real output growth rather than the inflation expectations. Consistently with all previous results the transition probabilities point out that the first regime is particularly persistent compared to the smaller probability of occurrence of the second one. Table 12 displays the long-run response coefficients along with some relevant statistics.

Table 11: Perceived MRS Taylor Rule, Alternative Model (AM)

	Regime 1	Regime 2
$\rho_{s_{t+1}}$	0.9625***	
	(0.0059)	
$\gamma_{\pi_{s_{t+1}}}$	0.0270***	-0.2499***
	(0.0035)	(0.0046)
$\gamma_{y_{s_{t+1}}}$	0.0419***	
	(0.0004)	
γ_c	0.0000	
	(0.0000)	
σ_ϵ	0.0010***	
	(0.0001)	
$P[S_{t+1} = i \mid S_t = 1]$	0.9503***	0.0497***
	(0.1753)	(0.0036)
$P[S_{t+1} = i \mid S_t = 2]$	0.7492***	0.2508***
	(0.1081)	(0.0039)
Observations	141	
Log-likelihood	736.484	

Note: The table displays the short-run coefficients. $\rho_{s_{t+1}}$, $\gamma_{\pi_{s_{t+1}}}$, $\gamma_{y_{s_{t+1}}}$, γ_c denote the policy inertia, inflation and output growth expectations coefficients respectively and the constant term. Estimates in the middle of the columns refer to parameters that do not switch across regimes. Iterative MLE, HAC standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 12: Perceived MRS Taylor Rule, AM long-run parameters

	Regime 1	Regime 2
$\rho_{s_{t+1}}$	0.9625***	
	(0.0059)	
$\beta_{\pi_{s_{t+1}}}$	0.7200***	-6.6714***
	(0.1998)	(0.9444)
$\beta_{y_{s_{t+1}}}$	1.1197***	
	(0.1863)	
Observations	141	
LL MRS model	736.484	
LL linear model	725.544	
LR test	21.880***	
AIC MRS model	-1452.967	
BIC MRS model	-1423.480	
AIC linear model	-1441.087	
BIC linear model	-1426.343	
RMSE MRS model	0.001001	
RMSE linear model	0.001409	

Note: The table displays the implied long-run coefficients. $\rho_{s_{t+1}}$, $\beta_{\pi_{s_{t+1}}}$, $\beta_{y_{s_{t+1}}}$ denote the policy inertia, inflation and output growth expectations coefficients respectively. Estimates in the middle of the columns refer to parameters that do not switch across regimes. Standard errors are computed with the Delta method and are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

In line with the results for the Actual Taylor Rule, the estimated long-run coefficients point out that the Taylor Principle is not satisfied for the Perceived Taylor Rule as well.

Furthermore, in the first regime the Central Bank responds more strongly to the real output growth rather than to the inflation expectations. In a similar way, when switching to the second regime the inflation responsiveness coefficient becomes even negative possibly indicating that the latter occurs in periods of economic downturn when some exceptional circumstances lead the Central Bank to deviate temporarily from its overriding price stability objective. As previously emphasized, this result does not necessarily imply that the ECB implements a destabilizing policy with respect to inflation but more likely reflects the fact that in a period of economic turmoil the Central Bank's priority gears towards preventing a further decline in the economic outlook. The monetary institution also focuses on securing the stability of the financial system rather than anchoring inflation expectations with its price stability objective. The likelihood-ratio test of nonlinearity indicates that there is evidence in favor of the regime switching model compared to the linear one. Moreover, the AIC statistic shows that the MRS model should be preferred to the linear one in contrast to the evidence stemming from the BIC information criterion. Finally, from the perspective of minimizing the in-sample prediction error the RMSE points out that one should select the regime switching Taylor Rule instead of the linear specification. Figure 7 displays the actual and perceived filtered regime probabilities.

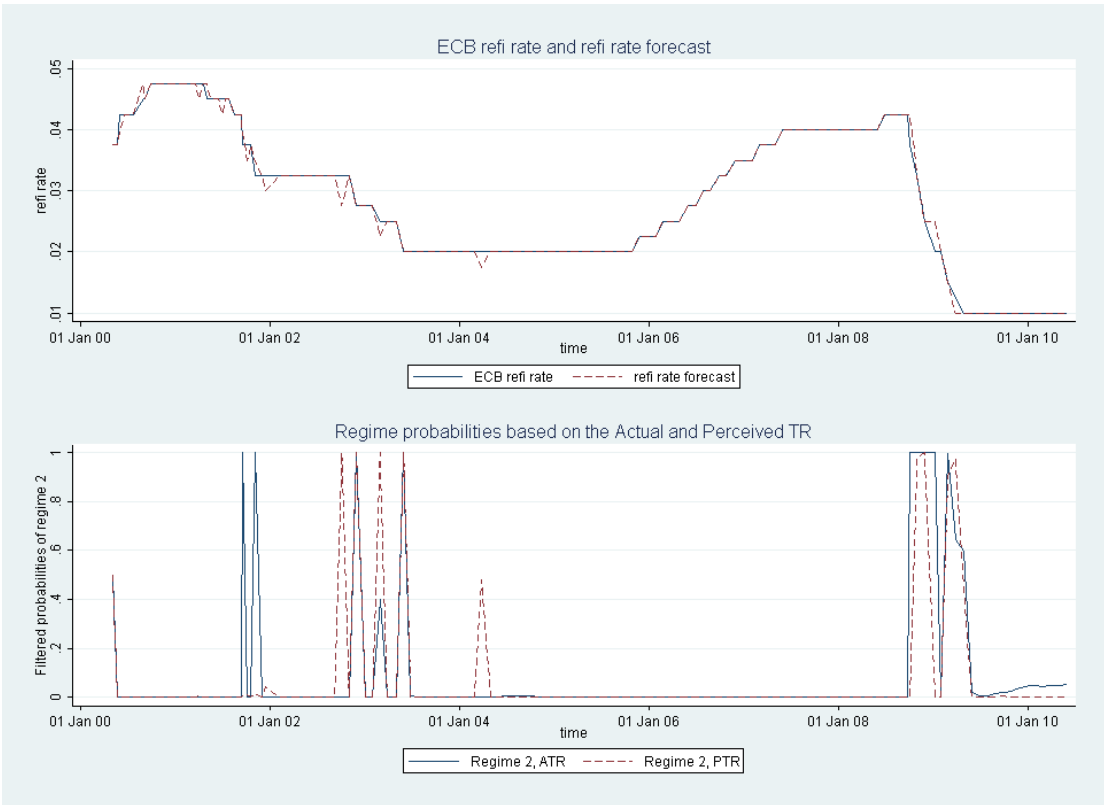

Figure 7: Actual and perceived filtered probabilities, alternative model

As a first remark, it is compelling to notice that the actual and perceived filtered regime probabilities are well aligned over most of the estimation period. This result shows that the professional forecasters have broadly well predicted the timing of the regime switches in the ECB's main policy rate. In addition, this evidence corroborates the results obtained for the baseline specification of the Taylor Rules. In particular, the estimations are in line with the previous economic intuition about the estimated regimes. Indeed, regime 1 occurs in normal periods when the Central Bank is focused on maintaining its primary objective of price stability, while the second regime takes places in times of economic downturn when the ECB has to react quickly to the turmoil by cutting swiftly its main policy rate.

Consistently with the benchmark results there are, however, some small misalignments between the actual and perceived filtered probabilities. The first one occurs in the 2001-2003 cycle of interest rate cuts when the economists have not expected the temporary switch to the second regime occurring at the end of 2001. In fact, with the start of this interest rate easing cycle the actual policy rate has switched to the second regime in September and in November 2001, while the refi rate point forecast has switched to the latter only consecutively to the 2002 policy rate cuts. Besides, the economists have perceived a temporary switch to the crisis regime in October 2002 and in March 2003 since they have expected sharp interest rate cuts which have not materialized. Then, in March 2004 as the professional forecasters have expected a 25 basis points rate cut the perceived filtered probability of the second regime has increased substantially even though the actual policy rate has not changed. Finally, at the broadening of the financial crisis in 2008, the economists have well predicted the occurrence of the crisis regime, even though the switch of the forecasted refi rate to the second regime has been delayed by one meeting of the Governing Council. The latter has switched back to the normal regime earlier than the actual refi rate in January 2009 as the economists have not expected the sharp rate cut occurring in that month. The Actual and Perceived Taylor Rules have switched again to the crisis regime in March 2009 as the Central Bank has resumed the series of refi rate cuts after the February 2009 break. Then, the actual and perceived policy rates have transited back to the normal regime since June and May 2009 respectively.

The empirical results of this subsection are also robust to using the inflation and real GDP growth consensus forecasts with the one-year fixed horizon. In particular the transition probabilities point to the same regimes previously estimated. The results are not presented since they are qualitatively very similar. In the next subsection I conduct some robustness analysis of the Taylor Rule specification considered in the previous regressions. In particular, I estimate an augmented Taylor Rule which contains a policy response of the Central Bank to the growth rate of M3 and to the nominal effective exchange rate. Indeed, given the two-pillar approach of the European monetary policy strategy it might be relevant to include the growth rate of M3 to account for the importance of the monetary pillar in the ECB's interest rate setting. In addition, this monetary aggregate could provide some additional indication on the long-run inflationary pressures in the euro area that might represent a valuable information for the decisions on the appropriate monetary policy stance. The nominal effective exchange rate is included in the regressions to control for the Central Bank's responsiveness to this variable when setting the refi rate as well. Actually, as the ECB might be concerned about the impact of the nominal effective exchange rate fluctuations on the euro area current account it could potentially respond to this variable when deciding on the level of the refi rate.

5.3 Augmented Taylor Rules

The goal of this subsection is to challenge the standard specification of the Taylor Rule by considering an augmented model with some additional explanatory variables. As previously indicated, I include the growth rate of the monetary aggregate M3 and the growth rate of the nominal effective exchange rate in the regressions.[22] Hence, for a well specified model the regressors included in the baseline specification should contain all relevant information in determining the policy interest rate and including additional variables in the estimations should not improve upon significantly the model. In that sense, the M3 and the nominal effective exchange growth rates should not provide relevant information for the decisions

[22]The nominal effective exchange rate refers to a broad basket of currencies of the euro area trading partners. An increase of the former leads to an appreciation of the euro vis-à-vis this basket of currencies. The growth rates of both the M3 and the nominal effective exchange rate are obtained from the real-time database of the European Central Bank.

on the appropriate monetary policy stance. Table 13 reports the estimation results for the linear Actual and Perceived Taylor Rules. In line with the MRS methodology, the linear policy rules are estimated with the maximum likelihood method since the Portmanteau test statistics and the LM tests for serial correlation indicate that there is not any structure in the residuals and that the latter can be considered as white noise.

The results from table 13 point out that the baseline specification of the Taylor Rule is quite robust to including the growth rate of M3 and the nominal effective exchange rate in the regressions. Indeed, the coefficient estimates for these variables are statistically insignificant except for the M3 growth rate coefficient in the Actual Taylor Rule which is significant only at the 10% level. Besides, the magnitude of the estimated additional parameters is very small suggesting that most likely the ECB does not respond to these variables when setting its main policy rate. Therefore, the evidence from both the actual and perceived augmented linear policy rules suggests that the inflation and real output growth forecasts contain all relevant information for determining the policy interest rate and one does not have to include the additional variables in the estimations. Table 14 reports the results from the augmented regime switching Taylor Rules.

Table 13: Augmented Taylor Rules, linear model

	Actual Taylor Rule	Perceived Taylor Rule
ρ	0.9514***	0.9549***
	(0.0121)	(0.0110)
γ_π	0.1091**	0.1558***
	(0.0471)	(0.0451)
γ_y	0.1274***	0.1085***
	(0.0309)	(0.0301)
γ_m	0.0074*	0.0056
	(0.0044)	(0.0041)
γ_e	0.0032	0.0025
	(0.0030)	(0.0032)
γ_c	-0.0038***	-0.0043***
	(0.0009)	(0.0009)
σ_ϵ	0.00135***	0.0013***
	(0.0001)	(0.0001)
Observations	141	141
Log-likelihood	732.012	732.501

Note: The table displays the short-run coefficients. ρ, γ_π, γ_y, γ_m, γ_e, γ_c denote the policy inertia, inflation and output growth expectations, the M3 and the nominal effective exchange rate coefficients respectively and the constant term. MLE, robust standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

One can see from the evidence of table 14 that including the growth rate of M3 and the nominal effective exchange rate in the regressions does not provide important additional information to the model. Indeed, even though the estimated coefficients of the supplementary variables are significant in both regimes, the magnitude of the point estimates is very small to infer that the ECB has indeed taken them into account when setting the policy rate. The results are consistent with Berger, de Haan and Sturm (2006) who find that the ECB has most likely not responded to the growth rate of M3 based on newly constructed communication indicators from the introductory statements of the Governing Council's press conferences. The estimates from table 14 are also in line with Gerlach and Lewis (2010) who find little evidence for the importance of M3 and the nominal effective exchange rates in the ECB's policy rule. Besides, it is also consistent with Taylor (2010)

who states that simple rules are robust to various specifications of the reaction function and additional regressors. Considering some augmented Taylor Rules, Siklos, Werner and Bohl (2004) do not find evidence that the ECB has responded directly to asset prices in the estimated policy rules even though they can be considered as useful indicators for monetary policy. Their results corroborate the simulation exercise of Bernanke and Gertler (2001) who show that an optimal policy rule does not involve a response of the Central Bank to asset prices, even if it is known to policymakers that the market is driven by a bubble because the response can be harmful to the economy.

Table 14: Actual and Perceived MRS Taylor Rules, augmented model

	Actual Taylor Rule		Perceived Taylor Rule	
	Regime 1	Regime 2	Regime 1	Regime 2
$\rho_{s_{t+1}}$	0.9840***	0.9392***	0.9765***	0.5848***
	(0.0036)	(0.0038)	(0.0037)	(0.0593)
$\gamma_{\pi_{s_{t+1}}}$	0.0238***	-0.2231***	0.0178***	0.4735***
	(0.0015)	(0.0114)	(0.0045)	(0.1652)
$\gamma_{y_{s_{t+1}}}$	-0.0001***	0.0508***	0.0056***	0.2189***
	(0.0000)	(0.0003)	(0.0011)	(0.0562)
$\gamma_{m_{s_{t+1}}}$	0.0053***		0.0059***	
	(0.0000)		(0.0015)	
$\gamma_{e_{s_{t+1}}}$	-0.0037***		-0.0065***	
	(0.0003)		(0.0001)	
γ_c	0.0000		0.0000	
	(0.0000)		(0.0000)	
σ_ϵ	0.0009***		0.0013***	
	(1.010e-05)		(3.970e-05)	
$P[S_{t+1} = i \mid S_t = 1]$	0.9511***	0.0489***	0.9774***	0.0226***
	(0.0841)	(0.0051)	(0.2613)	(0.0009)
$P[S_{t+1} = i \mid S_t = 2]$	0.5705***	0.4295***	0.1442***	0.8558***
	(0.0832)	(0.0280)	(0.0253)	(0.0353)
Observations	141		141	
Log-likelihood	751.990		722.963	

Note: The table displays the short-run coefficients. $\rho_{s_{t+1}}$, $\gamma_{\pi_{s_{t+1}}}$, $\gamma_{y_{s_{t+1}}}$, $\gamma_{m_{s_{t+1}}}$, $\gamma_{e_{s_{t+1}}}$, γ_c denote the policy inertia, inflation and output growth expectations, the M3 and the nominal effective exchange rate coefficients respectively and the constant term. Estimates in the middle of the columns refer to parameters that do not switch across regimes. Iterative MLE, HAC standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 14 points out the estimated coefficients of the growth rate of M3 and the nominal effective exchange rate feature the expected sign. Hence, if there is an increase in the monetary aggregate M3, the Central Bank will raise the refi rate to prevent the build-up of medium to long-term inflationary pressures in the euro area. Conversely, an appreciation of the euro vis-à-vis the trading partners' currencies will call for a rate cut in order to alleviate the negative impact on the euro area exports. Finally, it is important to highlight that the additional explanatory variables do not alter the results from the baseline specification. Indeed, when switching from the first to the second regime the policy inertia decreases and the ECB attempts to stabilize the economic outlook rather than inflation expectations, consistently with the previous results for the Actual Taylor Rule. However, for the Perceived Taylor Rule it seems that when switching to regime 2 the Central Bank tries to stabilize both the inflation and real output growth expectations with a higher emphasis on the former. The actual transition probabilities are well aligned with the results for the benchmark model. For the Perceived Taylor Rule, the transition probability of the

first regime is also consistent with the previous estimations, while it seems that the second regime is more persistent than previously found.

Figure 8 displays the estimated filtered probabilities from both reaction functions. A comparison of figures 8 and 3 reveals that the estimated filtered probabilities of the augmented model are broadly in line with the results from the benchmark specification. The evidence from the Actual Taylor Rule points out that the timing of the regime switches in the augmented model corresponds well to the one estimated with the benchmark specification. There is only one exception occurring in March 2003 when the actual refi rate has not switched to the second regime in the augmented model. The Perceived Taylor Rule estimates indicate that the timing of the regime switches is in line with the previous findings especially during the financial crisis in 2008 and 2009. However, there are some small differences at the beginning of the decade as the professional forecasters have perceived some switching to the second regime occurring in the second half of 2000. Then, they have perceived a longer duration of the second regime as the forecasted policy rate has remained in the crisis regime from December 2002 until October 2003 compared to the shorter duration of this regime as estimated in the baseline model for the same period. Finally, in the augmented model the economists have not forecasted a temporary switch to the second regime occurring in March 2004 as they have expected in the benchmark model. However, the professional forecasters have predicted the transition to the crisis regime at the broadening of the financial crisis in November 2008 in line with the previous estimates. They have also perceived a shorter duration of the turmoil as the policy rate point forecast has switched to the first regime in March 2009. The empirical evidence from the baseline model is therefore broadly corroborated from the estimation results with the augmented Taylor Rules.

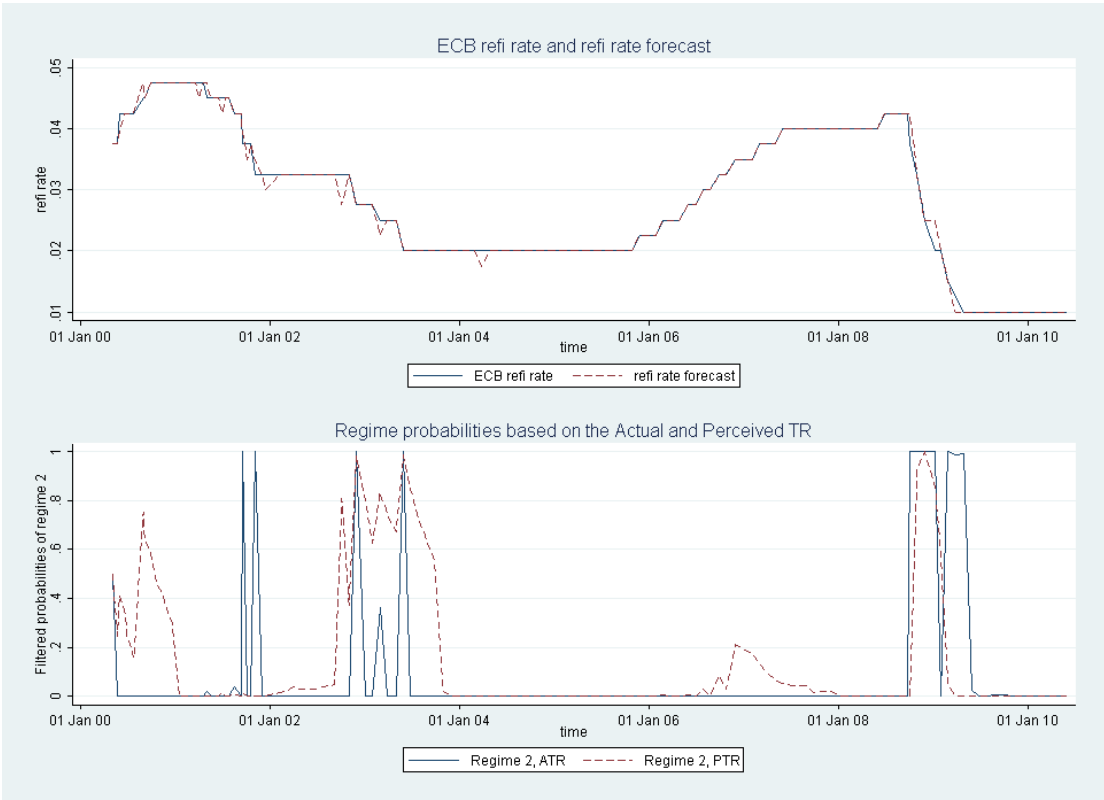

Figure 8: Actual and perceived filtered probabilities, augmented model

Table A.5 in the appendix presents the estimation results of the augmented model using the inflation and real output growth forecasts with a one-year horizon in the regressions.

The table points out that the previous findings are further confirmed since the estimated coefficients of the additional explanatory variables are statistically insignificant. Hence, including the growth rate of the monetary aggregate M3 and the nominal effective exchange rate does not seem to provide additional insights on both the Actual and Perceived Taylor Rules within the one-year fixed horizon framework. Notice, however, that in the actual reaction function the inflation point estimate becomes insignificant as there might be some interaction between inflation expectations and the growth rate of M3. Therefore, as it seems that the ECB does not respond to these additional variables when setting the policy rate, one should not take them into account in the model's specification.

An inspection of the results from table A.6 reveals that the augmented perceived regime switching model yields similar results to the baseline specification when including the additional regressors in the estimations. Importantly, the results are comparable with those of the benchmark model when a switching in the policy inertia, inflation and real output growth coefficients is allowed. Indeed, when switching to the second regime the policy inertia decreases and the ECB puts a higher emphasis on stabilizing the real output growth rather than inflation expectations. Besides, it is possible that the monetary aggregate M3 provides some information about future expected inflation which is not reflected in the one-year inflation expectations because the latter are not entirely forward-looking in this setting. Even though the estimated coefficients of M3 and the nominal effective exchange rate have the expected sign their magnitude is very small. This evidence thus suggests that the ECB has most likely not considered these variables as of primary importance when deciding on the appropriate monetary policy stance. In addition, the estimated transition probabilities indicate that regime 1 is highly persistent compared to regime 2 which is in line with the earlier findings.

Finally, the estimated filtered probabilities which are displayed in figure A.3, point out that the timing of the regime switches is consistent with the baseline results. However, there are some exceptions occurring in the period from 2000 to 2003 when the actual and forecasted refi rates have switched more frequently to the second regime. In addition, after the bankruptcy of Lehman Brothers the policy rates have entered the second regime consistently with the previous results. Nevertheless, the actual and forecasted refi rates have switched back to the first regime in April and in May 2009 for the Actual and Perceived Taylor Rules respectively which is earlier than previously found. Therefore, the empirical evidence suggests that the estimated regimes and the filtered probabilities of the baseline and the alternative models are in general robust to including the monetary aggregate M3 and the nominal effective exchange rate as additional regressors in the model.

The regime switching policy rules have also been estimated with the Economic Sentiment Indicator (ESI) growth rate with respect to its long-run average as an additional sensitivity analysis. Overall, the results show that the estimated regimes and the timing of the transitions are robust to including the ESI growth rate in the regressions both for the year ahead and the one-year horizons. Consistently with the previous findings, the results point out that the policy inertia has decreased substantially and the ECB responds relatively more strongly to the deviations of the business cycle indicator from its long-run average in the crisis regime. This evidence is also corroborated from the estimations with the consensus inflation forecasts and the ESI growth rate for the year ahead and the one-year horizons.[23]

The empirical results previously presented indicate that it is appropriate to consider a two regimes switching specification of the Actual and Perceived Taylor Rules. Moreover, one could also envisage the possibility that the ECB might respond differently to macroeconomic fundamentals within a higher order of policy regimes. Therefore, the aim of the next

[23] The results are qualitatively similar to the previous empirical evidence and therefore are not reported in the paper.

section is to further investigate the relevance of a third regime for the key ECB's policy rate. However, one should be aware of the fact that estimating a three regimes MRS model involves a higher computational burden and one should not heavily rely on the estimation results. The latter should be considered more likely as indicative rather than as a formal evidence for the possibility of detecting a third regime in the ECB's interest rate setting policy.

6 A three regimes switching model

This section is devoted to further investigating the presence of a third regime in the ECB's refi rate. The previous empirical evidence has highlighted the occurrence of two policy regimes: the first one occurs in normal times and the second regime takes place in periods of economic turmoil. In addition, one could also determine whether the key interest rate enters a third regime that might appear in particularly turbulent periods as for instance during the broadening of the financial crisis in 2008. This investigation will thus shed new light on understanding more in-depth the ECB's policy responsiveness to economic fundamentals within a three regimes switching specification. Table 15 reports the results for the baseline model when considering a switching in the policy inertia, inflation and real output growth expectations.

Table 15: Actual MRS Taylor Rule, Three Regimes Model (TRM)

	Regime 1	Regime 2	Regime 3
$\rho_{s_{t+1}}$	0.9896***	0.8262***	0.4095***
	(0.0009)	(0.0317)	(0.0318)
$\gamma_{\pi_{s_{t+1}}}$	0.0368***	-0.4319***	0.9163***
	(0.0008)	(0.0069)	(0.0490)
$\gamma_{y_{s_{t+1}}}$	-0.0102***	0.5521***	0.2288***
	(0.0004)	(0.0381)	(0.0068)
γ_c		-0.0000	
		(0.0000)	
σ_ϵ		0.0006***	
		(3.595e-05)	
$P[S_{t+1} = i \mid S_t = 1]$	0.8631***	0.0753***	0.0616***
	(0.1091)	(0.0095)	(0.0022)
$P[S_{t+1} = i \mid S_t = 2]$	0.7826***	0.2174***	0.0000
	(0.0748)	(0.0113)	(0.0000)
$P[S_{t+1} = i \mid S_t = 3]$	0.5158***	0.1038***	0.3804***
	(0.0096)	(0.0102)	(0.0514)
Observations		141	
Log-likelihood		780.598	

Note: The table displays the short-run coefficients. $\rho_{s_{t+1}}$, $\gamma_{\pi_{s_{t+1}}}$, $\gamma_{y_{s_{t+1}}}$, γ_c denote the policy inertia, inflation and output growth expectations coefficients respectively and the constant term. Estimates in the middle of the columns refer to parameters that do not switch across regimes. Iterative MLE, HAC standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

At a first glance, table 15 points to the presence of three regimes for the ECB's refi rate. First, one can easily identify the two regimes previously estimated. In line with the core results, when switching from the first to the second regime monetary policy becomes less inertial and the ECB focuses on stabilizing real output growth rather than inflation expectations. There is a small difference as regards the real output growth forecasts point

estimate in the first regime which is slightly negative when estimated within the three regimes model. Importantly, the third regime features the least inertial monetary policy and the Central Bank responds quite strongly to both the inflation and real output growth expectations compared to the previous regimes. Consistently with the earlier intuition, regime 1 is the most persistent and regime 2 has the smallest probability of occurrence. Indeed, the former lasts on average 7.30 policy meetings and the latter features an average duration of 1.28 meetings. As regards the third regime it lasts on average 1.61 meetings. Finally, notice that conditional on being in either the third or in the second regime there is a high probability to transit to the first one, while it is much less likely to switch to the third one conditional on being in either the first or in the second regimes. Table 16 presents the estimated long-run coefficients along with some relevant statistics.

Table 16: Actual MRS Taylor Rule, TRM long-run parameters

	Regime 1	Regime 2	Regime 3
$\rho_{s_{t+1}}$	0.9896***	0.8262***	0.4095***
	(0.0009)	(0.0317)	(0.0318)
$\beta_{\pi_{s_{t+1}}}$	3.5460***	-2.4848***	1.5516***
	(0.2487)	(0.4512)	(0.1665)
$\beta_{y_{s_{t+1}}}$	-0.9873***	3.1760***	0.3875***
	(0.1155)	(0.7945)	(0.0322)
Observations		141	
LL MRS three regimes		780.598	
LL MRS two regimes		749.329	
LR test		62.538***	
AIC MRS three regimes		-1521.195	
BIC MRS three regimes		-1462.220	
AIC MRS two regimes		-1474.659	
BIC MRS two regimes		-1439.274	
RMSE MRS three regimes		0.000628	
RMSE MRS two regimes		0.000899	

Note: The table displays the implied long-run coefficients. $\rho_{s_{t+1}}$, $\beta_{\pi_{s_{t+1}}}$, $\beta_{y_{s_{t+1}}}$ denote the policy inertia, inflation and output growth expectations coefficients respectively. Estimates in the middle of the columns refer to parameters that do not switch across regimes. Standard errors are computed with the Delta method and are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

The previous evidence suggests that in regime 1 the policy rate is the most inertial and the Central Bank responds strongly to inflation expectations. In fact, given that the Taylor Principle is clearly satisfied the ECB exerts a stabilizing effect on inflation while its response to the real output growth forecasts is at odds with the baseline results. In the second regime, the ECB implements a higher fraction of the desired policy rate target and focuses on stabilizing the real output growth rather than the inflation expectations consistently with the benchmark results. Finally, in the third regime it is compelling to notice that the coefficient estimates are the closest to the original findings of Taylor (1993). In the latter, the point estimates indicate that the Central Bank attempts to stabilize both the inflation and real output growth expectations. Furthermore, the LR test points out that there is evidence in favor of a three regimes specification compared to a two regimes switching model. The AIC and BIC information criteria further suggest that the former should be preferred to the latter. As regards the RMSE there is a slight advantage of using the three regimes model compared to the specification with two regimes, as the former permits to reduce a little the in-sample prediction error of the policy rate. Table 17 reports the estimation results for the Perceived Taylor Rule.

Table 17: Perceived MRS Taylor Rule, Three Regimes Model (TRM)

	Regime 1	Regime 2	Regime 3
$\rho_{s_{t+1}}$	0.9901***	0.8852***	0.6468***
	(0.0013)	(0.0142)	(0.0470)
$\gamma_{\pi_{s_{t+1}}}$	0.0315***	-0.1373***	0.6057***
	(0.0024)	(0.0237)	(0.0736)
$\gamma_{y_{s_{t+1}}}$	-0.0060***	0.0346***	0.1422***
	(0.0003)	(0.0006)	(0.0039)
γ_c		0.0000	
		(0.0000)	
σ_ϵ		0.0006***	
		(1.951e-06)	
$P[S_{t+1} = i \mid S_t = 1]$	0.8291***	0.0605***	0.1104***
	(0.1310)	(0.0006)	(0.0146)
$P[S_{t+1} = i \mid S_t = 2]$	0.7072***	0.2928***	0.0000
	(0.1918)	(0.1035)	(0.0000)
$P[S_{t+1} = i \mid S_t = 3]$	0.9168***	0.0000	0.0832***
	(0.0537)	(0.0000)	(0.0017)
Observations		141	
Log-likelihood		764.723	

Note: The table displays the short-run coefficients. $\rho_{s_{t+1}}$, $\gamma_{\pi_{s_{t+1}}}$, $\gamma_{y_{s_{t+1}}}$, γ_c denote the policy inertia, inflation and output growth expectations coefficients respectively and the constant term. Estimates in the middle of the columns refer to parameters that do not switch across regimes. Iterative MLE, HAC standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 18: Perceived MRS Taylor Rule, TRM long-run parameters

	Regime 1	Regime 2	Regime 3
$\rho_{s_{t+1}}$	0.9901***	0.8852***	0.6468***
	(0.0013)	(0.0142)	(0.0470)
$\beta_{\pi_{s_{t+1}}}$	3.1676***	-1.1961***	1.7148***
	(0.5255)	(0.0835)	(0.4366)
$\beta_{y_{s_{t+1}}}$	-0.5994***	0.3018***	0.4027***
	(0.0737)	(0.0328)	(0.0458)
Observations		141	
LL MRS three regimes		764.723	
LL MRS two regimes		736.512	
LR test		56.422***	
AIC MRS three regimes		-1489.446	
BIC MRS three regimes		-1430.470	
AIC MRS two regimes		-1449.023	
BIC MRS two regimes		-1413.638	
RMSE MRS three regimes		0.000603	
RMSE MRS two regimes		0.001011	

Note: The table displays the implied long-run coefficients. $\rho_{s_{t+1}}$, $\beta_{\pi_{s_{t+1}}}$, $\beta_{y_{s_{t+1}}}$ denote the policy inertia, inflation and output growth expectations coefficients respectively. Estimates in the middle of the columns refer to parameters that do not switch across regimes. Standard errors are computed with the Delta method and are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 17 points out that the results are in line with the empirical evidence for the Actual

Taylor Rule. More precisely, a robust finding is that when switching from the first to second regimes monetary policy is less inertial and the ECB is focused on stabilizing the real output growth rather than the inflation expectations. Besides, in the third regime the Central Bank's policy is the least inertial and exerts a stabilizing effect on both the inflation and real output growth expectations. The estimated transition probabilities indicate that regime 1 is the most persistent while regime 3 features the smallest probability of occurrence. In line with the evidence for the actual reaction function, there is a higher probability to switch to the first regime conditional on being in the second or in the third regimes rather than to transit to the third one conditional on being in either the first or in the second regimes. The implied long-run coefficients are reported in table 18.

The results of table 18 are qualitatively similar to the evidence from table 16. Indeed, in the first regime the ECB stabilizes inflation expectations and implements a particularly inertial policy, while in the second regime it aims at stabilizing the economic outlook. Finally, the policy stance is the least inertial in regime 3 and the Central Bank's policy switches towards stabilizing both the inflation and real output growth expectations in line with the recommendation stemming from a standard Taylor Rule. The LR test shows evidence in favor of a three regimes specification and the AIC and BIC information criteria also point in the same direction. Based on the RMSE evidence one should also prefer the three regimes model to reduce the in-sample prediction error of the policy rate. The estimated actual and perceived filtered probabilities are displayed in figure 9.

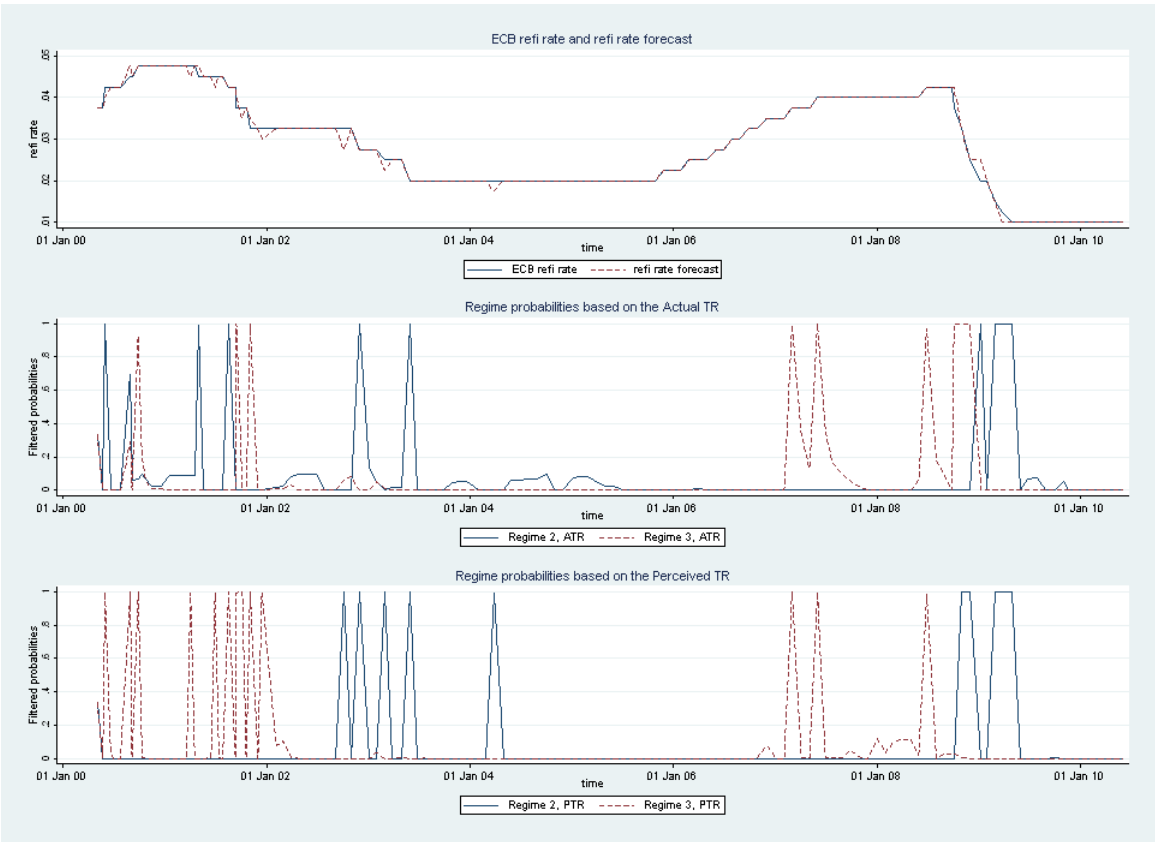

Figure 9: Actual and perceived filtered probabilities, three regimes model

Figure 9 shows that regime 2 corresponds to the one estimated within the two regimes switching specifications. Indeed, the latter occurs in crisis periods when the Central Bank cuts swiftly the policy rate to prevent a further decline in the economic outlook. This finding is thus robust to the number of regimes considered for the main policy rate. However,

it is more difficult to understand the economic intuition about the third regime. In the latter, the policy inertia is the lowest among all regimes and the ECB stabilizes both the inflation and real output growth forecasts. Figure 9 points out that this regime tends to occur in periods of monetary policy tightening as observed in 2000 or from 2007 to 2008 which corresponds with the last tightening cycle. As the ECB implements more frequent adjustments of the refi rate the policy stance is less inertial and the Central Bank attempts to stabilize both the inflation and real output growth expectations as recommended by a standard Taylor Rule specification. Hence, not surprisingly the estimated coefficients in the third regime are the closest to the original findings of Taylor (1993). Even though the latter regime takes place in periods of policy tightening and features the lowest policy inertia across all regimes, it is sometimes difficult to disentangle from the presence of the second regime.

The first evidence occurs in April 2001 when the economists have perceived a policy rate cut. Then the refi rate enters sporadically the third regime rather than the second one during the 2001-2003 cycle of policy rate cuts the ECB has implemented. At the July 2008 rate hike both the actual and perceived policy rates have switched to the third regime as one should have expected. During the large rate cuts the ECB has implemented since October 2008 the refi rate has mainly switched to the second regime but it has also transited to the third one in October, November and December 2008 as regards the Actual Taylor Rule. Concerning the Perceived Taylor Rule the policy rate has not entered the third regime during the implemented policy rate cuts which is consistent with the estimation results from the two regimes framework. Therefore, the empirical evidence on the third regime is rather mixed. While on the one hand, it seems that the latter occurs in periods of policy tightening when the Central Bank raises the policy rate, on the other hand this regime takes place also during some interest rate cuts and is sometimes difficult to disentangle from the occurrence of the second regime. One may conclude that estimating a two regimes model provides more clearly-cut results that are in line with the economic intuition and one does not have to rely too much on the three regimes specification. The latter is computationally less reliable given the higher number of parameters that are estimated.

Tables A.7 and A.8 in the appendix report the estimation results for the three regimes Actual Taylor Rule when considering a one-year fixed forecast horizon in the regressions. The evidence suggests that there are three regimes for the policy inertia coefficient which are consistent with the findings for the year ahead forecast horizon. Indeed, the policy rate is the most persistent in the first regime and the least inertial in regime 3. In addition, the ECB responds positively to both the inflation and real output growth forecasts whose coefficient estimates do not switch across regimes. The transition probabilities are in line with the findings obtained with the two regimes model. In particular, regime 1 is the most persistent and there is a high probability to switch to the latter conditional on being in regime 2. The former lasts 18.76 and the latter 1.20 policy meetings respectively. Conversely, regime 3 should not occur on average as the estimated probability is zero but is not significant.

Table A.8 points out that the Taylor Principle is not satisfied in neither regime as the Central Bank has focused more on stabilizing the economic outlook. This result is in line with the empirical findings for the two regimes model. The LR test statistic shows that there is no evidence against the model with two regimes. This result is corroborated by the AIC and BIC criteria which point out that one should prefer the two regimes model. The RMSE also indicate that there is almost no difference in the prediction error between the two specifications within the sample.

Finally, tables A.9 and A.10 in the appendix report the results for the Perceived Taylor Rule when considering the one-year fixed forecast horizon in the estimations. The results point out that the inflation responsiveness parameter has switched across three regimes.

In the first one the ECB does not seem to respond very much to inflation expectations while in the second it responds negatively to the inflation forecasts. This evidence is broadly consistent with the results obtained for the model with two regimes. In addition, in the third regime the Central Bank responds positively to inflation expectations and implements a stabilizing policy for the latter.[24] Notice also that, even though the first regime is the most persistent featuring an average duration of 19.84 policy meetings, the third regime seems to be persistent as well to some extent as it lasts 6.55 meetings on average. Finally, the LR test statistic suggests that there is no evidence in favor of the three regimes specification and the AIC and BIC criteria broadly indicate that the two regimes model should be preferred. Nevertheless, in terms of the RMSE there is some gain in choosing the three regimes model as it yields a slightly smaller prediction error of the main policy rate.

Figure A.4 in the appendix shows the actual and perceived filtered probabilities using the one-year horizon forecasts in the regressions. The estimated probabilities indicate that the occurrence of the second regime is fully in line with the above findings and the results from the model featuring two regimes with only two exceptions in December 2008 and in May 2009. Indeed, regime 2 takes place in crisis periods when the Central Bank has to cut swiftly the policy rate. However, the interpretation of the third regime is less clear-cut. As found with the year ahead forecasts, the latter tends to occur in periods of monetary policy tightening as the Central Bank focuses on stabilizing inflation expectations. Hence, the policy rate point forecast switches to the third regime in 2000 and during the 2006-2008 cycle of policy rate hikes. Besides, as previously highlighted the occurrence of the third regime is sometimes difficult to disentangle from the transition to the second one. In fact, the forecasted policy rate has switched to the third regime during the refi rate cuts in November 2002 and in 2003, as well as in the first half of 2009. In contrast, the actual policy rate has switched to the third regime only at the December 2008 meeting of the Governing Council. A possible explanation is that in view of reaching the ZLB the refi rate has switched to a regime in which the ECB implements a more aggressive policy than in normal periods to stabilize both the inflation and real output growth expectations. The Perceived Taylor Rule has also switched to the third regime of policy tightening in May 2009 as the economists may have perceived a higher responsiveness of the Central Bank to economic fundamentals. As the ECB has maintained the policy rate at the historically low level of 1% the refi rate point forecast has transited to the first regime in January 2010.

7 Conclusion

This paper has shed more light on understanding the European monetary policy within Actual and Perceived regime switching Taylor Rules. The former is based on the actual refi rate set by the ECB Governing Council while the latter relies on the professional point forecasts for the refi rate made before the upcoming monetary policy meeting. There are several main results that can be drawn from the empirical evidence of this paper.

First, the standard linear Taylor Rule has hidden finer policy regimes that have been identified within the MRS framework. Indeed, the results have shown that the Central Bank has switched between a regime that occurs in normal (non-crisis) periods to a regime of economic downturn that features sharp interest rate cuts. In the former, the ECB attempts to stabilize both the inflation and real output growth expectations and the policy rate features substantial inertia. In the latter the Central Bank implements a larger fraction of the desired policy rate and switches towards stabilizing the economic outlook rather than inflation expectations. This evidence points out that in crisis periods, as the Central Bank has to react quickly, it puts temporarily aside its overriding price stability goal and focuses

[24] The long-run inflation coefficient indicates that the Taylor Principle is satisfied in regime 3.

mainly on preventing a further decline in economic activity and on securing the stability of the financial system. The empirical results are consistent with a Central Bank loss function that contains a financial stability objective as outlined in Agur and Demertzis (2011). The evidence shows that the coefficient estimates in the corresponding regimes are sensitive to the measure of expectations used in the regressions. However, the estimated regimes are robust to using either the year ahead or the one-year fixed forecasting horizons. The estimations with the year ahead forecasts provide better results as they reflect more accurately the forward-looking nature of the expectations formation process, which is a salient feature of the Taylor Rules framework.

Second, the results point out that the professional forecasters have broadly well predicted the Central Bank's responsiveness to economic fundamentals in the corresponding policy regimes as well as the timing of the regime switches. Moreover, the results are robust to including consensus forecasts of inflation and real output growth instead of the investment bank forecasts in the regressions. The augmented Taylor Rule specification further suggests that including the growth rates of M3 and the nominal effective exchange rate in the estimations does not provide further insights on understanding the policy reaction function of the ECB. Besides, the estimated regimes remain robust to including these additional variables in the regressions.

Finally, the empirical evidence for the two regimes is broadly unaltered when estimating a model with three regimes. Even though some of the LM test statistics show evidence in favor of the three regimes specification, the economic evidence is rather mixed about the relevance of a third regime. Indeed, regime 3 seems to correspond to periods of monetary policy tightening when the Central Bank's policy switches towards stabilizing both the inflation and real output growth forecasts. However, for some periods the latter is quite difficult to disentangle from the occurrence of the second regime. In terms of policy recommendation, this paper has shown that it is particularly important to consider a regime switching specification of the Taylor Rules in order to better understand the behavior of the ECB and to more accurately predict its main interest rate. Following a regime switching policy rule will help the Governing Council to set the appropriate level of the refi rate according to the specific state of the economy. As avenues for future research, it would be valuable to understand more thoroughly the nature and sources of nonlinearities in monetary policy rules.

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8 Appendix

8.1 Variables used in the estimations

Table A.1: List of variables

Variable	Description
i_{t+1}	Refi rate set by the ECB at its policy meeting in period $t+1$.
$E_t i_{t+1}$	Refi rate point forecast reported by the investment bank's economists in period t for the refi rate decision in period $t+1$.
$E_t \pi_y$	Inflation point forecasts of the investment bank's economists and Consensus Economics for the current year horizon.
$E_t \pi_{y+1}$	Inflation point forecasts of the investment bank's economists and Consensus Economics for the year ahead horizon.
$E_t \bar{\pi}_y$	One-year inflation point forecasts horizon of the investment bank's economists and Consensus Economics.
$E_t y_y$	Real GDP growth point forecasts of the investment bank's economists and Consensus Economics for the current year horizon.
$E_t y_{y+1}$	Real GDP growth point forecasts of the investment bank's economists and Consensus Economics for the year ahead horizon.
$E_t \bar{y}_y$	One-year real GDP growth point forecasts horizon of the investment bank's economists and Consensus Economics.
M3	The yearly growth rate of the monetary aggregate M3 which is taken from the ECB's real-time database.
Nominal exchange rate	The yearly growth rate of the nominal effective exchange rate of the euro against a broad basket of currencies. A positive growth rate implies an appreciation of the euro vis-à-vis this basket of currencies. The series is from the ECB's real-time database.
ESI	The difference between the euro area Economic Sentiment Indicator (ESI) and its long-run average of 100 expressed in percentage points of the long-run average. The ESI is published by the European Commission on a monthly basis.

Table A.2: Summary statistics

DEPENDENT AND EXPLANATORY VARIABLES	Obs.	Mean	Std. deviation	Min	Max
ECB's main refinancing operations rate (refi rate) (%)	141	3.060	1.194	1.00	4.75
ECB's refi rate point forecast, investment bank (%)	141	3.057	1.200	1.00	4.75
Current year inflation, investment bank (%)	141	2.060	0.671	0.20	3.70
Year ahead inflation, investment bank (%)	141	1.788	0.358	1.00	2.60
One-year inflation, investment bank (%)	141	1.911	0.464	0.53	3.11
Current year real GDP growth, investment bank (%)	141	1.465	1.744	-4.30	4.00
Year ahead real GDP growth, investment bank (%)	141	2.042	0.776	-0.50	3.60
One-year real GDP growth, investment bank (%)	141	1.699	0.012	-2.24	3.87
Current year inflation, consensus forecasts (%)	141	2.005	0.655	0.30	3.60
Year ahead inflation, consensus forecasts (%)	141	1.790	0.265	1.10	2.50
One-year inflation, consensus forecasts (%)	141	1.871	0.442	0.32	3.26
Current year real GDP growth, consensus forecasts (%)	141	1.471	1.712	-4.40	3.40
Year ahead real GDP growth, consensus forecasts (%)	141	2.008	0.759	-0.90	3.20
One-year real GDP growth, consensus forecasts (%)	141	1.722	1.193	-3.80	3.29
M3 yearly growth rate (%)	141	6.660	2.751	-0.30	12.50
Nominal effective exchange rate, yearly rate of change (%)	141	1.723	6.276	-12.91	17.29
Economic Sentiment Indicator, deviation from long-run average (%)	141	0.804	10.287	-29.30	17.60

Note: The actual refi rate, the M3 growth rate and the nominal effective exchange rate are taken from the website of the ECB. The Economic Sentiment Indicator comes from the European Commission's website. The long-run average of the ESI is equal to 100 as computed by the Commission.

8.2 Unit root and stationarity tests

Table A.3: Unit root tests, Investment Bank Forecasts

Variables	ADF Z(t)	PP Z(t)	KPSS	Integration order
Refi rate	-1.940**	-0.682	0.585**	I(0)
	(0.027)	(0.851)		
Forecasted refi rate	-1.600*	-0.753	0.567**	I(0)
	(0.056)	(0.833)		
Expected inflation, current year	-3.102***	-2.845*	0.186	I(0)
	(0.001)	(0.052)		
Expected inflation, year ahead	-2.993***	-2.980**	0.134	I(0)
	(0.002)	(0.037)		
Expected inflation, one-year horizon	-3.795***	-2.626*	0.162	I(0)
	(0.000)	(0.088)		
Expected GDP growth, current year	-2.348***	-2.375	0.521**	I(0)
	(0.010)	(0.149)		
Expected GDP growth, year ahead	-2.987***	-3.055**	0.657**	I(0)
	(0.002)	(0.030)		
Expected GDP growth, one-year horizon	-2.809***	-2.317	0.566**	I(0)
	(0.003)	(0.166)		
M3 yearly growth rate	-1.117	-0.288	0.257	I(1)
	(0.133)	(0.927)		
Nominal exchange rate, yearly rate of change	-2.696***	-2.453	0.281	I(0)
	(0.004)	(0.127)		
ESI percentage deviation from the long-run average	-2.712***	-1.923	0.480**	I(0)
	(0.004)	(0.321)		
Observations	137	140	141	

Note: The ADF Z(t) and PP Z(t) refer to the Augmented Dickey-Fuller and Phillips-Perron tests for unit root in the variables. A statistically significant test shows evidence against the null hypothesis of unit root. For the ADF test 3 lags of the difference in the variables have been used, while the number of lags used in the Phillips-Perron test are determined automatically based on Newey-West bandwidth selection. The Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test reports the statistic for testing the null hypothesis of level stationarity based on Newey-West automatic bandwidth selection. A statistically significant test shows evidence against the hypothesis of stationarity. The integration order is determined on the basis of the ADF, PP and KPSS test statistics. MacKinnon approximate p-values are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A.4: Unit root tests, Consensus Economics Forecasts

Variables	ADF Z(t)	PP Z(t)	KPSS	Integration order
Expected inflation, current year	-3.165***	-2.681*	0.167	I(0)
	(0.001)	(0.077)		
Expected inflation, year ahead	-2.316**	-2.447	0.111	I(0)
	(0.011)	(0.129)		
Expected inflation, one-year horizon	-2.393***	-3.296**	0.142	I(0)
	(0.009)	(0.015)		
Expected GDP growth, current year	-2.467***	-2.251	0.564**	I(0)
	(0.007)	(0.188)		
Expected GDP growth, year ahead	-1.879**	-2.011	1.090***	I(1)
	(0.031)	(0.282)		
Expected GDP growth, one-year horizon	-1.897**	-2.947**	0.772***	I(0)
	(0.030)	(0.040)		
Observations	137	140	141	

Note: The ADF Z(t) and PP Z(t) refer to the Augmented Dickey-Fuller and Phillips-Perron tests for unit root in the variables. A statistically significant test shows evidence against the null hypothesis of unit root. For the ADF test 3 lags of the difference in the variables have been used, while the number of lags used in the Phillips-Perron test are determined automatically based on Newey-West bandwidth selection. The Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test reports the statistic for testing the null hypothesis of level stationarity based on Newey-West automatic bandwidth selection. A statistically significant test shows evidence against the hypothesis of stationarity. The integration order is determined on the basis of the ADF, PP and KPSS test statistics. MacKinnon approximate p-values are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

8.3 Fitted policy rates of the baseline model

Figure A.1: MRS and linear model fitted rates, ATR baseline model

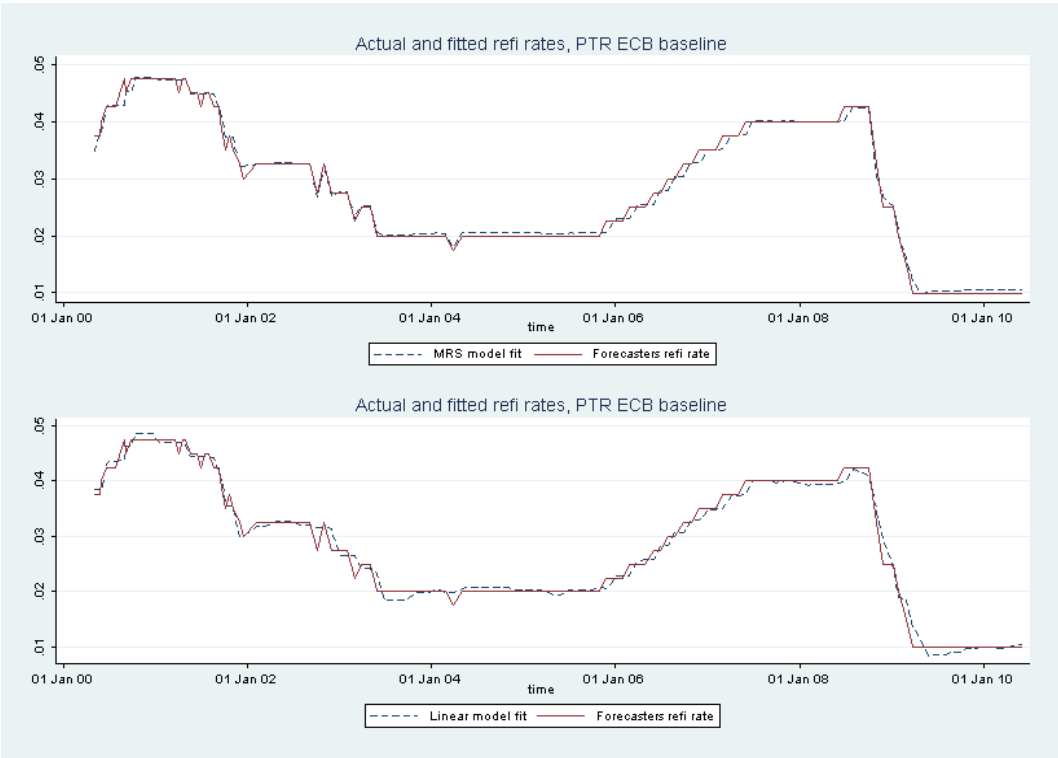

Figure A.2: MRS and linear model fitted rates, PTR baseline model

8.4 Augmented Taylor Rules with a one-year forecast horizon

Table A.5: Augmented Taylor Rules, linear model (one-year)

	Actual Taylor Rule	Perceived Taylor Rule
ρ	0.9416***	0.9446***
	(0.0124)	(0.0113)
γ_π	0.0300	0.0690***
	(0.0472)	(0.0381)
γ_y	0.0792***	0.0620***
	(0.0216)	(0.0201)
γ_m	0.0068	0.0065
	(0.0042)	(0.0041)
γ_e	-0.0020	-0.0037
	(0.0026)	(0.0027)
γ_c	-0.0007	-0.0013***
	(0.0006)	(0.0005)
σ_ϵ	0.0014***	0.0014***
	(0.0001)	(0.0001)
Observations	141	141
Log-likelihood	728.351	727.022

Note: The table displays the short-run coefficients. ρ, γ_π, γ_y, γ_m, γ_e, γ_c denote the policy inertia, inflation and output growth expectations, the M3 and the nominal effective exchange rate coefficients respectively and the constant term. MLE, robust standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A.6: Actual and Perceived MRS Taylor Rules, augmented model (one-year)

	Actual Taylor Rule		Perceived Taylor Rule	
	Regime 1	Regime 2	Regime 1	Regime 2
$\rho_{s_{t+1}}$	0.9753***	0.8844***	0.9685***	0.9244***
	(0.0027)	(0.0145)	(0.0030)	(0.0088)
$\gamma_{\pi_{s_{t+1}}}$	0.0022***	-0.1149***	0.0196***	-0.1768***
	(0.0003)	(0.0079)	(0.0002)	(0.0049)
$\gamma_{y_{s_{t+1}}}$	0.0257***	0.2303***	0.0137***	0.2317***
	(0.0004)	(0.0324)	(0.0004)	(0.0048)
$\gamma_{m_{s_{t+1}}}$	0.0078***		0.0086***	
	(0.0020)		(0.0001)	
$\gamma_{e_{s_{t+1}}}$	-0.0033***		-0.0048***	
	(0.0008)		(0.0001)	
γ_c	-0.0000		-0.0000	
	(0.0000)		(0.0000)	
σ_ϵ	0.0009***		0.0010***	
	(1.514e-05)		(9.354e-06)	
$P[S_{t+1} = i \mid S_t = 1]$	0.8338***	0.1662***	0.7783***	0.2217***
	(0.0814)	(0.0080)	(0.0166)	(0.0048)
$P[S_{t+1} = i \mid S_t = 2]$	0.7725***	0.2275***	0.8333***	0.1667***
	(0.0838)	(0.0187)	(0.0294)	(0.0029)
Observations	141		141	
Log-likelihood	755.072		744.779	

Note: The table displays the short-run coefficients. $\rho_{s_{t+1}}$, $\gamma_{\pi_{s_{t+1}}}$, $\gamma_{y_{s_{t+1}}}$, $\gamma_{m_{s_{t+1}}}$, $\gamma_{e_{s_{t+1}}}$, γ_c denote the policy inertia, inflation and output growth expectations, the M3 and the nominal effective exchange rate coefficients respectively and the constant term. Estimates in the middle of the columns refer to parameters that do not switch across regimes. Iterative MLE, HAC standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

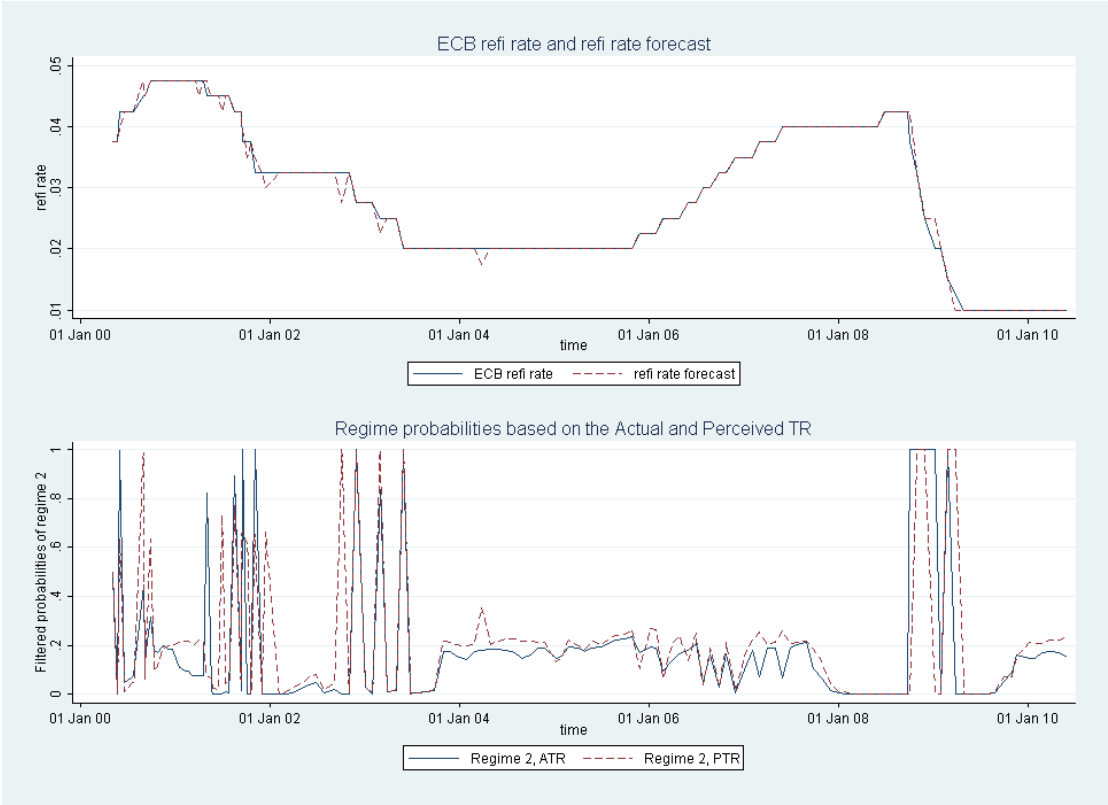

Figure A.3: Actual and perceived filtered probabilities, augmented model (one-year)

8.5 A three regimes switching model with a one-year forecast horizon

Table A.7: Actual MRS TR, Three Regimes Model (TRM, one-year)

	Regime 1	Regime 2	Regime 3
$\rho_{s_{t+1}}$	0.9784***	0.8479***	0.7683***
	(0.0030)	(0.0069)	(0.0665)
$\gamma_{\pi_{s_{t+1}}}$		0.0165***	
		(0.0009)	
$\gamma_{y_{s_{t+1}}}$		0.0304***	
		(0.0010)	
γ_c		-0.0000	
		(0.0000)	
σ_ϵ		0.0009***	
		(1.913e-05)	
$P[S_{t+1} = i \mid S_t = 1]$	0.9467***	0.0482***	0.0051***
	(0.0656)	(0.0024)	(0.0005)
$P[S_{t+1} = i \mid S_t = 2]$	0.7200***	0.1665***	0.1135***
	(0.0288)	(0.0122)	(0.0030)
$P[S_{t+1} = i \mid S_t = 3]$	0.0785***	0.9215***	0.0000
	(0.0041)	(0.0536)	(0.0000)
Observations		141	
Log-likelihood		754.851	

Note: The table displays the short-run coefficients. $\rho_{s_{t+1}}$, $\gamma_{\pi_{s_{t+1}}}$, $\gamma_{y_{s_{t+1}}}$, γ_c denote the policy inertia, inflation and output growth expectations coefficients respectively and the constant term. Estimates in the middle of the columns refer to parameters that do not switch across regimes. Iterative MLE, HAC standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A.8: Actual MRS TR, TRM long-run parameters (one-year)

	Regime 1	Regime 2	Regime 3
$\rho_{s_{t+1}}$	0.9784***	0.8479***	0.7683***
	(0.0030)	(0.0069)	(0.0665)
$\beta_{\pi_{s_{t+1}}}$	0.7625***	0.1083***	0.0711***
	(0.0804)	(0.0020)	(0.0243)
$\beta_{y_{s_{t+1}}}$	1.4050***	0.1996***	0.1310***
	(0.2310)	(0.0149)	(0.0336)
Observations		141	
LL MRS three regimes		754.851	
LL MRS two regimes		752.061	
LR test		5.580	
AIC MRS three regimes		-1477.701	
BIC MRS three regimes		-1430.521	
AIC MRS two regimes		-1484.121	
BIC MRS two regimes		-1454.634	
RMSE MRS three regimes		0.000889	
RMSE MRS two regimes		0.000890	

Note: The table displays the implied long-run coefficients. $\rho_{s_{t+1}}$, $\beta_{\pi_{s_{t+1}}}$, $\beta_{y_{s_{t+1}}}$, denote the policy inertia, inflation and output growth expectations coefficients respectively. Estimates in the middle of the columns refer to parameters that do not switch across regimes. Standard errors are computed with the Delta method and are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A.9: Perceived MRS TR, Three Regimes Model (TRM, one-year)

	Regime 1	Regime 2	Regime 3
$\rho_{s_{t+1}}$		0.9624***	
		(0.0041)	
$\gamma_{\pi_{s_{t+1}}}$	0.0006***	-0.2569***	0.0413***
	(0.0000)	(0.0118)	(0.0019)
$\gamma_{y_{s_{t+1}}}$		0.0466***	
		(0.0002)	
γ_c		-0.0000	
		(0.0000)	
σ_ϵ		0.0009***	
		(1.196e-05)	
$P[S_{t+1} = i \mid S_t = 1]$	0.9496***	0.0000	0.0504***
	(0.0232)	(0.0000)	(0.0003)
$P[S_{t+1} = i \mid S_t = 2]$	0.0000	0.2729***	0.7271***
	(0.0000)	(0.0056)	(0.0256)
$P[S_{t+1} = i \mid S_t = 3]$	0.0602***	0.0924***	0.8474***
	(0.0007)	(0.0047)	(0.0195)
Observations		141	
Log-likelihood		742.773	

Note: The table displays the short-run coefficients. $\rho_{s_{t+1}}$, $\gamma_{\pi_{s_{t+1}}}$, $\gamma_{y_{s_{t+1}}}$, γ_c denote the policy inertia, inflation and output growth expectations coefficients respectively and the constant term. Estimates in the middle of the columns refer to parameters that do not switch across regimes. Iterative MLE, HAC standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A.10: Perceived MRS TR, TRM long-run parameters (one-year)

	Regime 1	Regime 2	Regime 3
$\rho_{s_{t+1}}$		0.9624***	
		(0.0041)	
$\beta_{\pi_{s_{t+1}}}$	0.0158***	-6.8279***	1.0967***
	(0.0009)	(1.0520)	(0.1688)
$\beta_{y_{s_{t+1}}}$		1.2394***	
		(0.1394)	
Observations		141	
LL MRS three regimes		742.773	
LL MRS two regimes		736.484	
LR test		12.578	
AIC MRS three regimes		-1453.545	
BIC MRS three regimes		-1406.365	
AIC MRS two regimes		-1452.967	
BIC MRS two regimes		-1423.480	
RMSE MRS three regimes		0.000891	
RMSE MRS two regimes		0.001001	

Note: The table displays the implied long-run coefficients. $\rho_{s_{t+1}}$, $\beta_{\pi_{s_{t+1}}}$, $\beta_{y_{s_{t+1}}}$, denote the policy inertia, inflation and output growth expectations coefficients respectively. Estimates in the middle of the columns refer to parameters that do not switch across regimes. Standard errors are computed with the Delta method and are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

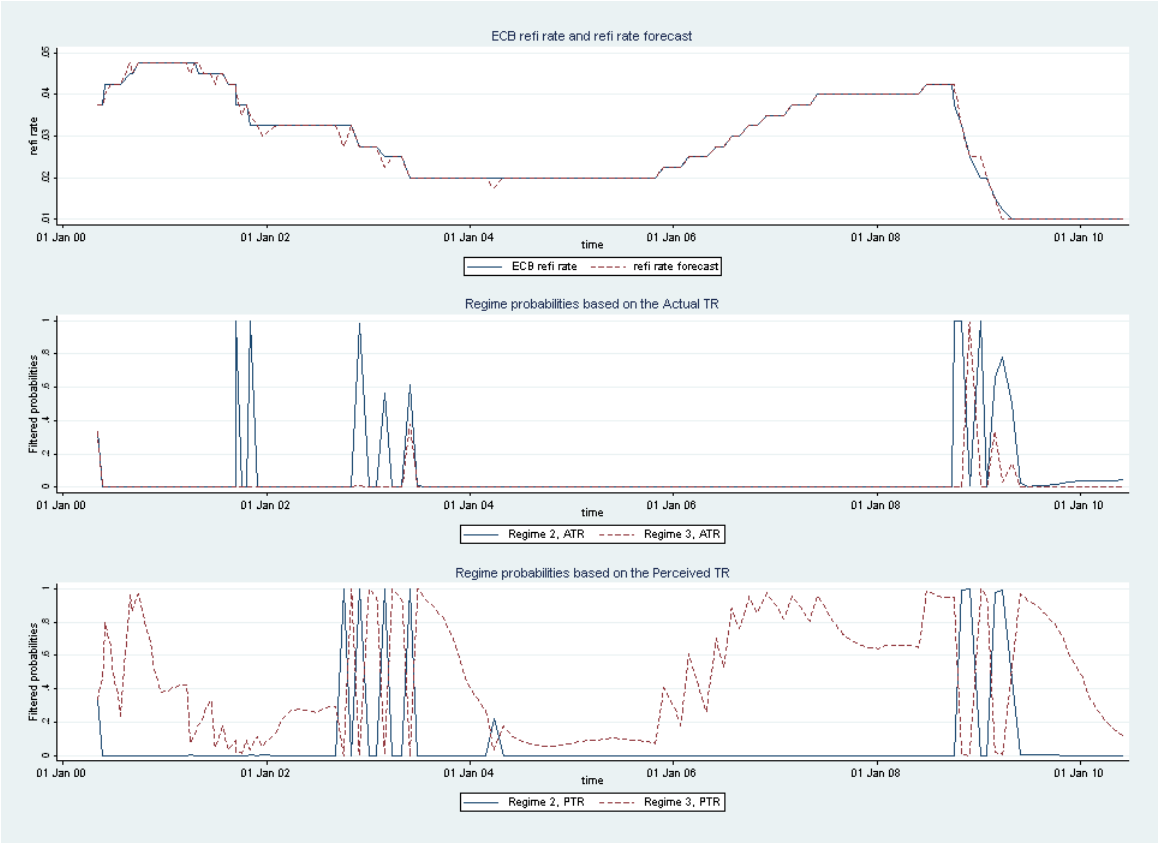

Figure A.4: Actual and perceived filtered probabilities, three regimes model (one-year)