ATHENS UNIVERSITY OF ECONOMICS AND BUSINESS

DEPARTMENT OF ECONOMICS

WORKING PAPER SERIES **07-2012**

Unveiling eurozone's monetary policy behavior under different inflation regimes

Thanassis Kazanas* and Elias Tzavalis**

76 Patission Str., Athens 104 34, Greece
Tel. (++30) 210-8203911 - Fax: (++30) 210-8203301
www.econ.aueb.gr

Unveiling eurozone's monetary policy behavior under different inflation regimes

Thanassis Kazanas* and Elias Tzavalis**

Abstract

Based on a threshold monetary policy rule model which allows for two inflation policy regimes: a low and high, this paper provides clear cut evidence that eurozone monetary authorities follow an asymmetric policy concerning more about inflation rather than real output. This asymmetric policy can be attributed to the attitude of the eurozone monetary authorities to build up credibility on stabilizing inflationary expectations. To evaluate the economic implications of the above monetary policy rule behavior, the paper simulates a small New Keynesian model. This exercise clearly indicates that the absence of reaction of the eurozone monetary authorities to negative output deviations when inflation is very low reduces their efficiency on dampening the effects of negative demand shocks on the economy.

JEL Classification: E52, C13, C30

Keywords: Monetary policy rule, Threshold models, regime-switching, generalized method of moments, New Keynesian model

The authors would like to thank Heather Gibson, Alex Michaelides, George Tavlas, as well as the participants at the seminar series of the Bank of Greece for helpful comments on an earlier version of the paper. Thanassis Kazanas also acknowledges financial support from the Bank of Greece for carrying out this research.

*Athens University of Economics and Business, Department of Economics, 76 Patission Str., 104 34, Athens, Greece. Email: tkazanas@aueb.gr
**Athens University of Economics and Business, Department of Economics, 76 Patission Str., 104 34, Athens, Greece. Email: etzavalis@aueb.gr

1. Introduction

Unveiling central banks' (CBs') policy behavior on their lending interest rate, which nowadays is considered as their main policy instrument, has attracted a lot of research interest over the last decade. This can indicate whether monetary authorities set this interest rate according to their official announcements about inflation or output. Answering this question has important policy implications as it will reveal the credibility of monetary authorities on their economic policy objectives. In contrast to US and UK economies, there are only a few studies which estimate monetary policy rule models for the eurozone economy.[1] This can be obviously attributed to the short history of the European Central Bank (ECB) and thus, the lack of low frequency data over a long period. Estimation of monetary policy rule models for eurozone is also very interesting from a political economy point of view. It can indicate whether actual the eurozone monetary policy rule is in line with that followed by Bundesbank in the past, which was strongly anti-inflationary (see, e.g., Clarida, Gali and Gertler (1998), (2000)). The latter has been challenged by some empirical studies (see, e.g., Ullrich (2003), and Sauer and Sturm (2007)).

This paper attempts to answer the following questions regarding the intervention interest rate policy followed by the eurozone monetary authorities, and ECB. First, is this policy mainly anti-inflationary and focused on stabilizing inflation expectations, as is mandated by the Maastricht treaty? Someone may expect that, for some economic periods like during recessions or when inflation rate is low (see, e.g., Martin and Milas (2004) or Surico (2007)), the ECB's monetary policy is focused more on anti-cyclical policies rather than on inflation. Has this happened since the sign of Maastricht treaty, or the launch of euro as a common currency? Second, do the ECB tend to set inflation target at 2% over the medium term, as has been officially announced? As some recent studies indicate, many CBs try to keep inflation within a range rather than pursuing a point target (see, e.g., Martin and Milas (2004)). Third, can the eurozone monetary policy rule followed in practice reduce macroeconomic fluctuations in response to economic shocks? As it is claimed by the Maastricht treaty, without prejudice to the price stability objective, the ECB should also accompany the

[1] See, e.g., Fourçans and Vranceanu (2006), (2007), Ullrich (2003), Gerlach-Kristen (2003), Gerdesmeier and Roffia (2003), Gorter *et al*. (2007), Surico (2007) and Milas and Naraidoo (2010).

eurozone economic goals which include high level of employment and sustainable growth.[2] Answering the above questions can shed light not only on the credibility of the ECB on policy objectives mentioned before, but also on the efficiency of this policy in achieving these objectives.

To answer the above questions, the paper estimates a forward-looking threshold monetary policy rule model whose policy parameters, capturing the effects of inflation and output deviations from their target levels on the CB interest rate, are subject to regime-switching. The latter depends on the level of current inflation rate.[3] This is done based on monthly data from January 1994 until September 2011. This sample includes period 1994-1998, after the sign of Maastricht Treaty in year 1992, and thus can show if the eurozone monetary policy objectives remained the same before and after the launch of euro in year 1999. Compared to other threshold forward-looking monetary policy rule models estimated in the literature, our model has the following attractive features. First, it considers the threshold value of inflation rate above (or below) which regime-switching occurs as an unknown parameter, which can be estimated by the data. This can indicate whether the inflation rate target of the eurozone monetary authorities followed in practice is different from the 2% level. Second, our model allows for the threshold variable to be endogenous, i.e. contemporaneously correlated with the explanatory variables of the model, as is expected to happen in practice. As aptly noted by Kazanas and Tzavalis (2010), ignoring this correlation will lead to substantial bias of the policy rule parameter estimates. To estimate the model allowing for the above endogenous nature of threshold variable, the paper adopts a novel econometric technique, suggested recently by Kourtellos *et al.* (2011).

The estimation results of the paper lead to a number of interesting conclusions. First, they indicate that the eurozone monetary policy rule can be characterized by two distinct inflation regimes: the low and high. Second, this rule behaves asymmetrically in these two regimes. The CB's lending rate responds more aggressively to deviations

[2] See, also Trichet (2005).

[3] Threshold models of monetary policy rules have been estimated in many recent studies (see, e.g., Kim *et al.* (2005), Taylor and Davradakis (2006), Gredig (2007), and Kazanas *et al*. (2011)). In contrast to smooth transition autoregressive (STAR) model (see, e.g., Martin and Milas (2004) and Surico (2007)), these models are suitable for modelling abrupt changes in interest rates response functions observed in reality (see, e.g., Assenmacher-Wesche (2006)).

of inflation rate from its target level in the high inflation regime, compared to the low inflation regime. However, this does not happen with the economic (output) cyclical deviations. The paper provides clear cut evidence that the eurozone monetary authorities do not ease their interest rate policy with respect to output deviations in the low inflation regime, despite the fact that their price stability objective can have been achieved. The above results support the view that the eurozone monetary authorities concern mainly about inflation, and not about sustainability of growth. This attitude can be attributed to the emphasis put by this young central bank on building credibility on anchoring inflation expectations. It can be also supported by evidence provided by the paper that the threshold value of inflation rate above (or below) which these authorities change their policy rule is less than the 2% level. Thus, they act proactively on inflation rate increases, so as to stabilize inflation expectations and enhance their credibility.

To assess the policy implication of the above results with respect to their effects on economic activity, the paper simulates a small-scale New Keynesian (NK) IS-LM model, which is based on the sample estimates of our threshold monetary policy rule model. The results of this exercise clearly indicate that the eurozone monetary policy authorities could become more efficient in achieving their inflation and economic activity objectives if, in addition to inflation, they were also concerned about negative deviations of output from its target level in the low inflation regime. These deviations can be very large and prolonged when they are generated by demand shocks. Anchoring inflation expectations by following a strong anti-inflationary policy is not sufficient to avoid them and, thus, sustain economic growth.

The plan of the paper is as follows. Section 2 presents the forward-looking threshold monetary policy rule model, considered in our analysis. Section 3 provides estimates of this model. Section 4 conducts our simulation study, based on the estimates of Section 3. Section 5 concludes the paper.

2. Model set up

Let i_t denotes the nominal short-term (one period) interest rate of the central bank (CB) and i_t^* be its current, *t*-time desired (or target) level. Assume that target rate i_t^* depends on two different inflation regimes: the high (*H*) and low (*L*), and it is described by the following forward-looking threshold switching monetary policy rule model:

$$i_t^* = \begin{cases} a + \beta_L [E_t(\pi_{t+n}) - \pi^*] + \gamma_L [E_t(y_{t+k}) - y^*] & \text{if } \pi_t \le \overline{q} \\ \\ a + \beta_H [E_t(\pi_{t+n}) - \pi^*] + \gamma_H [E_t(y_{t+k}) - y^*] & \text{if } \pi_t > \overline{q}, \end{cases} \tag{1}$$

where a is a constant denoting the long-run equilibrium level of target interest rate, $E_t(\cdot) \equiv E(\cdot \mid \Omega_t)$ denotes conditional expectation on the current information set of the economy at time *t*, denoted as Ω_t, π_{t+n} is the rate of inflation *n*-periods ahead, y_{t+k} is real output *k*-periods ahead, and π^* and y^* denote the desired levels for inflation and real output, respectively. In the above model, $\overline{q}$ stands for the threshold parameter determining switching between inflation regimes *H* and *L*. In our empirical analysis, the value of this parameter will be treated as unknown and, thus, will be estimated from the data.

Model (1) implies that, when the current inflation rate π_t is in regime *H* (defined by inequality $\pi_t > \overline{q}$), then its monetary policy rule parameters beta and gamma will be given as β_H and γ_H. On the other hand, when it is in regime *L* (defined by $\pi_t \le \overline{q}$), then these parameters will be denoted as β_L and γ_L. Allowing for interest rate smoothing, which assumes that the actual level of rate i_t, set by the CB, is driven by the following partial adjustment process: [4]

[4] See, e.g., Clarida *et al*. (1999) and more recently Martin and Milas (2010). The tendency of CBs to smooth changes in short-term interest rates stems from various reasons, e.g., for fears of disrupting capital markets and financial instability, the loss of credibility from sudden large policy reversals or the need for consensus building to support a policy change. Moreover, CBs may regard interest rates smoothing as a learning device due to imperfect market information.

$$i_t = (1-\rho)i_t^* + \rho i_{t-1} + \varepsilon_t ,$$

where $\varepsilon_t \sim IID(0,\sigma^2)$ is an error term reflecting monetary shocks and $\rho \in [0,1)$, model (1) can be written as follows:

$$i_t = \begin{cases} (1-\rho)\left\{a^* + \beta_L[E_t(\pi_{t+n}) - \pi^*] + \gamma_L[E_t(y_{t+k}) - y^*]\right\} + \rho i_{t\text{-}1} + \varepsilon_t & \text{if } \ \pi_t \le \overline{q} \\ \\ (1-\rho)\left\{a^* + \beta_H[E_t(\pi_{t+n}) - \pi^*] + \gamma_H[E_t(y_{t+k}) - y^*]\right\} + \rho i_{t\text{-}1} + \varepsilon_t & \text{if } \ \pi_t > \overline{q} \end{cases} \qquad (2)$$

If there is no regime-switching, the last model reduces to the forward-looking linear (standard) Taylor rule model given by the following equation:

$$i_t = (1-\rho)\left\{a + \beta[E_t(\pi_{t+n}) - \pi^*] + \gamma[E_t(y_{t+k}) - y^*]\right\} + \rho i_{t\text{-}1} + \varepsilon_t, \qquad (3)$$

where $\beta_L = \beta_H = \beta$ and $\gamma_L = \gamma_H = \gamma$.

Threshold model (2) belongs to the class of regime-switching monetary policy rule models.[5] This class of models considers abrupt changes of the monetary policy rule parameters beta and gamma, which are consistent with recent evidence provided in the literature by many empirical studies.[6] To capture these changes, most of these studies are based on dummy variables intervention approach, or they carry out estimation of the Taylor rule model (3), by splitting the sample into different sub-samples. To determine these sub-samples, this approach relies on exogenous information from the sample. Furthermore, sample splitting is like to assume that, after a shift in a new regime, economic agents believe that they will stay in the same regime for ever. This assumption can not account for the dynamic expectation formation effects of regime-switching monetary policy rule models on the economy which can be proved very important in practice, as they can increase the efficiency of monetary policy, as aptly noted recently by Davig and Leeper (2007). These effects arise whenever agents' rational expectations about a future regime change in

[5] See, e.g., Sims and Zha (2006), Davig and Leeper (2007, 2008), Farmer, Waggoner and Zha (2008), and Liu, Waggoner and Zha (2009).

[6] See, e.g., Judd and Rudebusch (1998), Dolado, María-Dolores and Naveira (2000), Neumann and von Hagen (2002), Ullrich (2003) and Surico (2003).

monetary policy induce them to alter their expectations about inflation or economic activity.

Within the class of regime-switching models, threshold model (2) has the following attractive property, especially compared to the Markov-Chain model (MRS) frequently used in practice to capture regime type of shifts in the monetary policy rule parameters (see fn 5). It contrast to the MRS, model (2) considers policy parameter changes triggered by a value of an observed variable (e.g., inflation rate π_t, in our context) which can be treated as endogenous, i.e. correlated with monetary shocks ε_t. The MRS model assumes that regime-switching in the above parameters is driven by a latent random variable (i.e. a Markov chain) which is exogenous to shocks ε_t. As noted in the introduction, this assumption about ε_t is quite restrictive. It may not be also true in practice.

Threshold model (2) allows us to formally address the following questions regarding the eurozone monetary policy on the CB's intervention interest rate i_t. First, we can use the model to investigate if there are asymmetric preferences of the eurozone monetary authorities with respect to deviations of inflation rate or output from their target levels depending on the inflation. We can also examine if these preferences have stabilizing effects on inflation expectations.[7] Such effects require that $\beta_H > 1$ at the high inflation regime, *H*. By the Maastricht Treaty and European Central Bank's (ECB) announcements (see, e.g., Fourçans and Vranceanu (2006)), one would expect eurozone monetary policy to be more aggressive with respect to deviations of inflation rate from its target level in the high inflation regime, compared to the low. Once the inflation rate target is achieved, then the eurozone monetary authorities may attempt to dampen cyclical deviations of output and unemployment. The latter can be investigated by testing if inequality $\gamma_L > 0$ holds in the low inflation regime, *L*.

[7] Note that this asymmetric behavior is different than that considered in nonlinear monetary policy models such as the smooth transition autoregressive (STAR) model, or its version used by Martin and Milas (2004), and Surico (2007). These models are suitable in investigating possible asymmetries in the CB's preferences about inflation rate or output gap deviations under a specific regime, and they do not assume regime-switching.

A second question which can be addressed by estimating model (2) is related to inflation targeting. By estimating threshold value $\overline{q}$ from the data, we can examine if eurozone policy makers set inflation target at 2%, as has been officially announced. An estimate of $\overline{q}$ different than 2% level can be taken as evidence supporting the view that, in practice, the ECB follows policies with inflation zone targeting characteristics (see, e.g., Orphanides and Wieland (2000), or Martin and Milas (2004) for UK). If this estimate is less than the 2% level, one may argue that eurozone monetary authorities act preemptively on inflationary pressure and, thus, raise interest rate i_t if current inflation rate is below the 2% level, so as to anchor long-run inflation expectations.

3. Empirical analysis

In this section, we estimate threshold model (2), presented in the previous section, and we carry out some recently developed econometric tests to examine if there is evidence of regime-switching in the ECB monetary policy rule depending on the current inflation rate. Our analysis starts with estimating the standard forward monetary policy model, given by equation (3). Estimation of this model is very useful, as comparing its results with those of model (2) can reveal whether ambiguous evidence about the ECB monetary policy behavior can be attributed to the omission of regime-switching effects.

3.1 Data

Our data set was obtained from the ECB's website. Its frequency is monthly and it covers the period from 1994:01 to 2011:09. For the period before the launch of euro, the data were constructed by the ECB. We use the Euro Overnight Index Average (EONIA) lending rate on the money market as the short-term nominal interest rate, i_t. Inflation rate, π_t, is measured by the percentage change in the Harmonised Index of Consumer Prices over a year back $\pi_t = \frac{P_t - P_{t-12}}{P_{t-12}} \cdot 100$ and the inflation target is set to π^* =2%. As a measure of output gap deviation $y_{t+k} - y^*$, we take the deviation of the industrial production index (IPI) growth rate from its sample average, following other studies in the literature based on monthly data (see, e.g., Clarida *et al*. (1998), Fourçans and Vranceanu (2006), Surico (2007)). As inflation rate π_t, the IPI growth rate is calculated as the percentage change in IPI at time *t* from its previous year.

In addition to the above variables, our data set also includes the M3 money growth rate, the Dow Jones Euro STOXX - Price index, the economic sentiment indicator (ESIN) and the spread between the benchmark 10-year government bond and the 3-month euribor. These variables are often used as instruments in estimation procedures of monetary policy rules so as to avoid any estimation bias due to the forward-looking nature of these models (see, e.g., Ullrich (2003), Sauer and Sturm (2007), Fourçans and Vranceanu (2006)).[8] In Table 1, we give summary statistics of the key variables of monetary policy rule model (2), namely of nominal interest rate i_t, inflation rate π_t and IPI growth rate y_t. The results of the table indicate that, for our sample, inflation rate has a mean which is close to the 2% target level and its standard deviation is quite small given by 0.74%. Note that this level of standard deviation is much smaller than that of industrial production growth rate and interest rate i_t, given as 5.12% and 1.62%, respectively. These results are consistent with the policy objective mandates of the ECB to maintain price stability. However, they indicate that reduction of real output variability may not be a major concern for the eurozone monetary authorities.

Table 1: Summary statistics

Variables	*Mean*	*St. Dev.*
Nominal interest rate	3.27	1.62
Inflation rate	2.01	0.74
IPI growth	1.69	5.12

Notes: *St. Dev*. stands for standard deviation. The sample period of our data is from 1994:01 to 2011:09.

[8] The use of variable ESIN as an instrument in the estimation procedure of forward-looking monetary policy rule models can indicate if the econometric specification of these models is robust to changes in financial stability or recession conditions in the economy, which are captured by this variable (see, e.g., Martin and Milas (2010)). The same can be supported for the use of M3 as an instrumental variable. This variable can capture quantitative easing effects on interest rate i_t.

3.2. Estimates of the forward-looking Taylor rule model

To estimate the standard forward-looking Taylor rule model, given by (3), we will replace the expected values of its explanatory variables with their realized. The resulting model will be estimated by the generalized method of moments (GMM) procedure which exploits the following moment (orthogonality) conditions:

$$E\left\{i_t - (1-\rho)\left[a + \beta\left(\pi_{t+n} - \pi^*\right) + \gamma\left(y_{t+k} - y^*\right)\right] - \rho i_{t-1} \middle| \mathbf{z}_t\right\} = \mathbf{0},$$

where $\mathbf{z_t}$ is a vector of instrumental variables used in the estimation procedure. This vector includes the following variables: the constant and one up to six lagged values of dependent and explanatory variables i_t, π_t and y_t, respectively, as well as one up to three lagged values of the M3 money growth rate, the stock price index, the economic sentiment indicator and the spread between the benchmark 10-year government bond and the 3-month euribor. The number of lead-periods n and k of the two explanatory variables of model (3), namely π_{t+n} and y_{t+k}, are set to n=3 and k=0, respectively.[9] Due to the overlapping nature of these two variables, in our GMM estimation procedure of model (3) the weighting matrix allows for serial correlation of 11 lags based on the Newey-West method.

The GMM estimates of the vector of parameters of model (3), i.e. $(\alpha,\beta,\gamma,\rho)'$, are reported in Table 2. To see if policy rule parameters β and γ are different than zero, the table also reports weak instrument robust test statistics of the joint hypothesis β=γ=0. In particular, these statistics are the conditional likelihood ratio (LR) test statistic of Moreira (2003), denoted as *MQLR*, and the Lagrange multiplier (LM) based test statistics suggested by Kleibergen (2005, 2007) denoted as *KLM* and *JKLM* (see Kleibergen and Mavroeidis (2009)). The results of the table clearly reject the null hypothesis β=γ=0. They reveal that the behavior of the eurozone monetary authorities is strongly stabilizing towards inflation, given that the estimate of β is much bigger than unity, i.e. 2.82. To a lesser extent, it also seems to be stabilizing with respect to

[9] This choice of n and k leads has also been considered in many other studies estimating forward-looking monetary policy rule models (see, e.g., Clarida *et al*. (2000), and Taylor and Davradakis (2006)). In our study, we have found that these leads fit better into the data based on the Akaike information criterion.

output, as the estimate of γ is positive and significant.[10] Finally, note that the estimates of the remaining parameters of model (3) reported in the table, namely intercept α and autoregressive coefficient ρ indicate that the long-run equilibrium level of nominal short rate i_t is very close to its sample average value reported in Table 2, while ρ is close to unity (i.e., ρ=0.97). This very high value of ρ is consistent with that reported in other studies (see, e.g., Fourçans and Vranceanu (2006)). It implies a very strong tendency of the eurozone monetary authorities to smooth out the effects of monetary shocks on interest rate i_t, over time.

Table 2: Estimates of the linear monetary policy rule model (3)

α	β	γ	ρ	*MSE*	*BP*
1.83***	2.82***	0.10***	0.97***	0.038	68.55***
(0.25)	(0.50)	(0.04)	(0.01)		

MQLR (p-value=0.0), *KLM* (p-value=0.0), *JKLM* (p-value=0.0)

Notes: The table presents GMM estimates of the standard monetary policy rule model (3) for the period from 1994:01 to 2011:09. These are based on the Newey-West optimal weighting matrix allowing for 11 lags of serial correlation. As instruments, we use the constant and one to six periods back values of the short term rate, the inflation and the output gap and one to three periods back of the M3 money growth, the stock price index, the economic sentiment indicator and the spread between the benchmark 10-year government bond and the 3-month euribor. Standard errors are in parentheses. ***, **, * denote 1%, 5%, 10% significance levels. *MQLR*, *KLM* and *JKLM* denote the *LR* test statistic of Moreira (2003), and the *LM* based test statistics of Kleibergen (2005, 2007), respectively. These are robust to weak instruments statistics testing the null hypothesis H_0: β=γ=0. BP is Bai's and Perron (2003) UDmax multiple breaks test statistic. MSE stands for mean squared error.

Although the results of Table 2 seem to be consistent with the policy objectives of the eurozone monetary authorities on price stability, further econometric analysis shows that they are not stable across different intervals of our sample. In particular, the value of Bai's and Perron (2003) sequential multiple break test statistic reported in Table 3, denoted as BP, indicates that model's (3) parameters are subject to abrupt shifts,

[10] Note that this estimate of β is much higher than that reported in the studies of Gerdesmeier and Roffia (2003), Ullrich (2003) and Sauer and Sturm (2007), which find β to be less than unity. However, it is consistent with estimates of β based on real time data (see, e.g., Sauer and Sturm (2007)) or revised data (see, e.g., Fourçans and Vranceanu (2006), (2007)).

referred to in the literature as structural breaks.[11] These breaks are found at the following dates: 1997:01 (1996:12-1997:10) and 2008:07 (2008:06-2008:08), where confidence intervals are reported in parentheses. The first of the above structural break dates is associated with the East Asian financial crisis of years 1997-1998, which has temporally destabilized the efforts of many eurozone countries to fulfill the Maastricht criteria to enter the European monetary union (EMU). The second is linked to the more recent banking crisis started in September 2008. As will be seen in the next section, both of these dates are very close to those implied by the estimates of our threshold monetary policy rule model (2).

3.3 Estimation of threshold monetary policy rule model (2)

To estimate the threshold monetary policy rule model (2), in this section we rely on an econometric method suggested recently by Kourtellos *et al* (2011) (denoted henceforth as KST). This method extends the standard two-stage least squares (2SLS) (or GMM) method of Canner and Hansen (2004), which estimates forward-looking threshold models with lagged threshold variables, to allow for possible endogeneity of the threshold variable. That is, π_t in our context. This is allowed to be contemporaneously correlated with the disturbance term of model (2), ε_t, which reflects monetary shocks. This endogenous nature of threshold variable π_t will lead to seriously biased estimates of policy parameters beta and gamma of threshold model (2), if it is ignored in the estimation procedure. On economic grounds, it can be justified by the tendency of the CBs to associate their policy decisions on interest rate, i_t, with the current state of inflation rate, π_t, rather than that of past periods (see, e.g., Taylor and Davradakis (2006)).

To estimate model's (2) parameters, collected in vector $\Theta = (a, \beta_L, \gamma_L, \beta_H, \gamma_H, \rho)'$, the KST method works as follows. In the first step, it replaces the expected values of

[11] The implementation of the BP test is carried out on a reduced (backward-looking) form of model (3), which treats inflation deviations and output gap as predetermined variables. More specifically, this is given as $i_t = \alpha + \sum_{i=1}^{1} \varphi_i i_{t-i} + \sum_{i=1}^{3} b_i \pi_{t-i} + \sum_{i=1}^{3} c_i y_{t-1} + e_t$, using three lags of π_t and y_t to capture their dynamic effects on i_t.

π_{t+n} and y_{t+k} by their LS (least squares) based estimates (referred to as LS predictions) relying on the following reduced form regressions of π_t and y_t:

$$\pi_t = \mathbf{d}_1'\mathbf{z}_t + e_t \qquad \text{and} \qquad y_t = \mathbf{d}_2'\mathbf{z}_t + v_t, \tag{4}$$

respectively. Then, a consistent estimate of threshold parameter $\bar{q}$, denoted as $\hat{\bar{q}}$, is obtained by solving the following search problem over different possible values of $\bar{q}$ belonging to set Q, i.e.

$$\hat{\bar{q}} = \arg\min_{\bar{q}\in Q} S_T(\bar{q}),$$

where

$$S_T(\bar{q}) = \sum_{t=1}^{T}\Big\{i_t - (1-\rho)\Big[a + \big(\beta_L(\hat{\pi}_{t+n} - \pi^*) + \gamma_L(\hat{y}_{t+k} - y^*) + k\lambda_L(\bar{q} - \mathbf{d}_1'\mathbf{z}_t)\big)I(\pi_t \le \bar{q})$$

$$+ \ \big(\beta_H(\hat{\pi}_{t+n} - \pi^*) + \gamma_H(\hat{y}_{t+k} - y^*) + k\lambda_H(\bar{q} - \mathbf{d}_1'\mathbf{z}_t)\big)I(\pi_t > \bar{q})\Big] - \rho i_{t-1}\Big\}^2$$

is the sum of the squared errors of model (2) based on LS predictions of expected values $E_t(\pi_{t+n})$ and $E_t(y_{t+k})$, denoted as $\hat{\pi}_{t+n}$ and $\hat{y}_{t+k}$, respectively, and $I(\cdot)$ is an indicator function of inflation regimes H and L. The two terms $k\lambda_L(\bar{q} - \mathbf{d}_1'\mathbf{z}_t)$ and $k\lambda_H(\bar{q} - \mathbf{d}_1'\mathbf{z}_t)$ entered into function $S_T(\bar{q})$ are bias correction terms of the conditional expectation $E\left[i_t \mid \mathbf{z_t}\right]$ due to the contemporaneous correlation of error terms ε_t and e_t (see equations (2) and (4), respectively), implying

$$\kappa = E(\varepsilon_t e_t) \neq 0.$$

Under the assumption that ε_t and e_t are normally distributed, it can be shown (see Kourtellos *et al*. (2011)) that these two bias correction terms are given as follows:

$$E(\varepsilon_t \mid \mathbf{z}_t, \pi_t \le \bar{q}) = k\lambda_L(\bar{q} - \mathbf{d}_1'\mathbf{z}_t) \quad \text{and} \quad E(\varepsilon_t \mid \mathbf{z}_t, \pi_t > \bar{q}) = k\lambda_H(\bar{q} - \mathbf{d}_1'\mathbf{z}_t),$$

where $\lambda_L(\bar{q}-\mathbf{d}_1'\mathbf{z}_t) = -\dfrac{\varphi(\bar{q}-\mathbf{d}_1'\mathbf{z}_t)}{\Phi(\bar{q}-\mathbf{d}_1'\mathbf{z}_t)}$ and $\lambda_H(\bar{q}-\mathbf{d}_1'\mathbf{z}_t) = \dfrac{\varphi(\bar{q}-\mathbf{d}_1'\mathbf{z}_t)}{1-\Phi(\bar{q}-\mathbf{d}_1'\mathbf{z}_t)}$ are the inverse Mills ratio bias correction terms, where $\varphi(\cdot)$ and $\Phi(\cdot)$ denote the normal probability and cumulative density functions, respectively.[12]

Conditionally on the above consistent estimate of $\bar{q}$, estimates of vector $\Theta = (a, \beta_L, \gamma_L, \beta_H, \gamma_H, \rho)'$ can be obtained based on the GMM procedure, in the second step. To this end, in the vector of instrumental variables $\mathbf{z}_t$ we will also include a dummy variable taking the value of zero, or one, depending on whether the economy is in the high, or low, inflation regime, respectively. Estimates of $\bar{q}$ and vector Θ derived by the above two-step KST procedure are reported in Table 3 (see column (a)). Together with these estimates, the table also reports the value of the Wald test statistic, denoted as *Wald-stat*, examining the following null hypothesis:[13]

$$H_0 : \beta_L = \beta_H \text{ and } \gamma_L = \gamma_H$$

against its alternative:

$$H_a : \beta_L \neq \beta_H \text{ or } \gamma_L \neq \gamma_H$$

The above null hypothesis implies that the monetary policy rule given by the linear Taylor rule model (3), while its alternative is consistent with the predictions of threshold monetary policy rule model (2). Testing the above null hypothesis is critical

---

[12] Note that, when κ=0, the two bias correction terms are zero and thus, the KST estimation procedure corresponds to that of Canner and Hansen (2004).

[13] Since under null hypothesis $H_0 : \beta_L = \beta_H$ and $\gamma_L = \gamma_H$ policy rule parameters beta and gamma are not identified, the significance levels (probability values) of *Wald-Stat* reported in the table are obtained based on a non-parametric bootstrap simulation procedure (see, e.g. Hansen (1996)). This procedure involves the following steps. First, based on the GMM procedure we estimate linear model (3), which assumes no regime-switching under the above null hypothesis, and we save its residuals and fitted values. Then, we draw values from the saved residual series with replacement. These values are added to the fitted values of interest rates i_t based on threshold model's (2) parameter estimates so as to generate a new series of i_t. This series is then used to estimate the threshold parameter, $\bar{q}$, and calculate the value test statistic *Wald-Stat*. The above procedure is repeated five thousand times. The obtained 5000 values of $\bar{q}$ and *Wald-Stat* are used to estimate the probability value of *Wald-Stat* reported in Table 3.

in investigating whether threshold model (2) constitutes a better specification of the data than model (3).

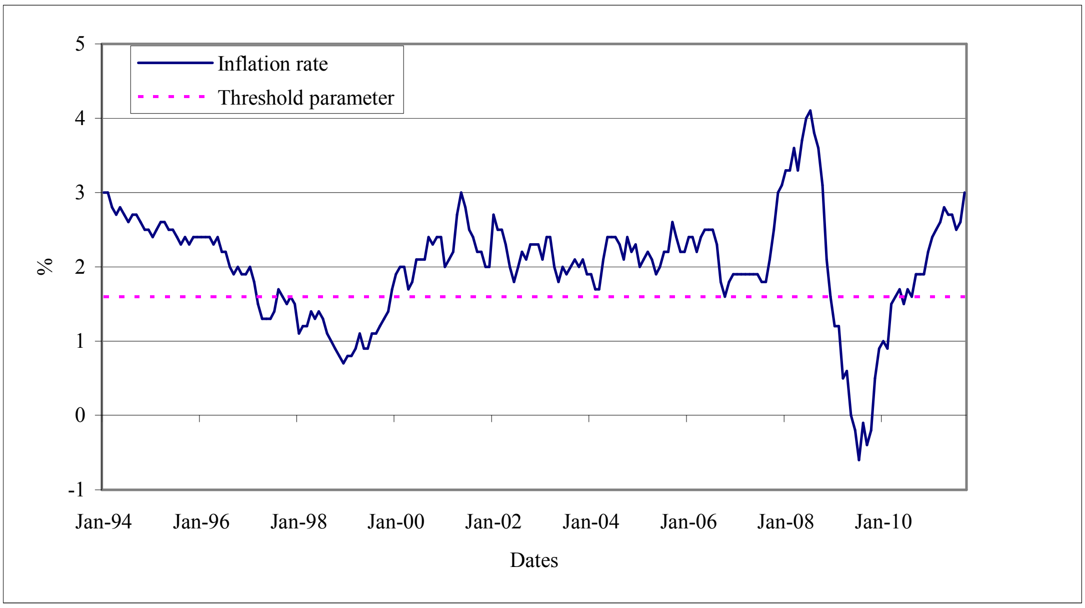
Table 3: Estimates of the threshold model (2)

Parameters	(a)	(b)	(c)
α	1.83*** (0.42)	1.83*** (0.40)	0.91** (0.46)
β_L	1.90** (0.77)	1.90** (0.66)	
γ_L	-0.001 (0.08)		0.13* (0.08)
β_H	3.49*** (1.31)	3.48*** (1.30)	6.25*** (1.19)
γ_H	1.36*** (0.21)	1.36*** (0.19)	1.13*** (0.21)
ρ	0.96*** (0.01)	0.96*** (0.01)	0.96*** (0.01)
$\bar{q}$	1.60		
CI($\bar{q}$)	[1.40 , 1.90]		
Wald-test (p-value)	31.88 (0.009)		
J-Stat (p-value)	12.77 (0.98)	12.77 (0.98)	12.95 (0.98)
MSE	0.037	0.037	0.043

Notes: The table presents GMM estimates of threshold model (2) based on the Newey-West optimal weighting matrix with 11 lags using the same set of instruments with those used for the estimates of the linear model reported in Table 3. Standard errors are reported in parentheses, except if it is said alternatively. The CI($\bar{q}$) is a heteroskedasticity corrected asymptotic confidence interval for threshold estimate that is computed using a quadratic polynomial as in Caner and Hansen (2004). ***, **, * denote 1%, 5%, 10% significance. Column (a) presents estimates of the full specification of model (2), while columns (b) and (c) of its specifications assuming $\gamma_L = 0$ and $\beta_L = 0$, respectively.

The results of Table 3 (column (a)) clearly indicate that the eurozone monetary policy rule function is subject to regime-switching. The value of statistic *Wald-Stat,* reported in the table, clearly rejects null hypothesis $H_0 : \beta_L = \beta_H$ and $\gamma_L = \gamma_H$, at a very low probability level of type I error (almost 0%). This result supports our threshold switching monetary policy rule model (2) against its linear specification given by equation (3), which does not allow for regime-switching. Further support of model (2) can be also obtained from the overidentifying restrictions test statistic implied by the GMM estimation procedure reported in Table 4, denoted as *J-Stat*.[14] The p-value of this statistic is very close to unity, which means that model (2) constitutes a correct specification of the data at a very high probability level.

Figure 1: Graph of threshold variable (inflation rate) *vs* threshold parameter estimate



The estimate of threshold parameter $\overline{q}$ reported in Table 3 (i.e., 1.60%) indicates that the low inflation regime is defined by inequality $\pi_t \leq 1.60\%$, while the high by $\pi_t > 1.60\%$. Inspection of Figure 1, which presents the eurozone average inflation rate series, π_t, against its threshold value, reveals that the low inflation regime corresponds to the following sample intervals: 1997-2000 and 2008-2010. The estimate of the confidence interval of $\overline{q}$, denoted as CI($\overline{q}$), reported in the table indicates that a shift to the high inflation monetary policy rule regime, allowed by model (2), is more likely to happen (i.e. with probability 95%) when the eurozone's

[14] This test statistic is chi-squared distributed with fifteen degrees of freedom. It tests whether the additional orthogonality conditions implied by the instruments variables employed in the GMM estimation procedure of model (2) are satisfied by the data.

current inflation rate is less than 2%. This result can be attributed to the strong attitude of the eurozone monetary authorities to stabilize inflation expectations and increase their credibility upon this policy objective. To this end, these authorities tend to keep inflation within a range less than 2%, over our sample.

Turning into the discussion about the estimates of the policy rule parameters beta and gamma, the results of Table 3 (see column (a)) indicate that there are important asymmetries in the response of interest rate i_t to inflation rate and output deviations between the two inflation regimes of threshold model (2). The estimate of beta is found to be higher in the high inflation regime than in the low. But, note that under both these inflation regimes the estimates of beta are bigger than unity, which reveals the strong anti-inflationary attitude of the eurozone monetary authorities even if inflation rate is less than 2%. In contrast to the estimates of beta, those of gamma parameters, capturing the responses of i_t to real output deviations, reveal more profound asymmetries of the eurozone monetary policy with respect to its anti-cyclical attitude across the two different inflation regimes. In particular, the estimate of gamma policy parameter in the low inflation regime, i.e. γ_L, is not different than zero. The opposite happens in the high inflation regime, where the estimate of this parameter is found to be bigger than unity (i.e. 1.36). Given that the low inflation regime is associated with recessionary intervals of our sample, these results mean that the eurozone monetary authorities are not concerned about cyclical variations in real output. This is true even if inflation is at very low levels and, thus, price stability objective has been achieved.

Comparing the above estimate of gamma to that reported in Table 2 for linear model (3), which assumes $\gamma_L = \gamma_H = \gamma$, reveals that ignoring regime-switching in the monetary policy rule will lead to a false conclusion that eurozone monetary authorities conduct anti-cyclical policy. The results of Table 3 indicate that the significant value of gamma parameter reported in Table 2, for the linear Taylor rule model (2), can be attributed to the high positive value of this parameter in the high inflation regime, given as 1.36. In particular, this estimate of gamma reflects increases in interest rate i_t due to positive deviations of real output gap variable, $\tilde{y}_t$, occurred in this inflation regime.

Finally, to investigate if the above results are robust to reduced specifications of threshold model (2), which assume either $\gamma_L = 0$ or $\beta_L = 0$, in Table 3 we present estimates for these specifications for $\overline{q}$ =1.60. See columns (b) and (c) of the table, respectively. These specifications of model (2) require a smaller number of parameters to be estimated and thus, their estimates may be more robust to the small number of observations of the low inflation regime intervals of our sample and the quite high level of correlation between explanatory variables π_t and $\tilde{y}_t$ (about 71%), found in this regime. The results of columns (b) and (c) of the table do not change our main conclusions on the asymmetries of the eurozone monetary policy, drawn based on the estimation of the full-specification of model (2) (see column (a)). The estimates of beta and gamma parameters reported in the columns of (b) and (c) of Table 3 indicate that the reduced specification of model (2) which fits better into the data is that which assumes that $\gamma_L = 0$, as is also suggested by the estimates of column (a).

4. Policy reaction under the threshold monetary policy model

The finding of our empirical analysis that the eurozone monetary policy is not concerned about cyclical deviations of real output gap even under the low inflation regime raises doubts on the effectiveness of this policy to dampen output cyclical deviations and sustain economic growth. The latter, as mentioned before, is implicitly considered as a second in terms of priority objective of these authorities, after price stability. To formally assess the effectiveness of this monetary policy rule regarding the inflation and output objectives of the eurozone authorities, in this section we simulate a standard New Keynesian (NK) model. This relies on the estimates of the threshold monetary policy model (2), reported in Table 3 (see column (a)). This model is used to study the qualitative and quantitative effects of exogenous demand or supply shocks on output, inflation and the short-term interest rates of the economy. The supply shock is a cost-push structural shock, while the demand is a structural shock affecting the IS curve.

More specifically, the NK model that we consider in our analysis is given as follows:[15, 16]

$$\tilde{\pi}_t = bE_t(\tilde{\pi}_{t+1}) + \kappa \tilde{y}_t + z_{S,t}, \tag{5.a}$$

$$\tilde{y}_t = E_t(\tilde{y}_{t+1}) - \frac{1}{\delta}\left(i_t - E_t(\tilde{\pi}_{t+1})\right) + z_{D,t} \tag{5.b}$$

and

$$i_t = (1-\rho)\left[\left(\beta_L E_t(\tilde{\pi}_{t+3}) + \gamma_L \tilde{y}_t\right) I(\pi_t \le \overline{q}) + \left(\beta_H E_t(\tilde{\pi}_{t+3}) + \gamma_H \tilde{y}_t\right) I(\pi_t > \overline{q})\right] + \rho i_{t-1}, \tag{5.c}$$

where $\tilde{\pi}_{t+3} = \pi_{t+3} - \pi^*$ and $\tilde{y}_t = y_t - y^*$ denote deviations of π_{t+3} and y_t from their targets π^* and y^* respectively, b is a discount factor, δ is the relative risk aversion coefficient and $\kappa = \delta \frac{(1-\omega \cdot b)(1-\omega)}{\omega}$ is a function of how frequently price adjustments occur (see Calvo (1983)), where ω captures the degree of price stickiness in the economy. In equations (5.a) and (5.b), variables $z_{S,t}$ and $z_{D,t}$ represent two exogenous and regime-independent aggregate supply and demand processes. These are governed by the following independent autoregressive processes of lag order one:

$$z_{S,t} = \rho_S \, z_{S,t-1} + \varepsilon_{S,t} \quad \text{and} \quad z_{D,t} = \rho_D \, z_{D,t-1} + \varepsilon_{D,t},$$

respectively, where $|\rho_S| < 1$ and $|\rho_D| < 1$, while $\varepsilon_{S,t}$ and $\varepsilon_{D,t}$ constitute two i.i.d. zero-mean structural error terms which have $E(\varepsilon_{S,t}\varepsilon_{D,t}) = 0$, for all *t* and *s*. These two error terms represent two exogenous supply and demand shocks, respectively.

In the NK model defined by equations (5.a)-(5.c), the first equation (i.e., (5.a) defines the change in the aggregate price level from its target rate (i.e. inflation deviation $\tilde{\pi}_t$) as a function of its expected future level and the current deviation of real output from its steady state (i.e. output gap $\tilde{y}_t$). This relationship can be derived from the

---

[15] See, for instance, Davig and Leeper (2007), Farmer *et al.* (2008).

aggregation of optimal price-setting decisions by monopolistically competitive firms in an environment in which each firm adjusts its price with a constant probability at any period (see, e.g., Calvo (1983)). Equation (5.b) combines a standard Euler equation for consumption with a market clearing condition equating aggregate consumption and output. This is the IS equation which determines the current level of aggregate output, or output deviation $\tilde{y}_t$, as a function of the ex-ante real rate and its expected future level $\tilde{y}_{t+1}$. Finally, equation (5.c) is the CB's threshold monetary policy model (3), which is estimated in the previous section.

Model (5.a)-(5.c) can be written into the following structural-equation form:

$$\mathbf{B}(\tilde{\pi}_t \leq \overline{q})\mathbf{x}_t = \mathbf{A}(\tilde{\pi}_t \leq \overline{q})E_t(\mathbf{x}_{t+1}) + \mathbf{D}\mathbf{x}_{t-1} + \mathbf{z}_t \qquad (6.a)$$

and $$\mathbf{B}(\tilde{\pi}_t > \overline{q})\mathbf{x}_t = \mathbf{A}(\tilde{\pi}_t > \overline{q})E_t(\mathbf{x}_{t+1}) + \mathbf{D}\mathbf{x}_{t-1} + \mathbf{z}_t, \qquad (6.b)$$

with $$\mathbf{z}_t = \mathbf{R}\mathbf{z}_{t-1} + \boldsymbol{\varepsilon}_t,$$

where $\mathbf{x}_t = \left[\tilde{\pi}_t, \tilde{y}_t, \tilde{i}_t, E_t(\tilde{\pi}_{t+1}), E_t(\tilde{\pi}_{t+2})\right]'$ is the vector of endogenous variables augmented with expected inflation rates $E_t(\tilde{\pi}_{t+1})$ and $E_t(\tilde{\pi}_{t+2})$, vector $\mathbf{z}_t = \left[z_{S,t}, z_{D,t}, 0, 0, 0\right]'$ contains the two exogenous processes $z_{S,t}$ and $z_{D,t}$, vector $\boldsymbol{\varepsilon}_t = \left[\varepsilon_{S,t}, \varepsilon_{D,t}, 0, 0, 0\right]'$ contains the two structural shocks $\varepsilon_{S,t}$ and $\varepsilon_{D,t}$, and

$$\mathbf{B}(\tilde{\pi}_t \leq \overline{q}) = \begin{bmatrix} 1 & -\kappa & 0 & 0 & 0 \\ 0 & 1 & \frac{1}{\delta} & 0 & 0 \\ 0 & -(1-\rho)\gamma_L & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}, \quad \mathbf{A}(\tilde{\pi}_t \leq \overline{q}) = \begin{bmatrix} b & 0 & 0 & 0 & 0 \\ \frac{1}{\delta} & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -(1-\rho)\beta_L \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \end{bmatrix},$$

[16] This model is linearized around zero steady state values of the inflation rate and output gap.

$$\mathbf{B}(\tilde{\pi}_t > \overline{q}) = \begin{bmatrix} 1 & -\kappa & 0 & 0 & 0 \\ 0 & 1 & \frac{1}{\delta} & 0 & 0 \\ 0 & -(1-\rho)\gamma_H & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}, \quad \mathbf{A}(\tilde{\pi}_t > \overline{q}) = \begin{bmatrix} b & 0 & 0 & 0 & 0 \\ \frac{1}{\delta} & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -(1-\rho)\beta_H \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \end{bmatrix},$$

$$\mathbf{D} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \rho & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}, \text{ and } \mathbf{R} = \begin{bmatrix} \rho_S & 0 & 0 & 0 & 0 \\ 0 & \rho_D & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}.$$

The above model implies the following matrix of transition probabilities between the two different inflation regimes considered by model (2) from time t-1 to t:

$$\mathbf{P} = \begin{bmatrix} p_{LL} & p_{LH} = 1 - p_{LL} \\ p_{HL} = 1 - p_{HH} & p_{HH} \end{bmatrix}.$$

Solving out the above system of equations (6.a)-(6.b) for vector $\mathbf{x}_t$ gives the following Threshold Regime-Switching Rational Expectations (TRSRE) model:[17]

$$\mathbf{x}_t = \mathbf{B}(\tilde{\pi}_t \le \overline{q})^{-1}\mathbf{A}(\tilde{\pi}_t \le \overline{q})E_t(\mathbf{x}_{t+1}) + \mathbf{B}(\tilde{\pi}_t \le \overline{q})^{-1}\mathbf{D}\mathbf{x}_{t-1} + \mathbf{B}(\tilde{\pi}_t \le \overline{q})^{-1}\mathbf{z}_t \qquad (7.a)$$

and

$$\mathbf{x}_t = \mathbf{B}(\tilde{\pi}_t > \overline{q})^{-1}\mathbf{A}(\tilde{\pi}_t > \overline{q})E_t(\mathbf{x}_{t+1}) + \mathbf{B}(\tilde{\pi}_t > \overline{q})^{-1}\mathbf{D}\mathbf{x}_{t-1} + \mathbf{B}(\tilde{\pi}_t > \overline{q})^{-1}\mathbf{z}_t. \qquad (7.b)$$

The rational expectation equilibrium (REE) solution of this model can be written in the following minimum state variable (MSV) form:

$$\mathbf{x}_t = \mathbf{\Omega}(\tilde{\pi}_t \le \overline{q})\mathbf{x}_{t-1} + \mathbf{\Gamma}(\tilde{\pi}_t \le \overline{q})\mathbf{z}_t \qquad (8.a)$$

[17] Note that this model has an analogous representation to the Markov Regime-Switching Rational Expectation model studied, among others, by Cho and Moreno (2008), and Cho (2009).

and $$\mathbf{x}_t = \mathbf{\Omega}(\tilde{\pi}_t > \overline{q})\mathbf{x}_{t\text{-}1} + \mathbf{\Gamma}(\tilde{\pi}_t > \overline{q})\mathbf{z}_t\,, \tag{8.b}$$

where matrices $\mathbf{\Omega}(\cdot)$ and $\mathbf{\Gamma}(\cdot)$ are defined analytically in the Appendix. This solution implies that the vector of endogenous variables $\mathbf{x}_t$ depends on the inflation regime of the economy at time *t*, as well as its lag values $\mathbf{x}_{t-1}$ and the vector of exogenous processes $\mathbf{z}_t$. In the Appendix, we present some conditions which guarantee the forward convergence, mean square stability and determinacy (if it is uniquely bounded) of 8(a)-8(b).

The REE solution given by equations (8.a)-(8.b) can be used to obtain impulse response functions (IRFs) of the endogenous variables $\tilde{\pi}_{t+k}$, $\tilde{y}_{t+k}$ and i_{t+k}, at time *t*+*k*, to structural shocks $\varepsilon_{S,t}$ and $\varepsilon_{D,t}$, for *k* = 0,1,2,3… months ahead.[18] To this end, we need to calculate matrices $\mathbf{\Omega}(\cdot)$ and $\mathbf{\Gamma}(\cdot)$. This can be done numerically based on the forward method suggested by Cho(2009) and it requires to assign values of the vector of structural parameters of the NK model (5.a)-(5.b) entered in matrices $\mathbf{B}(\cdot)$ $\mathbf{A}(\cdot)$, $\mathbf{D}$ and $\mathbf{R}$, which define matrices $\mathbf{\Omega}(\cdot)$ and $\mathbf{\Gamma}(\cdot)$. Actually, two sets of parameters are needed. The first is invariant to monetary policy regime. This involves the subjective discount factor *b*, the relative risk aversion parameter δ, the degree of stickiness ω and the autoregressive coefficients ρ_S, ρ_D and ρ. Following Casares (2004), Davig and Leeper (2007), Liu, Waggoner and Zha (2009), the above parameters are set equal to the following values: *b*=0.995, δ=1.50, ω=0.67, κ=0.25, $\rho_S = 0.90$ and $\rho_D = 0.90$. The autoregressive coefficient ρ is set to its sample estimate 0.97, reported in Table 3. Note that the above all values of autoregressive coefficients ρ_S, ρ_D and ρ guarantee that the forward convergence condition (FCC) of the TRSRE model (7.a)-(7.b) hold for a broad set of values of the remaining parameter of the NK model.

The second set of parameters determining the REE solution (8.a)-(8.b) is monetary policy regime dependent. This includes the pairs of policy parameters (β_L,γ_L) and (β_H,γ_H) corresponding to the low (*L*) and high (*H*) inflation regimes, respectively, as well as transition probabilities p_{LL} and p_{HH}. The values of these pairs of parameters

[18] In the Appendix, we show how these IRFs can be obtained from the system of equations (8.a)-(8.b).

are set to their corresponding sample estimates reported in Table 3 (see column (a)), i.e. $\beta_L = 1.90$, $\gamma_L = 0.0$, $\beta_H = 3.49$ and $\gamma_H = 1.36$.[19] Note that γ_L is set to zero, since the results of Table 3 support that it is not significantly different than this value. The transition probabilities between the two regimes p_{LL} and p_{HH} are calculated ex post based on the number of times that the monetary policy rule stays in inflation regimes L and H, respectively, over our whole sample. These probabilities are found to be $p_{LL} = 0.89$ and $p_{HH} = 0.97$.

The above sets of beta and gamma values imply that the REE solution of model TRSRE (7.a)-(7.b), defined by equations (8.a)-(8.b), is determinate, mean square stable and forward convergent.[20] The determinacy of this solution can be attributed to the fact that the eurozone monetary policy rule is found to be active under both inflation regimes, considered by threshold model (2). The passiveness of this policy in the low inflation regime with respect to output gap is not enough to characterise this regime as totally passive. This happens because, even in this regime, short term interest rate i_t is found to respond substantially to the expected future inflation deviations, $E_t(\tilde{\pi}_{t+3})$. The determinacy/indeterminacy regions of the REE solution (8.a)-(8.b) are graphically presented in Figure 2. This is done with respect to values of policy rule parameters beta and gamma in the low inflation regime, L, which critically affect the determinacy condition of the REE solution of the TRSRE model. This figure clearly indicates that, in order to be determinate this solution, either β_L or γ_L should take a big in magnitude value. This graph also indicates that, for achieving determinacy, the values of β_L or γ_L should be slightly more asymmetric towards stabilizing inflation.

[19] Note that γ_L=0, since this coefficient is found that it is not significantly different than zero.

[20] The mean square stability condition of the REE solution given by equations (8.a)-(8.b) requires that the following condition must hold: $r_\sigma(\mathbf{\Sigma}_\Omega) < 1$, while determinacy requires $r_\sigma(\mathbf{\Sigma}_F) < 1$, where $r_\sigma(.)$ denotes the maximum eigenvalue of matrices $\mathbf{\Sigma}_F$ and $\mathbf{\Sigma}_\Omega$ defined in the Appendix. Necessary conditions for determinacy are mean square stability and forward convergence. The last condition rules out rational bubbles in the REE solution. The values of the above maximum eigenvalues are found as follows: $r_\sigma(\mathbf{\Sigma}_\Omega) = 0.46 < 1$ and $r_\sigma(\mathbf{\Sigma}_F) = 0.98 < 1$. Taking into account that the forward condition is also satisfied, the above maximum eigenvalues imply that the above REE solution is mean square stable and determinate.

Figure 2: Determinacy regions of the TRSRE model with respect to β_L and γ_L

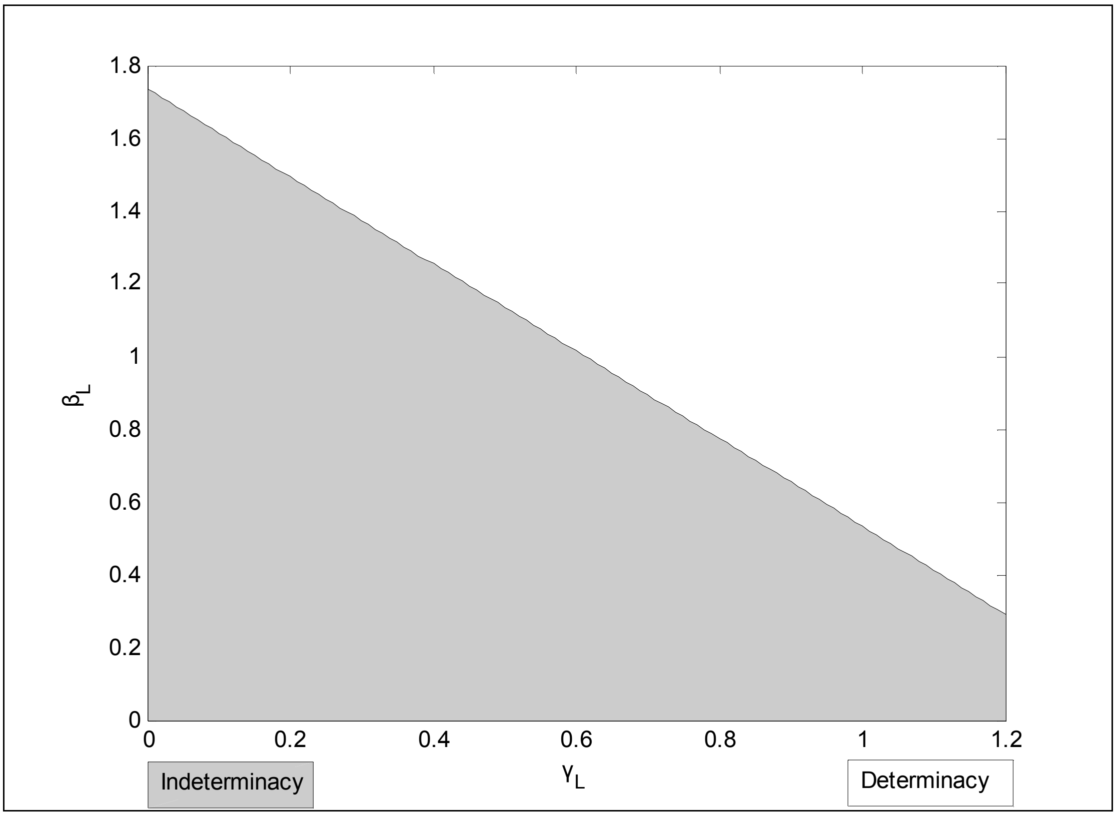
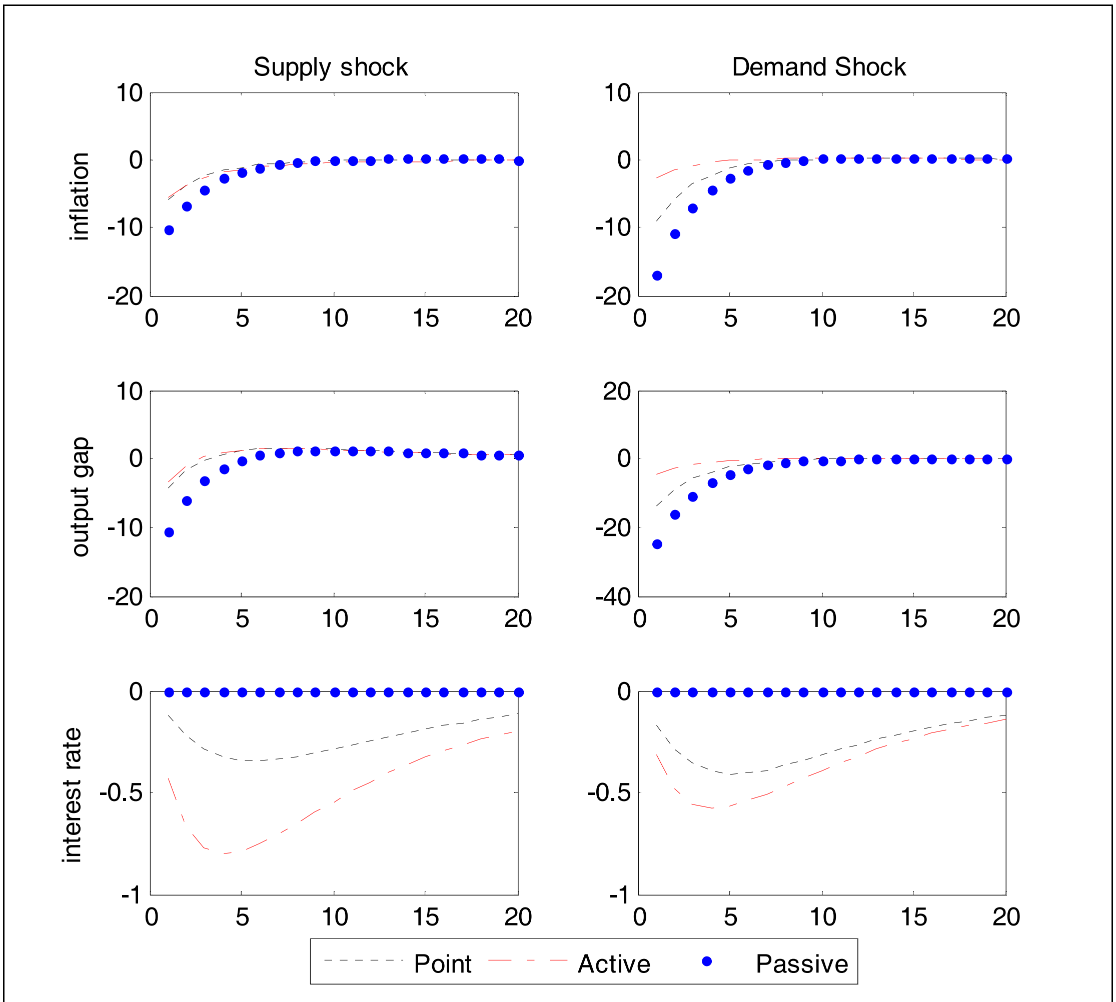


Figure 3 presents the IRFs implied by TRSRE model (7.a)-(7.b) for $\tilde{\pi}_{t+k}$, $\tilde{y}_{t+k}$ and $\tilde{i}_{t+k}$. As our analysis is mainly interested in assessing the effectiveness of the eurozone monetary policy under the low inflation regime, L, the IRFs reported by Figure 3 correspond to this regime. These functions are calculated following one-percent (i.e. 0.01) standard deviation negative supply and/or demand shocks $\varepsilon_{S,t}$ and $\varepsilon_{D,t}$, respectively. Note that the above IRFs allow for a possible regime-switching in a future period. Thus, they can capture dynamic expectation formation effects of regime-switching on the economy, mentioned in Section 2. To evaluate alternative monetary policy rule scenarios, Figure 3 reports three different sets of IRFs plots. The first is based on the point estimates of policy parameters beta and gamma in the low inflation regime, i.e. $\beta_L = 1.90,\ \gamma_L = 0.0$. The second set assumes that both estimates of β_L and γ_L are very close to zero, i.e. ($\beta_L = 0.005,\ \gamma_L = 0.00$), which implies a sufficiently passive monetary policy with respect to both inflation and output in low inflation regime.[21] Finally, the third set of IRFs assumes that the values of beta and gamma parameters are the same across the two inflation regimes *H* and *L*, i.e. there is no asymmetric behaviour between *H* and *L* inflation regimes. These values are taken to be $\beta_L = \beta_H = 3.48$ and $\gamma_L = \gamma_H = 1.36$, which characterize the active attitude of the eurozone monetary authorities in high inflation regime.

Figure 3: Impulse response functions (IRFs) driven by negative shocks in regime *L*



Notes: The point IRFs correspond to the estimates of β_L and γ_L found in the low inflation regime, *L*, the passive assume that monetary policy is sufficiently passive (i.e. β_L=0.005, γ_L=0.00) and, finally, the active consider the same values of beta and gamma coefficients across the two regimes.

Inspection of the IRFs of Figure 3 leads to the following conclusions. First, a passive monetary policy rule with respect to both output gap and inflation deviations from their corresponding target levels constitutes the worse choice of monetary policy rule to deal with the effects of negative supply or demand structural shocks on the

[21] Passive monetary policy with respect to inflation and output deviations are found to occur during recession and financial unstable regimes (see, e.g. Davig and Leeper (2008), Kazanas *et al.* (2011)). Under such regimes, interest rates tend to be driven by monetary shocks alone.

economy. Under this rule, the CB lending rate i_t remains almost unchanged and thus, the effects of the above shocks on output gap or inflation deviations from their target levels are negative. In terms of magnitude, these effects are the largest and most persistent ones among the three alternative monetary policy rule scenarios considered by our analysis.

Second, the fact that the CB's interest rate, i_t, does not respond to negative output gap in the low inflation regime implies that the eurozone monetary policy authorities can not sufficiently dampen the effects of negative shocks on real output, especially those due to demand shocks. These effects are found to be very large and quite persistent. To mitigate them, the IRF plots reported in Figure 3 clearly indicate that, for the case of demand shocks, the reaction of interest rate, i_t, to both negative inflation and output gap deviations in the low inflation regime should be analogous to that in the high. That is, it should become active with respect to output deviations from their target level in the low inflation regime. This is not necessary for the supply shocks. The negative effects of the latter on the economy can be mitigated by following only an anti-inflationary policy.

5. Conclusions

This paper has estimated a threshold monetary policy rule model for the eurozone, based on monthly data covering a period after the sign of Maastricht Treaty until very recently. The main aim of the paper is to unveil the attitude of the eurozone monetary authorities with respect to inflation and economic activity under two different inflation regimes: the high and low. The paper provides a number of results, which have important policy implications. First, it clearly indicates that the eurozone monetary policy is mainly anti-inflationary. This policy is characterized by the strong attitude of these authorities to stabilize inflation expectations and to increase the ECB's credibility upon this policy objective even in the low inflation regime. To achieve these targets, the eurozone monetary authorities tend to increase the ECB lending interest rate even if inflation rate is less than the 2% level, which is assumed to be the ECB's official target.

The second conclusion which can be drawn from the results of the paper is that anti-cyclical economic policy is not a major concern for the eurozone monetary authorities. Our analysis supports that this is true even if inflation expectations have been stabilized. To investigate the economic implications of this monetary policy behavior, the paper carries out a simulation study based on a small-scale New Keynesian IS-LM model. The results of this study clearly indicate that the monetary policy in eurozone can become more successful in achieving economic growth sustainability, if it becomes anti-cyclical when inflation is low and stable. The paper shows that this monetary policy can effectively dampen structural shocks on the economy, especially those coming from the demand side.

Appendix

A. Solution of TRSRE Models

In this appendix, we present the analytic relationships of the REE solution of the TRSRE model. In particular, we give the definitions of matrices $\mathbf{\Omega}(\cdot)$ and $\mathbf{\Gamma}(\cdot)$ involved in this solution, as well as of matrices $\mathbf{\Sigma}_{\Omega}$ and $\mathbf{\Sigma}_{F}$ whose maximum values determine the mean square stability and determinacy conditions. The above solution can be obtained following the same steps as Cho (2009), for the Markov chain regime-switching model.

The REE solution given by equations (8.a)-(8.b) can be obtained by solving forward the system of equations (7.a)-(7.b) and imposing the forward condition ruling out rational bubbles in equilibrium. This will yield

$$\mathbf{x}_t = \mathbf{\Omega}(\tilde{\pi}_t \leq \bar{q})\mathbf{x}_{t\text{-}1} + \mathbf{\Gamma}(\tilde{\pi}_t \leq \bar{q})\mathbf{z}_t$$

and

$$\mathbf{x}_t = \mathbf{\Omega}(\tilde{\pi}_t > \bar{q})\mathbf{x}_{t\text{-}1} + \mathbf{\Gamma}(\tilde{\pi}_t > \bar{q})\mathbf{z}_t$$

where

$$\mathbf{\Omega}(\tilde{\pi}_t \le \overline{q}) = \lim_{k\to\infty} \mathbf{\Omega}_k(\tilde{\pi}_t \le \overline{q}),\ \ \mathbf{\Omega}(\tilde{\pi}_t > \overline{q}) = \lim_{k\to\infty} \mathbf{\Omega}_k(\tilde{\pi}_t > \overline{q}),$$

$$\mathbf{\Gamma}(\tilde{\pi}_t \le \overline{q}) = \lim_{k\to\infty} \mathbf{\Gamma}_k(\tilde{\pi}_t \le \overline{q}),\ \mathbf{\Gamma}(\tilde{\pi}_t > \overline{q}) = \lim_{k\to\infty} \mathbf{\Gamma}_k(\tilde{\pi}_t > \overline{q})$$

and

$$\mathbf{\Omega}_1\left(\tilde{\pi}_t \le \overline{q}\right) = \mathbf{B}(\tilde{\pi}_t \le \overline{q})^{-1}\mathbf{D}\,,\ \mathbf{\Omega}_1\left(\tilde{\pi}_t > \overline{q}\right) = \mathbf{B}(\tilde{\pi}_t > \overline{q})^{-1}\mathbf{D}\,,$$

$$\mathbf{\Gamma}_1(\tilde{\pi}_t \le \overline{q}) = \mathbf{B}(\tilde{\pi}_t \le \overline{q})^{-1},\ \mathbf{\Gamma}_1(\tilde{\pi}_t > \overline{q}) = \mathbf{B}(\tilde{\pi}_t > \overline{q})^{-1},$$

$$\mathbf{\Omega}_k\left(\tilde{\pi}_t \le \overline{q}\right) = \mathbf{\Phi}_{k-1}\left(\tilde{\pi}_t \le \overline{q}\right)^{-1}\mathbf{B}(\tilde{\pi}_t \le \overline{q})^{-1}\mathbf{D},$$

$$\mathbf{\Omega}_k\left(\tilde{\pi}_t > \overline{q}\right) = \mathbf{\Phi}_{k-1}\left(\tilde{\pi}_t > \overline{q}\right)^{-1}\mathbf{B}(\tilde{\pi}_t > \overline{q})^{-1}\mathbf{D},$$

$$\mathbf{\Gamma}_k(\tilde{\pi}_t \le \overline{q}) = \mathbf{\Phi}_{k-1}\left(\tilde{\pi}_t \le \overline{q}\right)^{-1}\mathbf{B}(\tilde{\pi}_t \le \overline{q})^{-1} + \mathrm{E}_t\left[\mathbf{F}_{k-1}\left(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q} \mid \tilde{\pi}_t \le \overline{q}\right)\mathbf{\Gamma}_{k-1}\left(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q}\right)\right]\mathbf{R}$$

$$\mathbf{\Gamma}_k(\tilde{\pi}_t > \overline{q}) = \mathbf{\Phi}_{k-1}\left(\tilde{\pi}_t > \overline{q}\right)^{-1}\mathbf{B}(\tilde{\pi}_t > \overline{q})^{-1} + \mathrm{E}_t\left[\mathbf{F}_{k-1}\left(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q} \mid \tilde{\pi}_t > \overline{q}\right)\mathbf{\Gamma}_{k-1}\left(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q}\right)\right]\mathbf{R},$$

with

$$\mathbf{\Phi}_{k-1}\left(\tilde{\pi}_t \le \overline{q}\right) = \left(\mathbf{I} - E_t\left[\mathbf{B}(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q} \mid \tilde{\pi}_t \le \overline{q})^{-1}\mathbf{A}(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q} \mid \tilde{\pi}_t \le \overline{q})\mathbf{\Omega}_{k-1}\left(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q}\right)\right]\right),$$

$$\mathbf{F}_{k-1}\left(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q} \mid \tilde{\pi}_t \le \overline{q}\right) = \mathbf{\Phi}_{k-1}\left(\tilde{\pi}_t \le \overline{q}\right)^{-1}\mathbf{B}(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q} \mid \tilde{\pi}_t \le \overline{q})^{-1}\mathbf{A}(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q} \mid \tilde{\pi}_t \le \overline{q}),$$

$$\mathbf{\Phi}_{k-1}\left(\tilde{\pi}_t > \overline{q}\right) = \left(\mathbf{I} - E_t\left[\mathbf{B}(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q} \mid \tilde{\pi}_t > \overline{q})^{-1}\mathbf{A}(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q} \mid \tilde{\pi}_t > \overline{q})\mathbf{\Omega}_{k-1}\left(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q}\right)\right]\right),$$

$$\mathbf{F}_{k-1}\left(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q} \mid \tilde{\pi}_t > \overline{q}\right) = \mathbf{\Phi}_{k-1}\left(\tilde{\pi}_t > \overline{q}\right)^{-1}\mathbf{B}(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q} \mid \tilde{\pi}_t > \overline{q})^{-1}\mathbf{A}(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q} \mid \tilde{\pi}_t > \overline{q}),$$

Matrices $\mathbf{\Sigma}_{\mathbf{\Omega}}$ and $\mathbf{\Sigma}_F$ are defined as follows

$$\mathbf{\Sigma}_{\mathbf{\Omega}} = \left[p_{ji}\mathbf{\Omega}\left(\tilde{\pi}_t \le \overline{q}, \tilde{\pi}_t > \overline{q}\right) \otimes \mathbf{\Omega}\left(\tilde{\pi}_t \le \overline{q}, \tilde{\pi}_t > \overline{q}\right)\right]$$

$$\mathbf{\Sigma}_F = \left[p_{ji}\mathbf{F}\left(\tilde{\pi}_t \le \overline{q}, \tilde{\pi}_t > \overline{q}\right) \otimes \mathbf{F}\left(\tilde{\pi}_t \le \overline{q}, \tilde{\pi}_t > \overline{q}\right)\right]$$

B. Impulse Response Functions of TRSRE Model - IRFs

To see how the IRFs of the REE of the TRSRE model are calculated, first note that the forward solution of the TRSRE model is given as

$$\mathbf{x}_t = \mathbf{\Omega}(\tilde{\pi}_t \le \overline{q})\mathbf{x}_{t\text{-}1} + \mathbf{\Gamma}(\tilde{\pi}_t \le \overline{q})\mathbf{z}_t$$

$$\mathbf{x}_t = \mathbf{\Omega}(\tilde{\pi}_t > \overline{q})\mathbf{x}_{t\text{-}1} + \mathbf{\Gamma}(\tilde{\pi}_t > \overline{q})\mathbf{z}_t\,,$$

where $\mathbf{z}_t = \mathbf{R}\mathbf{z}_{t-1} + \boldsymbol{\varepsilon}_t$. The one-step ahead prediction of $\mathbf{x}_{t+1}$ conditional on the t-time information set is given as

$$E_t\mathbf{x}_{t+1} = \mathbf{F}_1(\tilde{\pi}_t \le \overline{q})\mathbf{x}_t + \mathbf{G}_1(\tilde{\pi}_t \le \overline{q})\mathbf{z}_t,\ E_t\mathbf{x}_{t+1} = \mathbf{F}_1(\tilde{\pi}_t > \overline{q})\mathbf{x}_t + \mathbf{G}_1(\tilde{\pi}_t > \overline{q})\mathbf{z}_t,$$

where

$$\mathbf{F}_1(\tilde{\pi}_t \le \overline{q}) = E\left[\boldsymbol{\Omega}\left(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q}\right) \mid \tilde{\pi}_t \le \overline{q}\right],$$

$$\mathbf{F}_1(\tilde{\pi}_t > \overline{q}) = E\left[\boldsymbol{\Omega}\left(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q}\right) \mid \tilde{\pi}_t > \overline{q}\right],$$

$$\mathbf{G}_1(\tilde{\pi}_t \le \overline{q}) = E\left[\boldsymbol{\Gamma}\left(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q}\right) \mid \tilde{\pi}_t \le \overline{q}\right]\mathbf{R},$$

$$\mathbf{G}_1(\tilde{\pi}_t > \overline{q}) = E\left[\boldsymbol{\Gamma}\left(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q}\right) \mid \tilde{\pi}_t > \overline{q}\right]\mathbf{R}.$$

The k-step ahead prediction of $\mathbf{x}_{t+k}$ is then given as

$$E_t\mathbf{x}_{t+k} = \mathbf{F}_k(\tilde{\pi}_t \le \overline{q})\mathbf{x}_t + \mathbf{G}_k(\tilde{\pi}_t \le \overline{q})\mathbf{z}_t \text{ and } E_t\mathbf{x}_{t+k} = \mathbf{F}_k(\tilde{\pi}_t > \overline{q})\mathbf{x}_t + \mathbf{G}_k(\tilde{\pi}_t > \overline{q})\mathbf{z}_t,$$

where

$$\mathbf{F}_k(\tilde{\pi}_t \le \overline{q}) = E\left[\mathbf{F}_{k-1}\left(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q}\right)\boldsymbol{\Omega}\left(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q}\right) \mid \tilde{\pi}_t \le \overline{q}\right],$$

$$\mathbf{F}_k(\tilde{\pi}_t > \overline{q}) = E\left[\mathbf{F}_{k-1}\left(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q}\right)\boldsymbol{\Omega}\left(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q}\right) \mid \tilde{\pi}_t > \overline{q}\right],$$

$$\mathbf{G}_k(\tilde{\pi}_t \le \overline{q}) = E\begin{bmatrix}\left(\mathbf{G}_{k-1}\left(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q}\right) + \mathbf{F}_{k-1}\left(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q}\right)\boldsymbol{\Gamma}\left(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q}\right)\right) \\ \mid \tilde{\pi}_t \le \overline{q}\end{bmatrix}\mathbf{R},$$

$$\mathbf{G}_k(\tilde{\pi}_t > \overline{q}) = E\begin{bmatrix}\left(\mathbf{G}_{k-1}\left(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q}\right) + \mathbf{F}_{k-1}\left(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q}\right)\boldsymbol{\Gamma}\left(\tilde{\pi}_{t+1} \le \overline{q}, \tilde{\pi}_{t+1} > \overline{q}\right)\right) \\ \mid \tilde{\pi}_t > \overline{q}\end{bmatrix}\mathbf{R}$$

for $k = 2, 3, \ldots$. For k = 0, we define $\mathbf{F}_0(\cdot) = \mathbf{I}_n$ and $\mathbf{G}_0(\cdot) = \mathbf{0}_{n\times m}$, where n is the number of endogenous variables and m the number of exogenous.

Given the above definitions, the impulse response functions (IRFs) of $\mathbf{x}_{t+k}$ to the l-th innovation at time t conditional on the state can be calculated by the following expressions:

$$\mathbf{IRF}_k\left(\tilde{\pi}_t \le \overline{q}\right) = \left(\mathbf{F}_k\left(\tilde{\pi}_t \le \overline{q}\right)\boldsymbol{\Gamma}\left(\tilde{\pi}_t \le \overline{q}\right) + \mathbf{G}_k\left(\tilde{\pi}_t \le \overline{q}\right)\right)\mathbf{e}_l,$$

$$\mathbf{IRF}_k\left(\tilde{\pi}_t > \overline{q}\right) = \left(\mathbf{F}_k\left(\tilde{\pi}_t > \overline{q}\right)\boldsymbol{\Gamma}\left(\tilde{\pi}_t > \overline{q}\right) + \mathbf{G}_k\left(\tilde{\pi}_t > \overline{q}\right)\right)\mathbf{e}_l,$$

for $k = 0,1,2,3,...$ where $\mathbf{e}_l$ is an indicator vector of which the l-th element is 1 and 0 elsewhere.

References

Assenmacher-Wesche, K. (2006). “Policy regime changes, judgment and Taylor rules in the Greenspan Era.” *Economica*, Vol. 78, pp. 89-107.

Bai, J., and Perron, P. (2003). "Computation and Analysis of Multiple Structural Change Models." *Journal of Applied Econometrics*, Vol. 18, No.1, pp. 1-22.

Calvo, G. (1983). “Staggered Prices in a Utility Maximization Framework.” J*ournal of Monetary Economics*, Vol. 12, pp. 383-398.

Caner, M., and Hansen, B. E. (2004). “Instrumental Variable Estimation of a Threshold Model.” *Econometric Theory*, Vol. 20, pp. 813-843.

Casares, M. (2004). “On Monetary Policy Rules for the Euro Area.” Bank of Spain, Working Paper No. 0415.

Cho, S. (2009). “Characterizing Markov-Switching Rational Expectations Models.” Working Paper. Available at SSRN: http://ssrn.com/abstract=1468331

Cho, S., and Moreno, A. (2008). “The Forward Method as a Solution Refinement in

Rational Expectations Models." Working Paper. Available at SSRN: http://ssrn.com/abstract=1092289

Clarida, R., Gali, J., and Gertler, M. (1998). "Monetary Policy Rules in Practice: Some International Evidence." *European Economic Review*, Vol. 42, No. 6, pp. 1033-67.

Clarida, R., Gali, J., and Gertler, M. (1999). "The Science of Monetary Policy: a New Keynesian Perspective." *Journal of Economic Literature*, Vol. 37, No. 4, pp. 1661-1707.

Clarida, R., Gali, J., and Gertler, M. (2000). "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory." *Quarterly Journal of Economics*, Vol. 115, No. 1.

Davig, T., and Leeper E. (2008). "Endogenous Monetary Policy Regime Change." NBER Chapters in: NBER International Seminar on Macroeconomics 2006, pages 345-391, National Bureau of Economic Research, Inc.

Davig, T., and Leeper, E. (2007). "Generalizing the Taylor Principle." *American Economic Review*, Vol. 97, No. 3, pp. 607-635.

Dolado, J. J., Maria-Dolores, R., and Naviera, M. (2000). "Asymmetries in Monetary Policy-Evidence for four Central Banks." Centre for Economic Policy Research (CERP), Discussion paper 2441.

Farmer, R. E. A., Waggoner, D. F., and Zha, T. (2008). "Minimal State Variable Solution to Markov-Switching Rational Expectations Models." Working Paper (23).

Fourçans, A., and Vranceanu, R. (2006). "Is the ECB so Special? A Qualitative and a Quantitative Analysis." ESSEC Working Paper, No. 06004.

Fourçans, A., and Vranceanu, R. (2007). "The ECB Monetary Policy: Choices and Challenges." *Journal of Policy Modeling*, Vol. 29, issue 2, pp. 181-194.

Gerdesmeier, D., and Roffia, B. (2003) "Empirical Estimates of Reaction Functions for the Euro Area." ECB, Working Paper No. 206.

Gerlach-Kristen, P. (2003). "Interest Rate Reaction Functions and the Taylor Rule in the Euro Area." ECB, Working Paper No. 258.

Gorter, J., Jacobs, J., and Haan, J. (2007). "Taylor Rules for the ECB using Consensus Data." De Nederlandsche Bank, Working Paper No. 160.

Gredig, F. (2007). "Asymmetric Monetary Policy Rules and the Achievement of the Inflation Target: The Case of Chile." Central Bank of Chile, Working Paper 451.

Hansen, B. E. (1996). "Inference When a Nuisance Parameter is not Identified under the Null Hypothesis." *Econometrica*, Vol. 64, pp. 413-430.

Judd, J. P., and Rudebusch, G. D. (1998). "Taylor's Rule and the Fed: 1970-1997." Federal Reserve Bank of San Francisco, Economic Review (3), pp. 3-16.

Kazanas T., and Tzavalis, E. (2010). "Estimating Forward Looking Monetary Policy Rules under Different Business Conditions." Mimeo, Athens University of Economics & Business.

Kazanas T., Philippopoulos, A., and Tzavalis, E. (2011). "Monetary Policy Rules and Business Cycles Conditions." *The Manchester School*, 79, Issue Supplement s2, pp. 73-97.

Kim, D. H., Osborn, D. R., and Sensier, M. (2005). "Nonlinearity in the Fed's Monetary Policy Rule." *Journal of Applied Econometrics*, Vol. 20, pp. 621-639.

Kleibergen, F. (2005). "Testing Parameters in GMM Without Assuming That They Are Identified." *Econometrica*, Vol. 73, pp. 1103-1124.

Kleibergen, F. (2007). "Generalizing Weak Instrument Robust IV Statistics Towards Multiple Parameters, Unrestricted Covariance Matrices and Identification

Statistics." *Journal of Econometrics*, Vol. 139, pp. 181-216.

Kleibergen, F., and Mavroeidis, S. (2009). "Weak Instrument Robust Tests in GMM and the New Keynesian Phillips Curve." *Journal of Business and Economic Statistics*, Vol. 27, No. 3.

Kourtellos, A., Stengos, T., and Tan, C. M. (2008). "THRET: Threshold Regression with Endogenous Threshold Variables", Working Papers, University of Guelph.

Liu, Z., D.F. Waggoner and T. Zha (2009). "Asymmetric expectation effects of regime shifts in monetary policy", *Review of Economic Dynamics*, Vol. 12, pp. 284-303.

Martin, C., and Milas, C. (2004). "Modelling Monetary Policy: Inflation Targeting in Practice." *Economica*, vol. 71, issue 282, pp. 209-21.

Martin, C., and Milas, C. (2010). "The sub-prime crisis and the UK monetary policy", *International Journal of Central Banking*, Vol. 6, No. 3.

Milas, C., and Naraidoo, R. (2010). "ECB policy and financial stability", Keele University, UK.

Moreira, M. J. (2003). "A Conditional Likelihood Ratio Test for Structural Models." *Econometrica*, Vol. 71, pp. 1027-1048.

Neumann, M. J. M., and von Hagen J. (2002). "Does Inflation Targeting Matter?" Zentrum für Europäische Integrationsforschung, Working Paper, No. B01.

Orphanides, A., and Wieland, V. (2000). "Inflation Zone Targeting." *European Economic Review*, vol. 44, No. 7, pp. 1351-1387.

Sauer, S., and Sturm, J. E. (2007). "Using Taylor Rules to Understand European Central Bank Monetary Policy." *German Economic Review*, Vol. 8, pp. 375-398.

Sims, C.A., Zha, T. (2006). "Were there regime switches in U.S. monetary policy?" *American Economic Review*, Vol. 96, No. 1, pp. 54–81.

Surico, P. (2003). "Asymmetric Reaction Functions for the Euro Area." *Oxford Review of Economic Policy*, vol. 19, issue 1, pp. 44-57.

Surico, P. (2007). "The Fed's Monetary Policy Rule and U.S. Inflation: The Case of Asymmetric Preferences." *Journal of Economic Dynamics and Control*, vol. 31, issue 1, pp. 305-324.

Taylor, M. P., and Davradakis, E. (2006). "Interest Rate Setting and Inflation Targeting: Evidence of a Nonlinear Taylor Rule for the United Kingdom." *Studies in Nonlinear Dynamics and Econometrics*, vol. 10, issue 4.

Trichet, Jean-Claude. (2005). "Monetary Policy and Credible Alertness" at the Panel Discussion "Monetary Policy Strategies: A Central Bank Panel", at the Symposium sponsored by the Federal Reserve Bank of Kansas City, Jackson Hole, Wyoming.

Ullrich, K. (2003). "A comparison Between the Fed and the ECB: Taylor Rules." ZEW Discussion Paper, No. 03-19, Mannheim.