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UNVEILING THE MONETARY POLICY RULE IN EURO-AREA

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ABSTRACT

This paper provides evidence that, since the sign of Maastricht Treaty, euro-area monetary authorities mainly follow a strong anti-inflationary policy. This policy can be described by a threshold monetary policy rule model which allows for distinct inflation policy regimes: a low and high. The paper finds that these authorities react more strongly to positive deviations of inflation and/or output from their target levels rather than to the negative. They do not seem to react at all to negative deviations of output from its target level in the low-inflation regime. We argue that this behaviour can be attributed to the attitude of the monetary authorities to build up credibility on stabilizing inflationary expectations. To evaluate the policy implications of the above euro-area monetary policy rule behaviour, the paper simulates a small New Keynesian model. This exercise clearly indicates that the absence of reaction of the euro-area monetary authorities to negative output gap 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, threshold models, regime-switching, generalized method of moments, New Keynesian model

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1. Introduction

Unveiling central banks' (CBs') policy behaviour on their lending rate, which nowadays is considered as their main policy instrument, from data analysis has attracted a lot of research interest over the last decade. This can indicate whether monetary authorities set this interest rate in practice 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 functions for the euro-area 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. Apart from the economic reasons mentioned above, estimating the monetary policy rule for euro-area is also very interesting from political economy point of view. It can indicate whether the euro-area monetary policy rule follows that of Bundesbank, which was strongly anti-inflationary (see, e.g., Clarida, Gali and Gertler, 1998; 2000). Evidence challenging this assumption has recently been provided by many 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 of the euro-area monetary authorities, and the 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 and Surico, 2007), the interest rate policy of the ECB 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 euro-area monetary authorities tend to set inflation target below but close to 2% over the medium term, as is 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 actual euro-area monetary policy rule, implied by our data analysis, reduce

[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).

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 euro-area economic goals which include high level of employment and sustainable growth. Answering the above questions can shed light not only on the credibility of the ECB on policy objectives, but also on the efficiency of its policy in achieving them.

To answer the above questions, the paper estimates a forward-looking threshold monetary policy rule model whose policy parameters capturing the effects of deviation of inflation and output from their target levels on the CB interest rate are subject to regime-switching depending on the level of current inflation rate.[2] This is done based on monthly data from January 1994 until December 2010. The consideration of period 1994-1998 in our analysis can show whether the euro-area monetary policy objectives remained the same before and after the launch of euro in year 1999, since the sign of Maastricht Treaty in year 1992. 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 actual inflation rate target of the euro-area monetary authorities 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 endogeneity of threshold variable, the paper adopts a new econometric technique suggested recently by Kourtellos, Stengos and Tan (2008).

The estimation results of the paper lead to a number of interesting conclusions. They indicate that the euro-area monetary policy rule can be characterized by two distinct inflation regimes: the low and high. The CB's lending rate responds more aggressively to

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[2] Threshold models of monetary policy rules have been estimated in many recent studies (see, e.g., Kim, Osborne and Sensier, 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).

deviations of inflation rate from its target level in the high inflation regime, compared to the low inflation regime. This does happen with the economic (output) cyclical deviations. The paper shows that in the low inflation regime, the euro-area monetary authorities do not ease their interest rate policy with respect to output deviations, despite the fact that their price stability objective has been achieved. The above results support the view that the euro-area monetary authorities mainly concern about inflation. This can be attributed to the emphasis put by this young central bank on building credibility on anchoring inflation expectations. This argument can be also supported by our finding that the threshold value of inflation rate above (or below) which these authorities change their policy rule is 1.60% something that implies that they may 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 relies on the sample estimates of our threshold monetary policy rule model. The results of this exercise clearly indicate that the euro-area monetary policy authorities could become more efficient in achieving their inflation and economic activity objectives when, 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 proved very large and prolonged, especially those due to demand shocks. Anchoring inflation expectations by following a strong anti-inflationary policy is not sufficient to avoid these real economic deviations and sustain economic growth, as is assumed by the euro-area authorities and the Maastricht treaty.[3]

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 and its linear (standard) specification estimated in other empirical studies. Section 4 conducts our simulation study based on the estimation results of the paper. Section 5 concludes the paper.

[3] See, e.g., Trichet (2005).

2. Model set up

Let i_t denotes the nominal short-term (one period) nominal interest rate which is set by 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:

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

for s={L,H}, where a is a constant denoting the long-run equilibrium level of target interest rate for each regime, $E_t(\cdot) \equiv E(\cdot \mid \Omega_t)$ is the conditional 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 the H and L inflation regimes. The value of this parameter will be treated as unknown and will be estimated from the data.

Model (1) implies that, when the current inflation rate π_t is in regime H (defined by condition $\pi_t > \overline{q}$), then its policy 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 $\pi_t \leq \overline{q}$), then they will be given as β_L and γ_L. Allowing for interest rate smoothing, which assumes that the level of rate i_t set by the CB is driven by the following partial adjustment process: [4]

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

[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.

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:

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

This model will be considered in our empirical analysis. Note that, if there is no regime-switching, it reduces to the forward-looking standard, linear Taylor rule model given by the following equation:

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

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 in policy rule parameters beta and gamma which are consistent with recent evidence provided in the literature by many 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, by splitting the sample into sub-samples is like to assume that after a shift in a new regime agents believe that they will stay in this regime permanently. 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 and 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 monetary policy induce them to alter their expectations about inflation or economic activity.

[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).

Within the class of regime-switching models, threshold model (2) has the following attractive property compared to the Markov-Chain model (MRS), which is frequently used in practice to capture regime type of shifts in the monetary policy rule parameters (see fn 5). It contrast to this, model (2) considers policy parameter changes triggered by a value of a random variable (e.g., of inflation rate π_t, in our context) which can be treated as endogenous. 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 monetary shocks e_t. As noted in the introduction, this assumption is quite restrictive and may not be true in practice.

Threshold model (2) allows us to address the following issues regarding the euro-area monetary policy on the CB's intervention interest rate i_t, raised in the introduction. First, we can investigate whether there are any asymmetric preferences of the euro-area monetary authorities with respect to deviations of inflation rate or output from their target levels which depend on inflation regime s and, second, whether these preferences have stabilizing effects on inflation expectations.[7] Such effects require that $\beta_s > 1$ at the high inflation regime. By the Maastricht Treaty and European central bank's (ECB) announcements (see, e.g., Fourcans and Vranceanu (2006)), someone expects to see that euro-area monetary policy is 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 euro-area monetary authorities may attempt to dampen cyclical deviations of output and unemployment from their desired levels.

A second question which can be addressed based on model (2) is related to inflation targeting. By estimating threshold value $\overline{q}$ from the data, threshold model (2) enables us to examine whether euro-area policy makers are pursuing a point target, or target range (see, e.g., Orphanides and Wieland (2000)) policy for inflation. An estimate of $\overline{q}$ substantially different than the 2% level of inflation rate can be also taken as evidence

[7] Note that this asymmetric behaviour 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 deviations under a specific regime, and they do not assume regime-switching.

supporting the view that, in practice, the euro-area monetary authorities follow policies with inflation zone targeting characteristics (see, e.g., Martin and Milas, 2004 for UK). Furthermore, if this estimate is less than the 2% level, it can be argued that the monetary authorities may act preemptively on inflationary pressure and raise interest rate i_t even if current inflation rate is below the 2% level, so as to achieve future price stability and anchor long-run inflation expectations.

3. Empirical analysis

In this section, we estimate the threshold monetary policy rule model presented in the previous section and we carry out some recently developed econometric tests to examine whether there is evidence of regime-switching in the euro-area monetary policy rule associated with the two different inflation regimes considered by this model. Our analysis starts with estimating the standard forward monetary policy model, given by equation (3). Estimation of this model is very useful as its comparison with model (2) can reveal whether ambiguous evidence about the euro-area's monetary policy behaviour 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 2010:12. 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 using 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), the unemployment rate 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] The definition of the above all variables and their sources can be found in Table 1A. In Table 1B, we give some descriptive statistics, namely means and standard deviations. The results of this table indicate that, for our sample, inflation rate π_t 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 y_t and interest rate i_t, given as 5.16% and 1.58%, respectively. These results are consistent with the policy objective mandates of the ECB to maintain price stability. They also show that reduction of real output variability may not be a major concern for the euro-area monetary authorities.

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 constant and one up to three lagged values of the following explanatory variables: i_t, π_t and y_t, as well as one up to two lagged values of the M3 money growth rate, the stock price index, the economic sentiment indicator, the

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

unemployment rate 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 3. To see whether 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 behaviour of the euro-area monetary authorities not only is strongly stabilizing towards inflation, given that the estimate of β is much bigger than unity, i.e. 2.20, but also with respect to output, as the estimate of γ is positive and high.[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, as was expected, the long-run equilibrium level of nominal short-term rate i_t is very close to its sample average value reported in Table 2, while ρ is close to unity, i.e. ρ=0.96. This value of ρ implies a very strong tendency of the euro-area monetary authorities to smooth out the effects of monetary shocks on interest rate i_t, over time.

Although the results of Table 3 seem to be consistent with the policy objectives of the euro-area monetary authorities on price stability, further econometric analysis shows

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[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.

[10] This estimate of β is in contrast to evidence provided in the literature (see, e.g., Gerdesmeier and Roffia, 2003, Ullrich, 2003 and Sauer and Sturm, 2007) which finds β much less than unity (see Table 2). However, it is consistent with estimates of β based on real time data (see, e.g., Sauer and Sturm, 2007).

that they suffer from some problems. 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, referred to in the literature as structural breaks.[11] These breaks are found at the following dates: 1999:11 (1999:10-2001:03) and 2008:05 (2008:01-2008:08), where confidence intervals are reported in parentheses. The first of the above structural break dates is associated with the East Asian and Russian financial crises of years 1997-1998, while the second with the more recent financial and economic 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 given in model (2).

3.3 Estimation of threshold monetary policy rule model (2)

To estimate threshold monetary policy rule model (2), in this section we rely on a novel econometric method recently developed by Kourtellos, Stengos and Tan (2008, henceforth KST). This method extends the standard two-stage least squares (2SLS) (or GMM) method of Canner and Hansen (2004), estimating forward-looking threshold models like model (2), to allow for endogeneity of the threshold variable (here, π_t), i.e. to be contemporaneously correlated with the disturbance term of model (2), ε_t, reflecting monetary shocks. This assumption is more realistic as the CBs are more likely 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). 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.

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 π_{t+n}

[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.

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:

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

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 regime $s=\{H,L\}$. 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 $E[i_t \mid \mathbf{z}_t]$ due to the contemporaneous correlation of error terms e_t and e_t (see equations (2) and (4), respectively), implying

$$k = E(e_t e_t) \neq 0.$$

Under the assumption that e_t and e_t are normally distributed, it can be shown (see Kourtellos *et al.*, 2008) 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 $\lambda_L(\overline{q}-\mathbf{d}_1'\mathbf{z}_t)=-\dfrac{\varphi(\overline{q}-\mathbf{d}_1'\mathbf{z}_t)}{\Phi(\overline{q}-\mathbf{d}_1'\mathbf{z}_t)}$ and $\lambda_H(\overline{q}-\mathbf{d}_1'\mathbf{z}_t)=\dfrac{\varphi(\overline{q}-\mathbf{d}_1'\mathbf{z}_t)}{1-\Phi(\overline{q}-\mathbf{d}_1'\mathbf{z}_t)}$ are the inverse Mills ratio bias correction terms, where $\varphi(.)$ and $\mathrm{F}(.)$ denote the normal probability and cumulative density functions, respectively.[12]

Conditionally on the above consistent estimate of $\overline{q}$, estimates of vector of parameters $\Theta=(a,\beta_L,\gamma_L,\beta_H,\gamma_H,\rho)'$ 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 inflation regime, or not. Estimates of $\overline{q}$ and vector Θ derived by the above two-step KST procedure are reported in Table 4 (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 standard, linear Taylor rule model (see equation (3)), while its alternative is consistent with the predictions of threshold monetary policy rule model (2). Testing this null

[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, $\overline{q}$, and calculate the value test statistic *Wald-Stat*. The above procedure is repeated five thousand times. The obtained 5000 values of $\overline{q}$ and *Wald-Stat* are used to estimate the confidence interval of $\overline{q}$ and the probability value of *Wald-Stat* reported in Table 4.

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

The results of Table 4 clearly indicate that the euro-area monetary policy rule on interest rate, i_t, is subject to regime-switching. The value of statistic *Wald-Stat,* reported in the table, rejects the null hypothesis $H_0 : \beta_L = \beta_H$ and $\gamma_L = \gamma_H$ at a very low probability level of type I error (about 3%). 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 our threshold model (2) relative to model (3) can be obtained from the value of the mean squared error (MSE) metric reported in Tables 4 and 2. This is found to be smaller for model (3). Finally, note that model (2) also satisfies the overidentifying restrictions test statistic implied by the GMM estimation procedure reported in Table 4, denoted as *J-Stat*.[14] The value of this test statistic implies that model (2) constitutes a correct specification of the data at a very high probability level, i.e. 75%.

The estimate of threshold parameter $\overline{q}$ reported in Table 4, i.e. 1.60%, indicates that the low inflation regime is defined by the following condition: p_t £ 1.60%, while the high by $p_t > 1.60\%$. Inspection of Figure 1, which presents the euro-area 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 above threshold value of inflation rate corresponds to the 30% percentile of its sample distribution. This percentile implies that the euro-area monetary authorities are quite likely to switch their interest rate policy towards one which is mainly anti-inflationary, as will be discussed below in more details. This switching can happen even if the current inflation rate is below the 2% level. Obviously, this behaviour of the euro-area monetary authorities can be attributed to their strong attitude to stabilize inflation expectations and increase their credibility upon this objective. The smaller than the 2% point estimate of threshold value, $\overline{q}$, combined with the quite large confidence interval of $\overline{q}$ found by our analysis, given as [1.40%, 2.50%],

[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.

supports the view that these authorities may also tend to keep inflation within a range. Note that the upper bound of this interval is 2.50%, which indicates that the euro-area monetary policy authorities may also consider a switch to the high inflation regime when current inflation is bigger than 2.5%.

Turning into the discussion about the estimates of the policy rule parameters beta and gamma, the results of Table 4 (see column (a)) indicate that there are important asymmetries in the response of interest rate, i_t, to both inflation and output deviations between the two inflation regimes considered. 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 this policy parameter are found to be clearly bigger than unity which reveals the strong anti-inflationary attitude of the euro-area monetary authorities. In contrast to the estimates of beta, those of gamma parameters, capturing the responses of i_t to deviations of real output from its target value, reveal more profound asymmetries of the euro-area monetary policy across the two different inflation regimes. In particular, the estimate of gamma in the low inflation regime, denoted as g_L, is not found to be different than zero.

The last result means that the euro-area monetary authorities are not concerned about cyclical variations in real output even when inflation is at very low levels. Comparing this estimate of gamma to that reported in Table 2 for linear model (3), which assumes $g_L = g_H = g$, reveals that ignoring regime-switching in the monetary policy rule will lead to a false conclusion that euro-area monetary authorities conduct anti-cyclical policy. The results of Table 4 indicate that the high and significant value of gamma reported in Table 3 for linear monetary policy rule model (3) can be attributed to the high positive value of this coefficient in the high inflation regime, given as 1.07. It reflects increases in interest rate i_t due to positive deviations of real output gap variable, $\tilde{y}_t$. To see whether the above results are robust to reduced specifications of threshold model (2) which assume γ_l=0, or β_l=0, in Table 4 (see columns (b) and (c)) we present estimates of these specifications. Due to the small number of observations in the low inflation regime intervals (55) and the high level of correlation between variables π_t and

$\tilde{y}_t$ found for them (0.71), estimation of these specifications may provide more accurate estimates of γ_I, or β_I. The results of the table do not change our main conclusions about the asymmetries of the euro-area monetary policy, drawn above.

4. Policy reaction under the threshold monetary policy model

The finding of our empirical analysis that the euro-area 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 cyclical deviations of output and sustain growth. This is considered as a second in terms of priority objective of these authorities, after price stability. To answer this question, in this section we simulate a standard New Keynesian (NK) model which relies on the estimates of the threshold monetary policy model (2), reported in Table 4. This model can be 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

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

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

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), the two 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:

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

respectively, where $|\rho_S| < 1$ and $|\rho_D| < 1$, while $\varepsilon_{S,t}$ and $\varepsilon_{D,t}$ constitute two i.i.d. zero-mean error 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 (or inflation deviation $\tilde{\pi}_t$) as a function of its expected future level and the current deviation of real output from its steady state, $\tilde{y}_t$. This relationship can be derived from the 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:

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

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

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

$$\mathbf{B}(\tilde{\pi}_t \le \overline{q}) = \begin{bmatrix} 1 & \text{-}\kappa & 0 & 0 & 0 \\ 0 & 1 & \frac{1}{\delta} & 0 & 0 \\ 0 & \text{-}(1\text{-}\rho)\gamma_1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}, \quad \mathbf{A}(\tilde{\pi}_t \le \overline{q}) = \begin{bmatrix} b & 0 & 0 & 0 & 0 \\ \frac{1}{\delta} & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \text{-}(1\text{-}\rho)\beta_1 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \end{bmatrix},$$

$$\mathbf{B}(\tilde{\pi}_t > \overline{q}) = \begin{bmatrix} 1 & \text{-}\kappa & 0 & 0 & 0 \\ 0 & 1 & \frac{1}{\delta} & 0 & 0 \\ 0 & \text{-}(1\text{-}\rho)\gamma_2 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}, \quad \mathbf{A}(\tilde{\pi}_t > \overline{q}) = \begin{bmatrix} b & 0 & 0 & 0 & 0 \\ \frac{1}{\delta} & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \text{-}(1\text{-}\rho)\beta_2 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \end{bmatrix},$$

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

The above model implies the following matrix of transition probabilities between the two 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:

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

and

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

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). Its rational expectation equilibrium (REE) solution can be written in the following minimum state variable (MSV) form:

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

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

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 this solution.

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.[17] 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 $\mathbf{B}(\cdot)\ \mathbf{A}(\cdot)$, **D** and **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,

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

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 0.96, reported in Table 4. 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 (b_L, g_L) and (b_H, g_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 are set to their corresponding sample estimates reported in Table 4 (see column (b)), i.e. b_L = 1.69, g_L = 0.0, b_H = 2.72 and g_H = 1.08.[18] Note that g_L is set to zero, since it is not found to be significantly different than it. 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 regimes L and H, respectively, over our whole sample. These probabilities are found to be $p_{LL} = 0.89$ and $p_{HH} = 0.96$.

The above sets of beta and gamma values imply that the REE solution of model TRSRE (7.a)-(7.b), given by equations (8.a)-(8.b), is determinate, mean square stable and forward convergent.[19] The determinacy of this solution can be attributed to the fact that the euro-area monetary policy rule is found to be active under both inflation regimes identified by our threshold model (2). The degree of passiveness of this policy in the low inflation regime with respect to output gap is not enough to characterise this regime as

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

[19] 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 $r_\sigma(\mathbf{\Sigma}_\mathrm{F}) < 1$, 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: $r_s(\mathbf{\Sigma_\Omega})$= 0.46< 1 and $r_s(\mathbf{\Sigma}_\mathrm{F})$ = 0.99< 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.

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, $E_t(\tilde{p}_{t+3})$. The determinacy/indeterminacy regions of the REE solution (8.a)-(8.b) are graphically presented in Figure 2 with respect to values of policy rule parameters in the low inflation regime, L, which critically affects the determinacy condition pf 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.

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 euro-area monetary policy under the low inflation regime, L, the reported by Figure 3 IRFs correspond only 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 these IRFs allow for a possible regime-switching in a future period and 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 corresponds to the point estimates of policy parameters beta and gamma in the low inflation regime, found in our empirical analysis (i.e. $b_L = 1.69,\ g_L = 0.0$). The second set assumes that both estimates of β_L and γ_L are very close to zero, i.e. ($b_L = 0.005,\ g_L = 0.0$), which implies a sufficiently passive monetary policy with respect to inflation and output deviations from their target levels.[20] Finally, the third set of IRFs assumes that the values of β_L and γ_L are the same with those of the high inflation regime. That is, we have $b_L = b_H = 2.72$ and $g_L = g_H = 1.08$. These values of β_L and γ_L mean that monetary policy in euro-area is active under both inflation regimes implied by

[20] 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, 2006 and Kazanas *et al*., 2011). Under such regimes, interest rates tend to be driven by monetary shocks alone.

our estimates of model (2). They also imply that there is no regime-switching across different inflation regimes.

Inspection of the IRFs of Figure 3 leads to the following conclusions which have important policy implications. First, a passive monetary policy rule with respect to both deviations of output gap and inflation from their corresponding target levels constitutes the worse economic policy scenario to deal with the effects of negative supply or demand structural shocks on the economy. Under this policy scenario, the effects of these shocks on CB lending rate i_t are minor while on deviations of output gap or inflation from their target levels are negative and the largest ones among the three different monetary policies considered by our analysis. As was expected, these effects are also very persistent.

Second, the fact that the CB's interest rate, i_t, doesn't respond to negative output gap when inflation is very low, which characterise the euro-area monetary policy, implies that monetary 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 rates to both negative deviations of inflation and output gap from their target levels in the low inflation regime should be analogous to that under the high. This result means that monetary policy should remain active independently on the inflation regime. However, this is not true for the supply shocks. The negative effects of the latter on the economy can be mitigated by a strong anti-inflationary policy alone.

5. Conclusions

This paper estimates a threshold monetary policy rule model for the euro-area using 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 euro-area monetary authorities with respect to inflation and/or economic activity under two different inflation regimes. The paper provides a number of useful results. First, it clearly indicates that the euro-area 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. To achieve these targets, the euro-area monetary authorities can abruptly increase its lending rate even if inflation rate is less than the 2% value.

The second conclusion which can be drawn from the results of the paper is that the euro-area monetary authorities are not concerned about negative output deviations even if inflation rate is in the low regime and, thus, inflation expectations have been stabilised. To investigate the economic implications of this monetary policy, 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 euro-area can become more efficient in achieving both goals of inflation and 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 $\mathbf{\Sigma}_{\mathbf{\Omega}}$ 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

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

and

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

where

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

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

and

$$\mathbf{\Omega}_1\left(\tilde{\pi}_{\mathrm{t}} \leq \overline{\mathrm{q}}\right) = \mathbf{B}(\tilde{\pi}_{\mathrm{t}} \leq \overline{\mathrm{q}})^{-1}\mathbf{D}\ ,\ \mathbf{\Omega}_1\left(\tilde{\pi}_{\mathrm{t}} > \overline{\mathrm{q}}\right) = \mathbf{B}(\tilde{\pi}_{\mathrm{t}} > \overline{\mathrm{q}})^{-1}\mathbf{D}\ ,$$

$$\mathbf{\Gamma}_1(\tilde{\pi}_{\mathrm{t}} \leq \overline{\mathrm{q}}) = \mathbf{B}(\tilde{\pi}_{\mathrm{t}} \leq \overline{\mathrm{q}})^{-1},\ \mathbf{\Gamma}_1(\tilde{\pi}_{\mathrm{t}} > \overline{\mathrm{q}}) = \mathbf{B}(\tilde{\pi}_{\mathrm{t}} > \overline{\mathrm{q}})^{-1},$$

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

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

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

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

with

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

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

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

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

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

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

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

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

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

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

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

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

where

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

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

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

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

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

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

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

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

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

$k = 2, 3, \ldots$. 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:

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

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

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.

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Table 1A: Data description and sources

Series	Source	Description
Short-term nominal interest rate	European Central Bank	Euro Overnight Index Average (EONIA), Euro area (changing composition)
Industrial Production Index	Eurostat	Euro area 17 (fixed composition), total industry excluding construction
Consumer price index	Eurostat	Harmonized Index of Consumer Prices, (HICP), Euro area (changing composition), neither seasonally nor working day adjusted
Money growth rate	Eurostat	M3 level, Euro area (changing composition), working day and seasonally adjusted
Stock price index	Eurostat	Dow Jones Euro STOXX - Price index, Euro area (changing composition)
Economic sentiment indicator	Eurostat	ESIN, Euro area 16 (fixed composition)
Unemployment Rate	Eurostat	Euro area (changing composition), Seasonally adjusted.
Euro area 10-year Government Benchmark bond yield	ECB	Euro area (changing composition)
Euribor 3-month	Reuters	Euro area (changing composition)

Table 1B: Descriptive statistics

Variables	*Mean*	*St. Dev.*
Nominal interest rate	3.37	1.58
Inflation rate	1.98	0.74
IPI growth	1.45	5.16

Notes: *St. Dev.* stands for standard deviation. The sample period of our data is 1994:01 to 2010:12.

Table 2: Monetary policy rule estimates for the euro zone						
Study	Type of rule	Sample Period	α	β	γ	ρ
Hypothetical euro area						
Peersman and Smets (1998)	Forward-looking	1980:I-1997:IV	3.87	1.2	0.76	0.76
Gerlach and Schnabel (2000)	Contemporaneous	1990:I-1998:IV	2.4	1.58	0.45	
	Contemporaneous	1990:I-1998:IV	3.9	2.22	0.72	0.32
	Forward-looking	1990:I-1998:IV	2.38	1.84	0.34	0.18
Clausen and Hayo (2002)	Contemporaneous	1979:I-1996:IV	4.07	2.15	2.12	0.86
Gerlach-Kristen (2003)	Contemporaneous	1988:I-2002:II	-1.23 (ns)	2.73	1.44	0.88
Ullrich (2003)	Contemporaneous	1995:1-1998:12	1.97	1.25	0.29	0.23
Actual euro area						
Fourçans and Vranceanu (2002)	Contemporaneous	1999:4-2002:2	1.22	1.16	0.18	0.73
Fourçans and Vranceanu (2006)	Forward-looking	1999:1-2006:3	1.9	4.25	1.28	0.96
Gerdesmeier and Roffia (2003)	Contemporaneous	1999:1-2002:1	2.6	0.45	0.3	0.72
Sauer and Sturm (2007)	Contemporaneous	1999:1-2003:3	2.58	0.51	0.37	
	Forward-looking (ex-post data)	1999:1-2003:3	1.72	0.86	0.86	0.88
	Forward-looking (real time data)	1999:1-2003:3	0.25 (ns)	2.31	2.35	0.92
Ullrich (2003)	Contemporaneous	1999:1-2002:8	2.96	0.25	0.63	0.19

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

α	β	γ	ρ	*MSE*	*BP*
2.03***	2.17***	0.76***	0.96***	0.04	39.57***
(0.33)	(0.69)	(0.18)	(0.01)		
MQLR (p-value=0), *KLM* (p-value=0), *JKLM* (p-value=0)					

Notes: The table presents GMM estimates of the standard monetary policy rule (3) for the period from 1994:01 to 2010:12. 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 three lags in the short-term rate, the inflation and the output gap and one to two lags in the M3 money growth, the stock price index, the economic sentiment indicator, the unemployment rate and the spread between the benchmark 10-year government bond and the 3-month euribor. Standard errors are in parentheses. ***, **, * denote significance at the 1%, 5% and 10% levels, respectively. *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: $\beta=\gamma=0$. BP is Bai's and Perron (2003) UDmax multiple breaks test statistic. MSE stands for mean squared error.

Table 4: Estimates of the threshold model (2)

Parameters	(a)	(b)	(c)
α	1.41*** (0.38)	1.43*** (0.42)	0.75 (0.51)
b_1	1.97** (0.81)	1.69** (0.64)	
g_1	-0.05 (0.10)		0.08 (0.09)
b_2	2.92*** (1.08)	2.72*** (1.02)	4.15*** (1.10)
g_2	1.07*** (0.21)	1.08*** (0.21)	1.19*** (0.25)
ρ	0.96*** (0.01)	0.96*** (0.01)	0.96*** (0.01)
$\overline{q}$	1.6		
CI of $\overline{q}$	[1.4 , 2.5]		
Wald-test (p-value)	27.94 (0.03)		
J-Stat (p-value)	11.21 (0.074)	11.38 (0.79)	11.78 (0.76)
MSE	0.036	0.036	0.040

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. ***, **, * denote significance at the 1%, 5% and 10% levels, respectively. Column (a) presents estimates of the full specification of model (2), while columns (b) and (c) of its specifications assuming $g_1 = 0$ and $b_1 = 0$, respectively.

Figure 1: Graphs of variables vs threshold parameter estimate

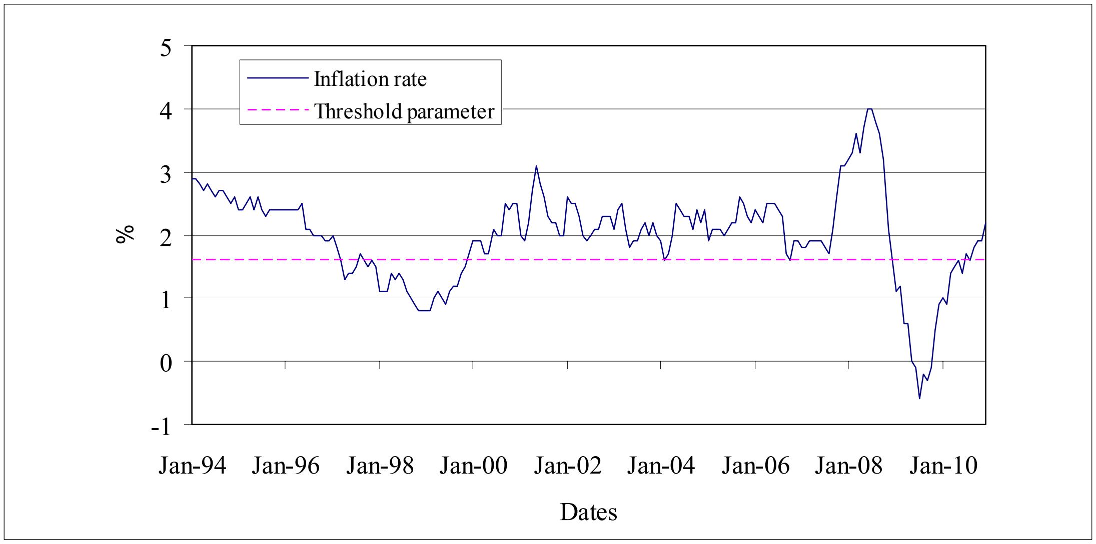


Figure 2: Determinacy regions of the TRSRE model with respect to β_1 and γ_1

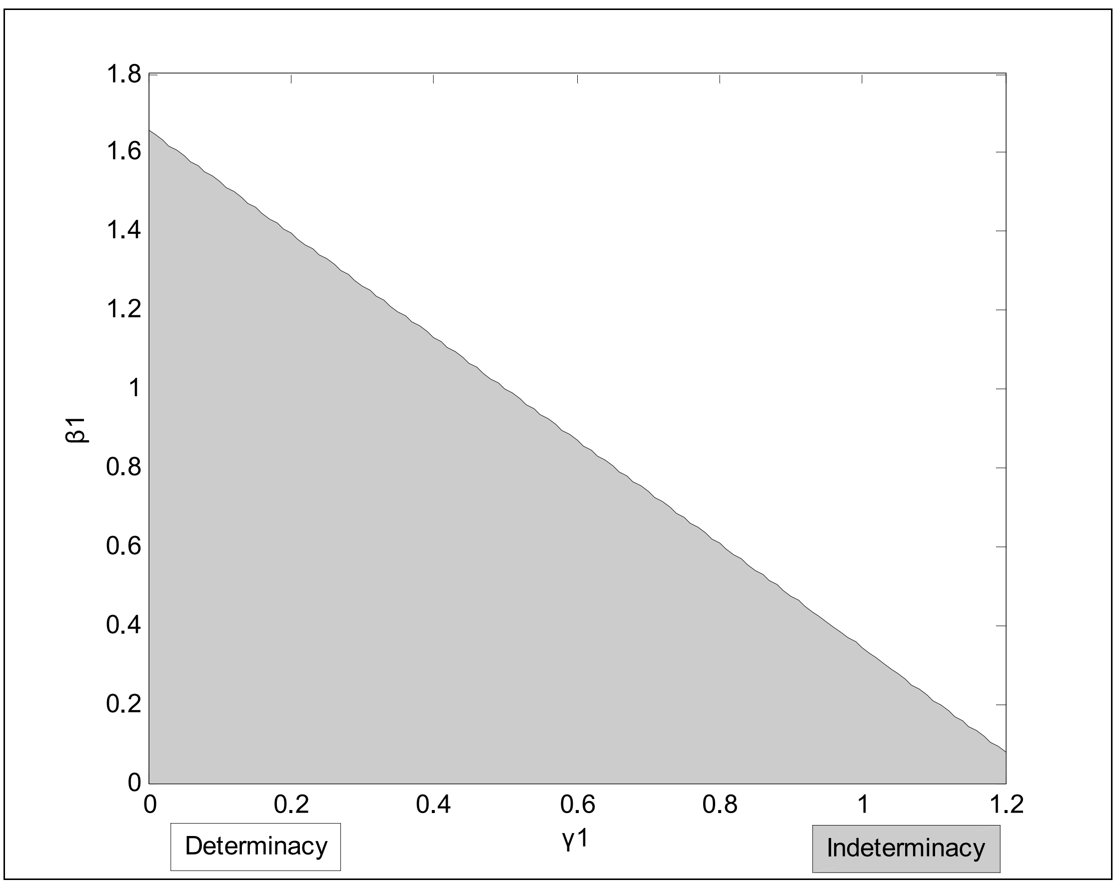
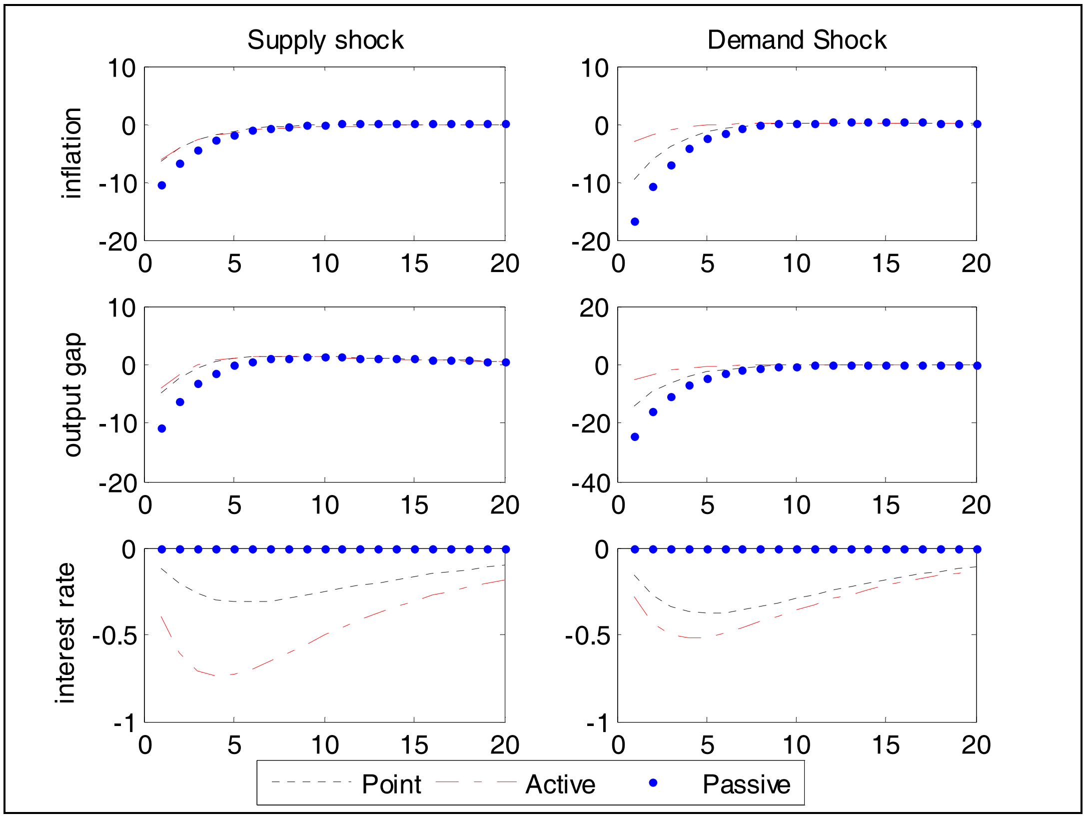


Figure 3: Impulse response functions (IRFs) driven by negative shocks in regime "1"



Notes: The point IRFs correspond to the estimates of β_1 and γ_1 found in low-inflation regime ("1"), the passive assume that monetary policy is sufficiently passive (i.e. β=0.005, γ=0.0) and, finally, the active consider the same values of beta and gamma coefficients across the two regimes.

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