TRABALHO FINAL DE MESTRADO

DISSERTAÇÃO

HOW WELL CAN SIMPLE RULES TRACK THE BEHAVIOR OF THE ECB?

POR

JODZINDA IRVINA DE ALMEIDA PIRES

Instituto Superior de Economia e Gestão
UNIVERSIDADE TÉCNICA DE LISBOA
DESDE 1911

MESTRADO EM

ECONOMIA MONETÁRIA E FINANCEIRA

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ALUNO:

Jodzinda Irvina De Almeida Pires

ORIENTAÇÃO:

Professora Doutora Maria Cândida Rodrigues Ferreira

JÚRI:

Presidente: Professor Doutor António Manuel Pedro Afonso

Arguente: Professor Doutor Emanuel Cláudio Reis Carvalho Leão

ISEG/UTL, 24 FEVEREIRO DE 2013

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Abstract

Taylor (1993) proposed a simple rule that drew attention of economists, scholars and central bankers due to its simplicity and outstanding description of Fed's behavior in 1980s. Over time, different versions of Taylor Rules (TRs) emerged aiming to evaluate the conduct of monetary policy of US and other countries, including recently the Euro area. Attending to the fact that previous studies concerning the Euro area are limited by short-time span of data, in this dissertation we analyze the performance of TRs in tracking the behavior of the European Central Bank (ECB), through a simple forward-looking approach and relatively long span of data (which comprises the two more severe economic turmoil of XXI century so far). The results obtained confirm that TRs, in general, track the ECB behavior very closely, mainly due to the gradualism of the ECB monetary policy. However, during economic turbulence we verified some deviations from the rule. The small magnitude of our empirical results reminds us that TRs are rough simplification of a complex reality.

JEL Classification: E52, E58

Keywords: Monetary policy, Taylor rule, Euro Zone.

QUAL A CAPACIDADE DAS REGRAS DE TAYLOR DE DESCREVER O COMPORTAMENTO DO BCE?

Resumo

Devido à sua simplicidade e excelente descrição da política monetária dos EUA entre os anos de 1987 e 1992, a Regra de Taylor (RT) (1993) atraiu a atenção dos académicos, analistas e decisores de política monetária; e, ao longo do tempo, foram surgindo diferentes versões de regras de Taylor, sendo cada versão uma tentativa de as tornar num instrumento mais prático a ser usado na avaliação da política monetária dos EUA e de outros países, incluindo recentemente a área do Euro. Atendendo ao facto de que os estudos anteriores associados à área do Euro estão, de certa forma, limitados por poucos dados disponíveis, nesta dissertação, analisamos as RT tendo em conta uma base de dados relativamente mais abrangente (que engloba, até então, as duas turbulências económicas mais severas do século XXI). Através de uma abordagem *forward-looking*, o objetivo é de verificar a capacidade das simples regras de Taylor em descrever as decisões de política monetária do Banco Central Europeu (BCE). Os resultados obtidos confirmam que as RT, no geral, fazem uma boa descrição da política monetária do BCE, principalmente devido ao ajuste gradual da política monetária. No entanto, face às turbulências económicas verificam-se desvios das RT. Além disso, a magnitude dos resultados estatísticos remete-nos para o facto de que as RT são uma simplificação de uma realidade muito complexa.

Classificação JEL: E52, E58

Palavras-chave: Política Monetária, Regras de Taylor, Zona Euro.

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I. Introduction

Most economic scholars consider that in the short-run, optimal monetary policy response to economic shocks should combine some sort of interest rate rules involving a certain level of discretion and set of inflation targets.

Proponents of simple interest rate rules argue that implementing monetary policy by means of rules provide low probability of time inconsistence problem and, consequently, of low inflation bias. Although simple rules cannot account completely for unexpected circumstances, they satisfy the need for transparency, adequate communication and robustness (e.g., Peersman and Smets, 1999; Orphanides, 2007). Furthermore, many foresight or rational expectation models require the presence of systematic (rule-like) behavior on the part of the central banks for the equilibrium rate to be found.

The most popular rule in the economic literature stems from Taylor (1993) in which the key interest rate set by the Federal Reserve System (Fed) is described as a linear combination of inflation and output gap. That is, a reaction function that describes how Fed should attain its two-fold mandates (i.e. control of inflation as well as the maintenance of low business cycle fluctuations).

Given the Taylor rule (TR) simplicity and its outstanding description of the behavior of the Fed funds rate during the 1987 and 1992 – a period of long expansions and short recessions – it rapidly drew attention of economists, analysts and central bankers. Over time, different versions of TR emerged in an attempt to make it a better and actualized tool for policy makers to evaluate the conduct of monetary policy of many central banks, including recently the

European Central Bank (ECB) (Asso et al, 2010, give detailed discussion on TR influence on the practice of central banking).

As responsible for conducting the monetary policy of the Euro area, the ECB has an overriding mandate – price stability over the medium term – that is not dual as suggested by the TRs framework. However, in line with the ECB Governing Council monetary policy strategy, built on an analytical framework which is based on two pillars - monetary and economic analysis (ECB, 2011, p.69) – one can find room for TRs in the first pillar strategy given that output gap measures are included in the set of leading indicators for future inflation. In addition, this stability-oriented monetary policy strategy causes the ECB to behave in a systematic manner; a feature that we expect TRs to be able to track.

Considering that previous studies on TRs for the Euro area were limited by short-time span of data available and also that there are few studies analyzing the impact of the recent economic turmoil in context of TRs, in this dissertation, we intend to contribute to the literature by dealing with: relatively long time span of data – a sample period that comprises the launch of the euro as single currency and two major economic turbulence (subprime crisis and the subsequent European sovereign debt crisis); three different measures of output gap, in which we specially include the OECD's composite leading indicator (CLI), given that it aims to reveal early signs of economic turning-points and move in the same direction as the business cycle. Through a simple forward-looking approach with a smoothing parameter we aim to assess the TRs' performance in tracking the ECB monetary policy-making. To complete this assessment, we extended the rule by a set of additional variables.

The results found do not differ much from those already seen in the literature, as will be mentioned through the dissertation: simple TRs seem to track the ECB policy decision very

closely (which testifies in favor of ECB's systematic behavior). The use of Hodrick-Prescott-filtered industrial production output gap points to output gap or the overall economic performance as the main trigger of ECB's intervention, while the use of annual growth in the industrial production index (and the CLI) as proxy for output gap point that ECB policy rate reacts not only to inflation but also to the output gap (both results are perfectly in line with the ECB's main objective of price stability as output gap measures serve as leading indicator of inflationary pressure).

Another result confirmed in this dissertation is the fundamental rule of interest rate smoothing in enhancing the fit of the TR: the particularly high and robust value of the smoothed interest rate coefficient is consistent with the ECB's cautious policy intervention and suggests that past interest rates are the main determinants of actual policy rates.

Nevertheless, the main advantage of TRs – simplicity – turns out to be their main weakness: TRs, in essence, capture the general course of a stability-oriented central bank such as the ECB, but leave out a wide range of information needed to backup a central bank's decision. This may justify the small (inflation and output gap) coefficients responses obtained. In fact, TRs are rough simplification of a complex, but may be used as an additional informative indicator.

The rest of the paper is organized as follows: section 2 reviews the theoretical and empirical background; section 3 develops the econometric model; section 4 reports the empirical results; section 5 draws conclusions.

II. Theoretical and Empirical Background

In this section we first present a brief background on TRs and then systematize the empirical results obtained from selected literature regarding the Bundesbank and the ECB.

2.1 Background on Taylor Rules

The economic literature related to Taylor-like rules is considerably vast. The different Taylor rule specifications vary from theoretical to empirical perspectives regarding: backward- and/or forward-looking perspective; measures of inflation and output gap; policy rate proxy; estimation methods; instruments and additional explanatory variables chosen; type of data; geography; sample period; models (e.g., Dynamic Stochastic General Equilibrium) and so on. Each line of research on TRs has been an attempt to make it a more actualized and operational tool.

Clearly a thorough survey on TRs literature is beyond the scope of this dissertation; hence, we modestly review the ones that contributed the most to the present analysis.

We start by Taylor (1993) which proposed a simple rule that states that Fed should set its short-term nominal interest rate (i_t) – federal funds rate – in response to the equilibrium real rate ($\overline{r}$); inflation gap ($\pi_t - \overline{\pi}$) defined as the deviation of inflation (π_t) from its target ($\overline{\pi}$); and output gap ($x_t = Y_t - Y_t^*$) defined as the deviation of real GDP (Y_t) from its potential level (Y_t^*). The rule is depicted as follows:

$$(1) \qquad i_t^* - \pi_t = \overline{r} + \beta_\pi (\pi_t - \overline{\pi}) + \beta_x x_t$$

Implicitly, the rule recommends central banks to match their policy rate to the nominal interest rate ($\overline{r} + \pi_t$) as inflation rate and output are at their respective long-run levels.

Taylor gave same emphasis to both inflation and output stabilization, by assuming that the betas of inflation (β_π) and output gap (β_x) were equal to 0.5, which implies that Fed should raise the fed funds rate about 0.5 percent as inflation (or output) raises 1 percent above the target. Additionally, he assumed that the equilibrium real interest rate ($\overline{r}$) and inflation target ($\overline{\pi}$) are equal to 2 percent.

With these values attributed in Taylor (1993), the TR entails what is called "Taylor principle", which assumes that β_π should be greater than a unit, implying that as inflation deviates from its target, nominal interest rates (i_t) should raise more than one-for-one (sufficiently) to cause an increase in the real rates ($\overline{r}$); where a β_π <1 would imply deficient policy response to rising inflation, tending to aggravate inflationary pressure. This principle also assumes that β_x should be positive but not necessarily above a unit, meaning that in order to achieve a stabilizing impact on output, monetary policy should accommodate shocks from the supply side. Such principle is consistent with the properties of model-specific optimal and more complex policy rules and provides a mean to anchor inflation over time. Such principle becomes visible when Taylor reaction function is rearranged as follows:

(2) $\quad i_t^* = 1.5\,\pi_t + 0.5x_t + 1 \quad$ where $x_t = (Y_t - Y_t^*)$

Clarida et al (1998) proposed a forward-looking version of TRs in which it is claimed that by considering inflation and output forecasts it is possible to incorporate a broad array of

information taken into account in monetary policy decision-making. This version of TRs comes as

(3) $$i_t^* = \overline{r} + \beta_\pi (E_t\pi_{t+n} | \Omega) - \overline{\pi}) + \beta_x (Ex_t | \Omega) + \varepsilon_t$$

where x denotes the measure of average output gap ($(EY_t | \Omega) - Y_t^*$); E denotes the expectation term; π_{t+n} stands for inflation rate at $t+n$; $\overline{\pi}$ is a constant target inflation rate; (Ω_t) is the set of information available to policy makers at the time of decision-making regarding the short-run interest rate, and ε_t denotes the error term (assumed to be i.i.d).

Given the environment of pervasive uncertainty faced by policy makers, it has been argued that they rather follow the "*Brainard conservatism*" (see Brainard, 1967) and implement monetary policy in a rather cautious and sluggish fashion. Hence, partial interest rate adjustment is modeled as

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

Where i_t^* stands for target nominal interest rate; $\rho \in (0, 1)$ denotes the degree of smoothing of the interest rates; and υ_t denotes an exogenous random walk shock to the interest rate.

Adding this partial adjustments into the equation (3)[1] and assuming that there are no systematic forecast errors we can re-write the reaction function in terms of realized variable as follows

(5) $$i_t = (1 - \rho) \alpha + (1 - \rho) \beta_\pi (\pi_{t+n} - \overline{\pi}) + (1 - \rho) \beta_x x_{t+n} + \rho i_{t-1} + \varepsilon_t ;$$

[1] At this step we get the following eq.: $i_t = (1 - \rho) (\overline{r} + \beta_\pi (E_t\pi_{t+n} | \Omega_t) - \overline{\pi})) + \beta_x ((EY_t | \Omega_t) - Y_t^*)) + \rho i_{t-1} + \varepsilon_t$.

where r_t^* stands for target interest rate; $\alpha = (\overline{r} - \beta_\pi \overline{\pi})$; x_{t+n} stands for the measure of average output gap and π_{t+n} stands for inflation rate at time $t+n$; $\overline{\pi}$ a constant target inflation rate; $\rho \in (0, 1)$ denotes the degree of smoothing of the interest rates; and ε_t denotes the error term .

Nevertheless, Rudebusch (2002) contradicts interpretation of ρ as monetary policy inertia, suggesting that ρ could be interpreted as persistent shocks faced by central banks and that the distinction between partial adjustment and serially correlated shocks is not clear. Gerlach-Kristen (2004) finds that ρ is mainly the result of omitted or unobserved variables, while Sauer and Strum (2007) advocate that it is an indication of a "too little and too late" policy rate response to changes in the economic outlook. Castelnuovo (2007) used modified models in first-differences to assess Rudebusch (2002) claims (for the case of the Euro area). His results confirm the importance of the lagged interest rate, but do not rule out the influence of the serially correlated shocks when fitting simple Taylor-like rules.

Another contribution to the TRs literature is related to the application of large number of explanatory variables as inputs in the TR aiming at the identification of relevant macroeconomic variables to monetary policy decision-making. These variables (among many others) include: unemployment rate (e.g., Clarida et al, 2000), exchange rate (e.g., Molodtsova et al, 2011), annual growth in the monetary aggregate (e.g., Ullrich, 2003; Gerdesmeier and Roffia, 2004), asset prices (e.g., Cecchetti et al, 2000), interest rate spread (e.g., Dotsey, 1998; Belke and Klose (2010); financial condition or stability index composed by indicators such as fiscal indicators, stock valuations, private sector expectations, international commodity prices, credit quality, etc,

that capture the vulnerability of the financial market, resilience of the banking system and external and internal vulnerability (e.g., Albulescu, 2010; Castro, 2011).

Concern regarding the stationarity of the variables is also an issue dealt with in the TRs literature. In some research papers, authors assume that relevant variables are stationary (e.g., Clarida et al. 2000), while in few other papers authors use variables in first differences (e.g., Orphanides, 2003) or implement techniques such as the error-correction, cointegration approach (e.g., Gelarch-Kristen, 2003; Ruth, 2007; Sauer and Strum, 2007) to avoid spurious results.

Other issues are associated with the use of real-time data instead of ex-post revised data. Orphanides (2001) emphasized the preeminence of using real-time data, the information available to central banks at the time they consider monetary policy decisions, in policy reaction functions. Many recent papers have been dealing with this issue; for instance, Gorter et al (2008) findings suggest that the ECB's monetary policy is stabilizing when real time expected inflation and output are used as opposed to the use of ex-post revised data (see also Orphanides, 2004; Gerdesmeier and Roffia, 2005; Belke and Klose, 2011 among others). However, Sauer and Strum (2007) suggest that real-time industrial production index data does not add much to the TR performance for the Euro area; in addition, Marcellino and Musso (2010) pointed out that real-time estimates of the Euro area output gap are associated with reasonable high degree of uncertainty and perform poorly as leading indicator for future inflation.

Given its simplicity and despite of its limitations (e.g., inability to assure that past mistakes will not be repeated (Orphanides, 2003)), over time Taylor-like rules became considered as a valuable guideline for policy makers (because TRs may enhance transparency

and monetary policy communication) and for the financial markets to evaluate the conduct of monetary policy of many central banks, including recently the European central bank (ECB).

As responsible for conducting the monetary policy of the Euro area, the ECB has an overriding mandate – price stability over the medium term (ECB, 2011, p.64) – that is not dual as suggested by the TRs framework. However, in line with the ECB Governing Council monetary policy strategy, built on an analytical framework based on two pillars – monetary and economic analysis (ECB, 2011, p.69) – one can find room for TRs, given that output gap measures are valuable leading indicators for future inflation. In this context, a number of researchers were motivated to examine the potential usefulness of TRs as an informal policy guide for the ECB. For instance, some studies focused in estimating Taylor-like rules for the "fictitious" ECB prior to 1999 when ECB was not yet in charge of the Euro area monetary policy (e.g., Peersman and Smets, 1999; Gerlach and Schnabel, 2000); Other studies estimate and compare the ECB monetary policy with a benchmark such as the Bundesbank (e.g., Faust et al, 2001), or the Federal Reserve System (Fed) (e.g., Ullrich, 2003), just to name a few.

2.2 Overview of empirical results from selected literatures

This section presents in the Table I an overview of the empirical results of different Taylor rule estimations regarding the Bundesbank and the ECB from selected literature, most of them mentioned above.

We start by presenting TRs estimates for the Bundesbank attending to the fact that due to its outstanding anti-inflationary monetary policy performance, it became a benchmark of monetary policy for European countries. Consequently, ECB was designed to follow the Bundesbank policy-making preferences (in order to inherit some credibility since there was no

track record proving ECB's reputation). Therefore, most studies on ECB monetary policy compare Bundesbank (and /or Fed's) reaction functions to the hypothetical ECB prior to 1999 and also to the actual ECB reaction functions.

A first look at the Table I shows that TRs produce a variety of results under different specifications and sample periods; some results are very similar while others seem discrepant. For instance, the inflation coefficient response, β_π, ranges from 6.62 to values very close to zero such as 0.08 or even negative ones.

TABLE I: OVERVIEW OF EMPIRICAL RESULTS OF TAYLOR RULE ESTIMATIONS REGARDING THE BUNDSBANK AND THE ECB

Study	Type of rule	Data	Sample period	α	β_π	β_x	ρ	Estimators
Bundesbank								
Clarida et al(1998)	Forward looking	ex-post	1979:3–1993:12	3.14 (0.28)	1.31 (0.09)	0.25 (0.04)	0.91 (0.01)	GMM
Peersman and Smets (1999)	Forward looking	ex-post	1979:1–1997:12	2.52 (0.32)	1.3 (0.10)	0.28 (0.05)	0.93 (0.01)	TSLS
Faust et al. (2001)	Forward looking	ex-post	1985:1–1998:12	2.85 (0.85)	1.31 (0.35)	0.18 (0.16)	0.91 (0.03)	IV
Fictitious ECB								
Peersman and Smets (1999)	Forward looking	ex-post	1980:1–1997:4	3.87 (0.44)	1.2 (0.09)	0.76 (0.13)	0.76 (0.13)	TSLS
Gerlach and Schnabel(2000)	Forward looking	ex-post	1990:1–1998:4	2.65 (0.39)	1.51 (0.11)	0.49 (0.12)	0.32 (0.19)	GMM
Gerlach-Kristen (2003)	Contemporaneous	ex-post	1988:1–2002:2	1.23 (1.59)	2.73 (0.55)	1.44 (0.76)	0.88 (0.04)	NLS
Ullrich (2003)	Contemporaneous	ex-post	1995:1–1998:12	1.97	1.25	0.29	0.23	TSLS
Gorter et al(2008)	Contemporaneous	ex-post	1997:1-2006:12	3.15 (0.40)	0.09 (0.53)	0.37 (0.24)	0.95 (0.02)	NLS
	Forward looking	real-time	1997:1-2006:12	3.6 (0.15)	1.39 (0.53)	1.52 (0.22)	0.86 (0.04)	
Actual ECB								
Fourçans and Vranceanu (2004)	Contemporaneous	exp-post	1999:1-2003:10	0.18	0.08	0.03	0.90	GMM
	Forward -looking		1999:1-2003:10	0.38	0.42	0.03	0.84	
Gerdesmeier and Roffia (2004)	Contemporaneous	exp-post	1999:1–2002:1	2.6 (0.06)	0.45 (0.11)	0.30 (0.07)	0.72 (0.04)	GMM
Sauer and Strum (2007)	Contemporaneous	ex-post	1991:1-2003:10	4.81 (2.82)	-0.84 (-0.89)	1.45 (1.99)	0.94 (25.50)	NLS
	Forward looking	real-time	1991:1-2003:10	-6.23 (-0.61)	6.62 (0.90)	9.24 (0.64)	0.98 35.57	GMM
	Forward looking	ex-post	1991:1-2003:10	-1.36 (1.10)	2.15 (3.83)	1.1 (3.22)	0.91 (31.20)	GMM
Ullrich (2003)	Contemporaneous		1999:1–2002:8	2.96	0.25	0.63	0.19	TSLS
Gerdesmeier and Roffia (2005)	Contemporaneous	ex-post	1999:1-2003:6	0.88 (0.13)	1.52 (0.08)	1.12 (0.05)	0.86 (0.01)	GMM
	Contemporaneous	real-time	1999:1-2003:6	2.86 (0.50)	0.61 (0.06)	2.14 (0.12)	0.99 (0.01)	
	Forward looking	ex-post	1999:1-2003:6	1.74 (0.15)	0.64 (0.07)	1.44 (0.04)	0.81 (0.01)	
Belke and Klose (2011)	Contemporaneous	ex-post	1999:1-2010:6	0.02 (0.19)	0.47 (0.35)	0.39 (0.21	0.95 (0.02	GMM
	Contemporaneous	real-time	1999:1-2010:6	1.48 (1.29)	-6.13 (6.29)	3.68 (3.31)	0.97 (0.02)	
	Forward looking	real-time	1999:1-2010:6	-0.49 (0.33)	0.14 (0.51)	1.28 (0.56)	0.97 (0.02)	

Note: standard errors in parentheses (when available); The contemporaneous TR refers to: $r_t = (1-\rho)\alpha + (1-\rho)\beta_\pi \pi_t + (1-\rho)\beta_x x_t + \rho r_{t-1} + \varepsilon_t$; Forward-looking TR refers to: $i_t = (1-\rho)(\overline{r} + \beta_\pi (E_t \pi_{t+n} | \Omega_t) - \overline{\pi})) + \beta_x x_t + \rho i_{t-1} + \varepsilon_t$, ($x_t = (EY_t | \Omega_t) - Y_t^*$); GMM stands for generalized method of moments; TSLS stands for Two-Stage Least Squares; NLS stands for nonlinear least-squares; and the IV stands for instrumental variables estimator.

As for the output gap response coefficient, β_x, the Table I shows that, in overall, it complies with the Taylor principle ($\beta_x > 0$), which may indicate that the ECB reacts to the economic activity to the extent it poses threats to price stability (possibility identified in the Economic analysis).

Also, it is evident that the coefficient responses regarding Bundesbank's and the "fictitious" ECB's monetary policy reveal small differences (probably because of the Germany's economic importance and, consequently, large weight in the calculation of the fictitious ECB's interest rate); both central bank's reaction functions fulfill the Taylor principle (i.e., $\beta_\pi > 1$, $\beta_x > 0$) and reflect a consistent anti-inflationary philosophy.

Next, we observe that, in general and independently of the specifications, we have positive and high degree of interest rate smoothing (ρ). This suggests that the ECB has engaged in interest-rate smoothing in its monetary policy and that actual short-term interest rate depends heavily on its past value, or decisions taken beforehand by the ECB Governing Council (fact which attest the important role of credibility in monetary policy).

Concerning the type of data, the use of real-time data seems to improve the ECB's policy rate response to inflation gap (β_π) relative to the use of ex-post revised data.

This brief survey also suggests that according to the Taylor principle (i.e., $\beta_\pi > 1$, $\beta_x > 0$), the actual ECB adopts a destabilizing policy regarding inflation and appears to give more emphasis to the output. However, given the ECB's anti-inflation philosophy, this might be an indication that the ECB loosened policy to stabilized output while creating credibility to anchor

inflation expectations, or TRs, more specifically, the Taylor principle is not in harmony with the reality of the actual ECB.

Interestingly and regardless of the criticisms undergone by the TRs, this kind of rule continues to be analyzed by researchers and economists over the years.

III. Empirical Model

In this section we present the econometric model, the definition of the variables, the diagnosis of the data and introduce the estimator used. The regressions are based upon aggregated data of the Euro area (EA), not regarding the asymmetric nature of shocks affecting each member state of the EMU and the heterogeneity that exist among them (since single monetary policy is not able respond to country-specific shocks). STATA is the statistical software chosen to carry out our analysis.

3.1 Model specification

We followed the type of Clarida et al (1999) reaction functions, without giving specific emphasis to the real interest rate, and estimated a simple TR model as depicted in the equation (6):

(6) $$i_t = \alpha + \beta_\pi (\pi_{t+p} - \overline{\pi}) + \beta_x x_{t+q} + \rho i_{t-1} + \varepsilon_t \quad .$$

where i_t stands for the money market interest rate; α is a constant; p and q correspond to the time horizon for inflation and output gap expectations, respectively; $\pi_{t+p} - \overline{\pi}$ denotes the inflation gap – deviation of expected realized inflation (π_{t+p}) at time $t+p$ from its target ($\overline{\pi}$), which accordingly to the ECB definition of price stability is set (below but close) to two percent

as assumed in the original TR; x_{t+q} represents the expected realized output gap at time $t+q$ (p and q denotes time horizon for inflation and output gap which happens to be different); β_π and β_x stands for the interest rate response to inflation and output gap respectively; ρ denotes the interest rate smoothing term; and ε_t denotes the residual term.

3.2 Data and variables

To deal with the short time span of data available for the actual ECB, we considered the beginning of the second stage of Economic and Monetary Union (EMU) and used monthly data covering the sample period 1994:01 to 2011:12. The estimations are carried out in levels and based upon ex-post revised data. In the Annex A1 all variables are explained in more detail, and in the Annex A2 we have the summary statistics.

As depicted in the eq. (6) the three main variables are: short-term nominal interest rate (i_t), inflation rate (π) and the output gap (x_t).

In normal circumstances, short-term money market rates such as the Euro Overnight Index Average (EONIA) is very close to the main policy rate, namely the Main Refinancing Operation (MRO) – minimum bid rate. Besides, the data on ECB key interest rates is not available on monthly (or quarterly) frequency, which makes it difficult to use any of the key rates directly in the reaction function. Therefore, we deemed appropriate to use the EONIA as proxy for the policy rate, which is in line with most TRs empirical work concerning the Euro area (e.g., Gerdesmeier and Roffia, 2005).

With regard to the inflation rate, it is measured by the year-over-year growth rate in the overall Harmonized Index of Consumer Prices (HICP). The inflation target is set according to

the definition of the Governing Council of the ECB, that is, bellow but close two percent over the medium term.

As for the output gap, we encounter two main issues: first, there is no monthly data available for real GDP; second, potential output is not observable. Therefore, we have to find proxies for both variables.

To deal with the lack of monthly real GDP data, some scholars implement linear interpolation methods such as Chow and Lin (1971) procedure to convert quarterly real GDP series into monthly series. However, attending to the fact that the Industrial Production (IP) index displays a strong co-movement with the GDP[2], we don't go through linear interpolation methods, but use annual growth rate in the overall IP as proxy for the annual growth rate in the real GDP instead.

To circumvent the potential output issue and get output gap measures, we took three different approaches, and hence started our analysis by using three different proxies for the output gap, which by definition fluctuate around zero mean:

1) The standard HP output gap: measured as the deviation of the logarithm of the annual growth of industrial production (IP) from its HP trend. Following e.g., Gerdesmeier and Roffia (2004) and Clarida et al (1998); we employed Hodrick-Prescott (HP) filter – a mathematical technique used to separate the cyclical component of in output from the growth component – with the smoothing parameter set to 14.400 for monthly series to fit a trend to the IP index data (Annex A1);

[2] See Annex B1 available on https://www.dropbox.com/s/lz9qtw0ha5n7t73/AnnexB.pdf

2) The IP output gap: measured by the annual growth of the index as proxy for the output gap (e.g., Fourçans and Vranceanu, 2004);
3) The CLI output gap: The two aforementioned output gap proxies are standard in the literature. In addition to it, we found interesting to proxy output gap by the annual growth of the OECD composite leading indicator (CLI), considering that (though it gives more qualitative than quantitative indication) it comprises a number of selected macroeconomic indicators and aims to forecast cycles or turning-points in the reference series chosen as proxy for economic activity (in this case, the IP index) (Annex A1).

We finalize our analysis by extending our baseline specification to consider the effect of other variables such as federal fund rate, Dow Jones Euro Stoxx 50 index, exchange rates, annual growth of monetary aggregate (M3) gap on the augmented TR. We also included an interest rate spread variable and sovereign (Greek and Portuguese) risk premium (see Annex A1), attending to the fact that there is a significant issue regarding the role risk plays in departures of policy from the rule.

3.3 Data diagnosis

At this stage we carry out the diagnosis of our time series with regard to the stationarity and endogeneity of the variables, the heteroskedasticity and serial correlation of the error term. In addition, we check the multicollinearity effect on the model and, finally, determine the time horizon.

In order to check the stationarity, we employed the modified Dickey-Fuller test (DF-GLS), which has the best overall performance in terms of small-sample size and power

compared to the ordinary Dickey-Fuller test; we complemented this test by employing the Kwiatkowski-Phillips-Schmidt-Shin (KPSS). The tests resulted that the short-term money market rate, inflation, and the growth rate in the IP index are nonstationary I (1) variables. The standard HP output gap is stationary I (0) by construction. The CLI as well as its annual growth rate are also stationary I (0). The stationarity test results are available in the annex (see Annex A3).

In fact, we found that the error term resulting from a linear combination between the variables is a stationary I (0) process. For this reason, the variables are cointegrated and hence, any regression relationship between those variables is non-spurious. Therefore we proceeded by using the variables in terms of level as opposed to first differences.

Regarding endogeneity, contrary to what is expected, the endogeneity test defined as the difference of two Sargan-Hansen statistics (see Annex A4), failed to reject the null hypothesis, and hence, inflation gap as well as output gap could be treated as exogenous.

To test for heteroskedasticity, we used tests such as Breusch-Pagan/ Cook-Weisberg (see Annex A5). Their rejection of the null hypothesis ascertains that the variance of the residuals is not constant over time. As result, the model is corrected to be robust to this fact.

The serial correlation test, Cumby-Huizinga test, failed to reject the null which states that there is no serial correlation (see Annex A6). This calls for feasibility of least square estimates and no need for model correction accounting for autocorrelation.

The degree collinearity of the variables was tested through variance inflation factor (VIF), which results came out no greater than 10, implying that multicolinearity does not represent a problem to the model. Besides, STATA automatically removes the variables that present collinearity problem.

Finally, we address the issue regarding the appropriate target horizon for both inflation (p) and output gap (q). There is no consensus about it, moreover, the ECB monetary strategy does not specify a fixed time horizon for policy stance, though it has a medium term (one to two years) target for inflation, inflation and economic activity forecasts over two to three years. The time horizon used here is not chosen randomly: after running several regressions with different horizons, the model was chosen based on link test (an option built into STATA) model specification, Root Mean Squared Errors (RMSE), the Akaike's (AIC) and Schwarz's Bayesian (BIC) information criteria. The time horizons implemented in this exercise are, therefore: six-month and three-month for inflation and output gap, respectively – which happens to reflects the "conventional wisdom" which shows that economic activity react faster to monetary policy decision than inflation does. When working with CLIs, no time lead is applied given that, conceptually, it is comparable to business cycle projections (see Annex A1) with short /medium term lead ranging between two to eight months.

3.4 Estimator

In general, forward-looking models are based upon future realized economic variables which in turn are affected by past policy. This should imply the existence of endogeneity and the need to implement instrumental variable (IV) estimators. However, as it was seen above, endogeneity test showed that inflation and output may be treated as exogenous variables. In this case, apart from providing us with descriptive statistics and working well as benchmark estimator, the ordinary least square (OLS) would be consistent and unbiased. Nevertheless, we

(questioning the test results) opted to employ the generalized method of moments (GMM) [3]even though in small-sample its performance may sometimes be poor requiring cautious interpretation of its estimates.

GMM estimator (as well as other IV estimators) is very sensitive to the choice of instrumental variables, which are to be orthogonal to error term and correlated with the endogenous variables. It is common to select the lags of inflation, output gap and other explanatory variables as potential instruments. Our instruments are set as follows: one-month lag of inflation, six- and twelve-month lags of the output gap (for both when it is measured by the standard HP output gap and by the annual growth rate of the IP index); one- and six month lag of inflation and three-month lag of output gap when proxied by CLIs. The j-test for over-identifying restrictions approves the validity of our instruments. The results produced by Limited-Information Maximum Likelihood (LIML), which is more robust to weak instruments, do not differ from those obtained from GMM, indicating that the instruments used are quite suitable.

IV. Empirical results

In this section we present the econometric results. First, we show the results of the GMM estimator using the three measures of output gap for the whole sample. Then, we consider a sample period that begins with the launch of the euro (January, 1999). Next, we analyze the effect of changes in the economic structure on the course of the ECB policy. And finally, we extend the model to account for the impact of additional variables.

[3] GMM deals with over-identification and in case of just identification it reduces to two stage least square (2SLS)

4.1 Baseline specification results

The Table II reports the results of our baseline specification (eq. 6) estimated through GMM with three different measures of output gap. At first glance, one may notice that the results are very sensitive to output gap measures. The results obtained from the standard HP output gap contradict those from the annual growth of the IP index and the annual growth of the OECD composite leading indicator (CLI) (regardless of estimator used, see Annex A7).

The use of standard HP output gap provides us with statistically insignificant policy rate response to inflation gap (or even a negative response under OLS, see Annex A7), and points to a prominent role of the output gap in the monetary transmission mechanism due to its strong influences on future inflation (e.g., economic growth acceleration triggers a hike in the inflation expectation) – as also pointed in Gerlach and Smets (1999).

TABLE II: ESTIMATES OF TR IN THE EURO AREA: 1994:01-2011:12

Estimators	GMM		
	HP output put gap	%IP	CLI
β_π	0.022 (0.038)	0.073** (0.025)	0.104*** (0.026)
β_x	3.722** (1.229)	0.016*** (0.004)	0.032** (0.012)
ρ	0.979*** (0.008)	0.989*** (0.008)	0.988*** (0.012)
α	0.055* (0.027)	-0.001 (0.028)	0.006 (0.039)
N	198	198	204
j-test (p-value)	3.366 (0.186)	1.756 (0.416)	2.721 (0.257)
AIC	-135	-146	-116
BIC	-121	-132	-103
RMSE	0.169	0.164	0.179
adj. R^2	0.987	0.988	0.986

Note:

1. Eq.6 : $i_t = {}_\alpha + \beta_\pi (\pi_{t+6} - \overline{\pi}) + \beta_x X_{t+3} + \rho i_{t-1} + \varepsilon_t$

2. Standard errors in parentheses. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$
3. AIC and BIC stands for the Akaike and Schwarz information criteria, respectively - the lower their value, the better the model; RMSE stands for root mean square error which measures the dispersion in the error term;
4. **HP output put gap** stands for the difference between the logarithm of the IP index and its Hodrick-Prescott-filtered trend; **%IP** stands for the annual growth rate of the Industrial production index, and **CLI** for the annual growth rate of the amplitude adjusted composite leading indicator (CLIs) of the OCDE (see Annex A1);
5. The j-test stands for the Sargan-Hansen test, a test of overidentifying restrictions. The joint null hypothesis is that the instruments are valid instruments (uncorrelated with the error term). A rejection casts doubt on the validity of the instruments.

Contrary, when the economic activity is measured by the annual growth rate of the IP index or by the annual growth rate of CLIs, the policy rate response to the output gap, though statistically different from zero, is reasonably small in magnitude. Also, in these two cases, inflation gap appears to gain statistical relevance. According to these results, the ECB not only adjust the policy rate in response to inflation but also to the economic activity (conclusion not very distinct from those of Fourçans & Vranceanu (2004)).

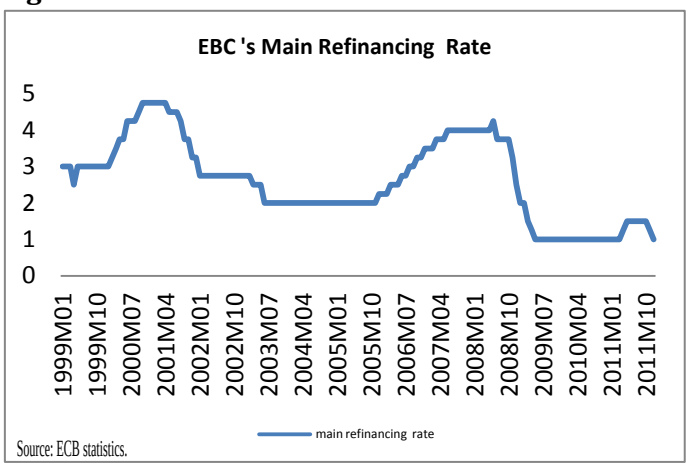
The aforementioned observations support the ECB mandate for price stability, but none of the specifications seems to fulfill the Taylor principle. Like in the Table 1, if we follow the precept of the Taylor principle, it can be inferred that, the general small or no reaction to inflation gap might indicate a destabilizing behavior of the ECB (which is not realistic considering the ECB's mandate). However, looking from other perspective, the small or no reaction to inflation gap might indicate the ECB's success in anchoring inflation expectations, which caused inflation to be stable with small or insufficient variation regarding its target[4]. In fact, higher credibility of inflation targeting leads to less monetary policy response to changes in inflation (e.g., Peersman and Smets, 1999)

[4] see Annex B2 available on https://www.dropbox.com/s/lz9qtw0ha5n7t73/AnnexB.pdf

The relatively small magnitude in both inflation and output gap response coefficients may also be justified by the high degree of interest rate smoothing (ρ) and by the fact that the ECB considers a wide range of indicators of macroeconomic development other than inflation and output gap.

Concerning the policy rate response to its past values (ρ), it can be seen from the Table II that ρ is robust and remarkably high, a common feature found across the different forms of TRs as noticed in the Table I (e.g., Clarida el al, 1998; Faust el al, 2001; among others), which points that the actual policy rate depends more on its past values that it does on the fundamentals. This monetary policy inertia suggests that only 3 to 4 percent of change in the interest rate is reflected in the policy rate within the month of change and that the rest will be adjusted in the remaining period. Therefore, rational agents should be able to anticipate future rates quite accurately.

Figure 1

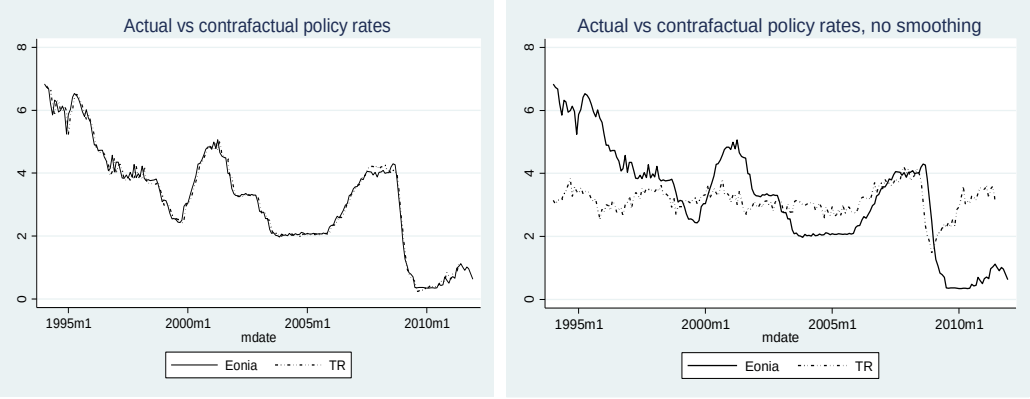


In fact, as depicted in the Fig.1, ECB follows interest-rate smoothing in its monetary policy: ECB interest rates slowly fell from 3 to 2.5 percent then raised gain to 3 percent during 1999 and remained unchanged until 2000 when it gently rose to 4.75 percent, falling to 2

percent throughout 2003 and then remained unchanged for more than two years, starting smoothly ascending until 2008 when the ECB began to lower interest rates in response to the critical economic conjecture. Most recently, the ECB has cut interest rate to historically low level (0.75 percent in July 2012).

No matter the interpretation of ρ, it does enhance the fit of TRs: as it is removed from the regression, TRs show a significant departure from the actual interest rate with reasonable serially correlated errors (Fig.2 right side). From Fig.2 (left side), it can be seen that TRs track the ECB actual policy rate very closely – feature robust to all measures of the output gap, independently of the estimator employed[5]. The major deviation of the actual policy rate from the TR can be found in the interval encompassing mid-1998, the outburst of the financial crisis (mid-2007) and the ongoing Euro area sovereign debt crisis (mid-2009 –).

Figure 2



These deviations can be seen not as ECB departure from a systematic behavior but an evidence of the need of some level discretion (or flexibility) in the implementation of monetary policy. The deviations from the TR correspond to crisis episodes (that impaired monetary policy

[5] The chart associated to the OLS and LIML estimates are available on request.

transmission channels) to which the ECB responded through non-standard measures (ECB, 2011, p.126-128).

The remarkably high adjusted R^2 confirms the feature observed in the Fig.2, showing that, under the specifications used and regardless of output gap measures, TRs fit the actual data pretty well(except during economic turbulence period).

In terms of preferred specification, the information criteria the Akaike's (AIC) and Schwarz's Bayesian (BIC) information criteria appear to reward the model in which the annual growth of the IP index is used as measure of the output gap. Intuitively, the annual growth of the IP index is not subjected to estimation uncertainty as the other two measures do, and hence, appears to be less misleading. Although the use of CLI produces better results regarding policy response to inflation, the model displays higher AIC. Therefore, in the rest of the paper the estimations will be based on the output gap measured by annual growth of the industrial production (IP) index.

4.2 Cross-checking different sample periods

In this section, the sample used covers the period which correspond to launch of euro area (January 1999) up to December 2011. The objective is to observe whether the use of unchained data displays major differences as compared to the chained pre-EMU and post-EMU data used so far (the estimation results are available in the Annex A8).

We observed a slight increase in the magnitude of the inflation response coefficient (β_π), a decrease in magnitude and statistical significance of the output gap response coefficient (β_x), which asserts the ECB's overriding mandate for price stability; and a slight decrease in the AIC and BIC. However, the results are not so far apart compared to the ones on the Table II, which

may tell us that though the ECB is more anti-inflationary than individual central banks of the EMU member states, the national central banks cooperation and monetary policy coordination in the pre-EMU was indeed aimed at low inflation.

The β_π still does not exceed the value embodied in the Taylor principle. When the expected realized output gap is removed from the TR (but included in the instruments set for inflation in the GMM estimator, as to reflect the ECB monetary policy mandate which does not respond directly to economic activity, but to its effects on inflation), β_π becomes statistically very significant but still does not exceed a unit (results available in the Annex A9).

4.3 Change in the Economic Structure

Here we analyze the impact of the changes in the economic structure associated with the introduction of the single currency in 1999, the two more recent and severe financial crisis since the Great Depression, namely, the outbreak of the subprime crisis (August 2007) and the European sovereign debt crisis (November 2009), by considering dummy variables. In addition, given the results obtained, we also cross-check the TRs performance during subprime crisis period (2007:8-2009:06) and in the absence of it (by removing crisis period of time from the sample).

The dummies were set such that it takes on value 0 prior and 1 after January 1999, August 2007, and November 2009, respectively. The equation is depicted as follows:

(7) $i_t = \alpha + \delta D + \beta_\pi(\pi_{t+6} - \overline{\pi}) + \beta_x x_t + \rho i_{t-1} + \varepsilon_t$, where D stands for dummies.

The results concerning the inclusion of the dummies are reported in the table III. With regard to the introduction of the single currency in 1999, under the specifications being used,

apparently it did not triggered monetary policy response. This comes without surprise given the monetary convergence process (Maastricht Treaty or Criteria) that preceded the introduction of the single currency. This is in line with the results we obtained in the previous section.

As for the subprime crisis, the ECB appears to ignore it as the coefficient (dummy 2) shows up statistically insignificant, which may correspond to the fact that the ECB didn't react aggressively to the subprime crisis at its outburst. This goes in line with Bouvet and King (2011), that found that August 2007 does not correspond to a structural break in the ECB policy (but December 2008, instead), given that the spillover effect of the US housing crisis on Europe started to feel severe only in the second half of 2008 (even though state interventions actuated offering liquidity to the banking system from the onset of the subprime crisis).

TABLE III: ESTIMATES OF TR IN THE EURO AREA: 1994:01-2011:12

DUMMIES FOR CHANGE IN THE ECONOMIC STRUCTURE

	GMM		
	Dummy 1	*Dummy 2*	*Dummy 3*
δ	-0.0292 (0.061)	0.00876 (0.042)	-0.0877* (0.044)
β_π	0.0835 (0.048)	0.0817*** (0.024)	0.0796** (0.028)
β_x	0.0153* (0.006)	0.0154** (0.005)	0.0155*** (0.004)
ρ	0.984*** (0.015)	0.991*** (0.010)	0.978*** (0.012)
α	0.0389 (0.094)	-0.00548 (0.045)	0.0426 (0.049)
j-test (p-value)	1.974 (0.3726)	2.639 (0.2672)	0.83 (0.6604)
N	198	198	198
adj. R^2	0.987	0.987	0.988

Note:

1. $i_t = \alpha + \delta D + \beta_\pi(\pi_{t+6} - \overline{\pi}) + \beta_x x_t + \rho i_{t-1} + \varepsilon_t$, estimated through GMM ;
2. Standard errors in parentheses (expect for the p-value). * p < 0.05, ** p < 0.01, *** p < 0.001;
3. Dummy1=0 prior and 1 after January 1999; Dummy2=0 prior and 1 after August 2007;and Dummy3= 0 prior and 1 after November 2009;
4. The output gap is measured as the annual growth in the industrial production index (%IP).

In fact, it was not until October 2008 that the ECB Governing Council decided on interest rate cut by 50 basis points to 3.75 percent. The positive sign observed may be an indication of the increase in the policy rate carried out by the EBC in July 2008 on the basis of its assessment of risk to price stability.

Apparently the subprime crisis caused no change in the ECB's behavior, so we cross-checked this outcome by both removing the financial crisis period from our sample and also restraining the sample to the crisis period[6]. In the first case, the policy response to both inflation and output gap increases in magnitude and statistical significance. However, during the subprime crisis, while policy response to output gap remains slightly the same, the response to inflation is rather statistically lower and has even a negative value. This may indicate that during the subprime crisis the focus of the ECB was not on inflation itself (variations appear to be perceived as temporary by the ECB, because long term inflation expectations are well-anchored), which by the way has been above 2 percent, but rather on factors that threat price stability (e.g., the economic activity). Also the interest rate smoothing coefficient, ρ, shows that monetary policy is more inertial in the absence of the crisis.

We also removed the output gap from the TR when working with the subprime crisis sample (see footnote 6), and found that policy response to inflation, β_π, becomes very significant. This outcome reinforces the important role of the output gap as leading indicators for inflation pressure.

As for the sovereign debt crisis (dummy 3) the result is consistent with the ECB dealing with it at its outburst through cuts in the interest rate.

[6] See Annex B3 and Annex B4 available on https://www.dropbox.com/s/lz9qtw0ha5n7t73/AnnexB.pdf

4.4 Impact of additional explanatory variables

As we have seen, the relatively small magnitude in both inflation and output gap response coefficients, may also suggest that the ECB base its decision regarding the adjustment of the policy rate on a wide range of indicators of macroeconomic development, other than inflation and output gap. Therefore, following e.g., Clarida et al (1998), Gerlach and Schnabel (2000) among others, we extended the baseline regression by taking into account additional variables to widen the set of information to some extent. The regression is depicted as follows (for the estimation results see AnnexA10)

$$(8) \qquad i_t = \alpha + \beta_\pi(\pi_{t+6} - \overline{\pi}) + \beta_x x_t + \beta_\gamma z_t + \rho i_{t-1} + \varepsilon_t$$

where z_t stands for additional explanatory variables such as federal funds rate; stock market barometers, namely, Dow Jones Euro Stoxx, the DJ corrected for the economic activity growth, and the interest rate spread measure as the difference between the Euro area 10-year Government bond yield and 3-month euribor; exchange rates, both Real effective (REER) and Nominal effective (NEER) measure as annual change rates; monetary aggregate (M3) gap measures as the deviation of M3 annual growth from the reference value (4½%) set by the ECB (see Annex A1). In addition, regarding the role sovereign risk played in departures of policy from the rule we included Greek and Portuguese risk premiums measured as the difference between 10-year bond yield (Greece, Portugal) and 10-year Germany Government ("risk-free") bond yield.

The results we obtained suggest that the predictive ability of many variables for future inflation has weakened. Except for the US monetary policy (fed funds), to which the ECB policy

is very responsive, given the existing financial flows links (a result that is contrary to Gerdesmeier and Roffia (2004) but consistent with Ullrich (2003)), the additional variables considered, appear to provide statically no additional information to the ECB governing council. However, they seem to have some economic significance, as we expect ECB to react to, for instance, a rise in the DJ euro stoxx by raising the policy rate, while lowering the policy rate in response to hikes in the interest rate spread[7]. The sovereign risk premium (Greece, Portugal) is only statically significant from August 2007 (only when both risk premiums are included in the regression simultaneously). The latter results may be related to ECB's non-standard measures and the intervention of "Troika"[8].

The result (from AnnexA10: $\beta_{\gamma\ (M3)}$= -0.003) suggests that, though the M3 plays an important role as a leading warning indicator of threats to price stability in medium to long term in the ECB monetary analysis, under the specification used (output gap measured by the annual growth in the IP index) the ECB policy rate is unresponsive to M3. This outcome is not uncommon in the TRs literature as e.g., Gorter et al (2008) and Gerlach and Schnabel (2000) testifies. Also, this negative coefficient confirms the conclusions of Ullrich (2003), by which the ECB follows a counterintuitive action regarding M3 growth, because, theoretically, we expect interest rate hikes in response to "harmful" money growth. Nevertheless, it does not imply that the growth of the M3 should be disregarded. As a matter of fact, monetary policy does not react mechanically to deviations of M3 growth from the reference value[9] .

[7] See Annex B5 on https://www.dropbox.com/s/lz9qtw0ha5n7t73/AnnexB.pdf
[8] The committee led by the European Commission(EC) with the ECB and the International Monetary Fund (IMF), that organize and monitor loans to the governments of Greece, Ireland and Portugal.
[9] ECB Monetary policy glossary available on http://www.ecb.int/home/glossary/html/act4m.en.html.

In general, the output gap and inflation gap coefficient response, (β_x) and (β_π) respectively, continues to point out to the ECB's overriding goal - price stability.

V. CONCLUSION

This dissertation analyzes the capability of Taylor rules in tracking the ECB behavior from 1994:01 to 2011:12. Three different measures of output gap were employed and the TRs were estimated through GMM, following a simple forward-looking approach. The impact of the change in the economic structure associated to the launch of the euro, the outbreak of the subprime crisis and the subsequent European sovereign debt crisis on the course of the ECB's policy-making were also analyzed. And finally, the TR was extended to consider the impact of additional explainable variables other than inflation and output gap.

It was found that policy rates response to either inflation or output gap is very sensitive to the output gap measure and estimation method: The standard Hodrick-Prescott output gap points to a prominent role of the output gap in the monetary transmission mechanism, which is consistent with the fact that economic growth is an indicator of risk to price stability. Contrary, when the economic activity measured by the annual growth rate of the industrial production (IP) index or by the annual growth rate of the composite leading indicator (CLIs), the general result suggests the ECB not only adjust the policy rate in response to inflation but also to the economic activity, even though their response coefficient are relatively small in magnitude.

Although the use of CLI (which components exhibit leading relationship with IP index at turning points) as proxy for the economic activity produces better result regarding the policy rate response to inflation gap, the model is penalized with higher Akaike's (AIC) and Schwarz's

Bayesian (BIC) information criteria.

The empirical results also point to ECB unresponsiveness to the launch of the euro (January 1999) and to the subprime crisis at its outburst (August 2007). However, the sovereign debt crisis seemed to trigger an immediate response from the ECB. Results which are roughly consistent with observed ECB's behavior.

With regard to the additional variables, our analysis suggests that the predictive ability of money and many other variables for inflationary pressure has weakened in recent years, showing no statistical significance.

We could see that, although simple, TRs seem to track the ECB policy decision very closely with major deviations occurring during the crises episodes. This close track is mainly caused by the gradualism of ECB monetary policy (attested by the high and robust degree of interest rate smoothing) and its systematic behavior. In fact, the outcome obtained points that the actual short-interest rate is heavily dependent on its own past values (fact which confirm the important role of credibility in the monetary policy). Despite of the close track, TRs may have little to say regarding all relevant information underlying the decision-making of the ECB.

For instance, none of the specifications employed fulfilled the Taylor principle and, in general, the coefficients obtained in our empirical results are quite small in magnitude. This may either be an evidence of a destabilizing behavior (according to the Taylor principle) of the ECB or of the ECB´s effort (through its two-pillar monetary policy strategy) to anchor inflation expectations which caused inflation to be stable with small variation regarding its target. Given the ECB's anti-inflationary philosophy, it may be inferred that TRs or, more specifically, the Taylor principle is not in harmony with the reality of the actual ECB. This outcome calls for further and deepest research.

Because TRs are superficial representation of a complex reality, it does not cover all relevant information underlying the decision-making of the ECB. Nevertheless, due to it nature, TRs may still be used as an additional informative indicator.

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VII. ANNEX

Annex A

Annex A1: Description of the variables and respective sources.

The ex-post data used in this exercise comprises monthly data covering the sample period 1994:01 to 2011:12, and refers to the Euro area - changing composition*. All the series are seasonally adjusted.

Variable	Explanation	Key	Source/retrieved on/Unit

				base
Policy rates (i_t)	The policy rate is represented by Eonia, the euro overnight index average; the rate at which banks borrow from each other is one of the benchmark interest rates for the money and capital markets. It is computed as a weighted average of all overnight unsecured lending transactions from banks participating in the inter-bank euro-zone market.	#	FM.M.U2.EUR.4F.MM.EONIA.HSTA	ECB statistics (23/05/2012)
Inflation rate (π_t)	"Consumer price inflation in the Euro area is measured by the Harmonised Index of Consumer Prices (HICP). The HICP is compiled by Eurostat and the national statistical institutes in accordance with harmonised statistical methods"[10] (ECB). The euro area HICP is constructed by taking a weighted average of price indices of EMU member states.	$\pi_t = 100*\log (HICP_t / HICP_{t-12})$	ICP.M.U2.S.000000.3.INX	ECB statistics (29/04/2012) 2005=100
Inflation gap (β_π)	Computed by subtracting the inflation rate of the ECB from the inflation target, which, by definition of the ECB price stability, is less but close to 2% over the medium term.	$\pi_{t+n} -= \pi_{t+n} - 2\%$.		
Industrial production Index (IP)	The overall industrial production index is a business cycle indicator which measures monthly changes in the price-adjusted output of industry. The IP used here covers the total industry which comprises the production in mining, manufacturing and public utilities (electricity, gas and water) and construction.		STS.M.I6.Y.PROD.NS0010.4.000	ECB statistics (origin: OECD) (29/04/2012) 2005=100
Growth rate in IP (β_x)	Measured by taking the annual percentage change in the IP index	$\%IP = 100*\log (IP_t/IP_{t-12})$	#	#
HP filter	Hodrick-Prescott (HP) filter is a data smoothing method that was first used by Robert J. Hodrick and Edward C. Prescott in 1997. This method removes the short-term trends or fluctuations from the data, which gives us a long-term feature of the data. Assuming that the x_t the original series is composed of a cyclical component (c_t) and a trend component (g_t). Where cyclical component (ct) = original time series (xt) - growth or trend component (gt). The parameter λ ($\lambda \geq 0$) penalizes variability in the gt series. The larger the λ, the smoother is the solution series. λ takes on values 100 for annual series, 1600 for quarterly series and 14.400 for monthly series	$\text{Min} \left(\sum_{t=1}^{T}(c_t)^2 + \lambda \sum_{t=2}^{T-1}[(g_t - g_{t-1}) - (g_{t-1} - g_{t-2})]^2 \right)$	#	#
Standard HP output (β_x)	The difference between the IP index and its HP trend.	xt = (yt - yt*) = 100*(log(IP)- HP(log(IP))		
OECD Composite Leading Indicators (CLIs)	The OECD created a composite leading indicator- which differs from GDP and output gap projections- that could be able not only to reveal early signs of economic turning-points, but also move in the same direction as the business cycle. Therefore, the selected indicators comprise	CLIAAt= (CLINormt-100)*StDev (RefSeriesRT) + 100	Monthly Monetary and Financial Statistics (MEI)	OECD statistics (08/07/2012)

[10] http://www.ecb.int/stats/prices/hicp/html/index.en.html

(β_x)	macroeconomic indicators that follow the business cycle. The CLI is optimized to detect turning points, not the levels of the industrial production (IP) index reference series. In this exercise, it was considered the CLI amplitude adjusted, because accordingly to the OECD, this method is the most straightforward and provides an interpretation in line with the output gap.[11] A word of cautious from the OECD is that CLIs should not be interpreted as providing exact forecasts. Furthermore, results provided by CLIs are qualitative rather than quantitative information on short-term economic movements.			
Additional explanatory variables (β_γ)				
Federal funds rate	This is the interest rate on US banks overnight loans. It is a benchmark rate and a barometer of credit market condition and the monetary policy stance of the Federal Reserve System (Fed)[12].	#	USA.IRSTCI01..... "Immediate interest rates, Call Money, Interbank Rate, Per cent per annum"	Monthly Monetary and Financial Statistics (MEI) - OECD
DJ Euro Stoxx 50 price index	DJ Euro Stoxx is a stock index of Eurozone stocks. The data on this "marker barometer" are historical close series.	#	FM.M.E1.EUR.DS.EI.DJSTO50.HSTA	ECB statistics (provided by DataStream) (13/06/ 2012)
Annual rate of change in the DJ Euro Stoxx 50 price index		log (DJ Stoxx 50t/DJ Stoxx 50t-12)*100	FM.M.U2.EUR.DS.EI.DJES50I.ANR	
Interest rate spread	Also a market barometer considered is the interest rate spread measured as the difference between the Euro area 10-year Government Benchmark bond yield and 3-month euribor. It is a simple but useful indicator of market stress or recession. In one hand, the as investors fear a coming recession, they short their short-term securities in exchange for long-term securities; this will cause the spread to be negative. By the other hand, the hike of interest rate spread signals rising risk within the capital market for long-term credits which drive investment decisions.	Euro area 10-year Government Benchmark bond yield minus 3-month euribor	FM.M.U2.EUR.4F.BB.U2_10Y.YLD FM.M.U2.EUR.RT.MM.EURIBOR3MD_.HSTA	ECB statistics (23/05/2012)

[11] http://stats.oecd.org/mei/default.asp?rev=2 and http://www.oecd.org/dataoecd/26/39/41629509.pdf.

[12] http://stats.oecd.org/OECDStat_Metadata/ShowMetadata.ashx?Dataset=MEI_FIN&Coords=%5bSUBJECT%5d.%5bIRSTCI%5d&ShowOnWeb=true&Lang=en.

GR and PT risk premium	Refers to a proxy of sovereign risk or risk premium for Greece and Portugal.	10-year government bond (Greece, Portugal) minus 10-year government bond (Germany).	IRS.M.GR.L.L40.CI.0000.EUR.N.Z IRS.M.PT.L.L40.CI.0000.EUR.N.Z IRS.M.DE.L.L40.CI.0000.EUR.N.Z	
ECB Nominal effective exchange rate (NEER) ECB Real effective exchange rate (REER)	CPI deflated referring to the Euro area-17 countries vis-a-vis the EER-20 group of trading partners (AU, CA, DK, HK, JP, NO, SG, KR, SE, CH, GB, US, BG, CZ, LV, LT, HU, PL, RO and CN) against US dollar.	#	EXR.M.Z64.USD.ERC0.A EXR.M.Z64.USD.EN00.A	ECB statistics (12/06/2012) 99Q1=100
Broad Money (M3) Index	Monetary aggregates are measures of money supply commonly defined by central banks. They range from M1 to M3 and differ according to the degree of liquidity of the assets included thereof[13].	M3= M2+ Repurchase agreements+ Money market fund (MMF) shares/units + Debt securities up to 2 years.	Monthly Monetary and Financial Statistics (MEI)	OECD statistics Origin :Euro Area Monetary aggregates and their components(ECB) (13/07/2012) 2005=100
M3 Gap	The ECB Governing Council set a reference value for M3 which refers to the annual growth rate of M3, namely an annual growth rate of 4½%, and is considered to be consistent with the ECB monetary goal and serves as a benchmark to assess monetary developments. According to the ECB this value is simply a reference, not a target.	(log (M3t/M3t-12)*100)-4½%		
Annual growth rate of M3	Measured by taking the annual percentage change in the M3 index	log (M3t/M3t-12)*100		

*Euro area changing composition:

- Euro11: January 1999 - Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain;
- Euro12: January 2001 – Greece;
- Euro 13: January 2007 –Slovenia;
- Euro 15 : January 2008 – Cyprus and Malta;
- Euro 16 : January 2009 –Slovakia;
- Euro 17: January 2011– Estonia.

13 http://stats.oecd.org/OECDStat_Metadata/ShowMetadata.ashx?Dataset=MEI_FIN&Coords=%5bSUBJECT%5d.%5bMABM%5d&ShowOnWeb=true&Lang=en

Annex A2: Summary statistics

Variables	Obs.	Mean	Std. Dev.	Min	Max
Eonia (r_t*)	216	3.23	1.64	.34	6.84
Inflation rate (π_t)	216	2.021	.745	-.614	4.087
OECD Composite Leading Indicators (CLIs) (x_t)	216	1.001	1.14	96.07	101.963
Annual growth CLIs (x_t)	216	.159	1.74	-5.11	4.37
Industrial production Index (IP) (x_t)	216	9.44	7.34	80.22	110.09
Growth rate in the IP	216	1.15	4.84	-20.82	7.66
Standard HP output gap	216	.0007	.0241	-.0950	.066
Fed funds rate	216	3.39	2.16	.07	6.54
Annual growth in the DJ Euro stoxx 50 price index	216	7.30	23.86	-45.12	59.12
DJCorr1	216	.022	27.41	-78.62	60.38
REER	216	-.487	6.02	-12.42	11.67
NEER	216	-.935	6.02	-12.31	12.55
grM3	216	5.89	2.87	-1.032	12.53
grM3_gap	216	1.39	2.87	-5.53	8.035

Note: REER and NEER refer to their respective annual growths; grM3 refers to annual growth rate of the monetary aggregate (M3); grM3_gap refers to the difference between the annual growth of the monetary aggregate (M3) and the reference value (4½%) set by the ECB.

Annex A3: Tests for Stationarity

	DF-GLS Statistic (5 % critical value)		KPSS-Statistic: 5 % critical value = 0.146	
Series	Level	First differences	Level	First differences
Eonia (r_t*)	-1.582 (-2.924)	-7.166 (-2.925)	0.256	0.0864
Inflation rate (π_t)	-2.368 (-2.924)	-7.840 (-2.925)	0.169	0.0398
OECD CLIs	-12.067 (-2.924)	-8.979 (-2.925)	0.0984	0.0522
Annual growth CLIs (x_t)	-14.709 (-2.924)	-8.954 (-2.925)	0.104	0.0505
Growth rate in IP (x_t)	-2.156 (-2.924)	-7.106 (-2.925)	0.102	0.0352
Standard HP output gap (x_t)	-2.540 (-2.924)	-9.346 (-2.925)	0.071	0.033
Fed funds rate	-1.410 (-2.924)	-4.763 (-2.925)	0.246	0.145
Annual growth in the DJ Euro stoxx 50 price index	-2.870 (-2.924)	-7.587 (-2.925)	0.168	0.0378
DJ Correction	-3.191	-7.935	0.143	0.0354

	(-2.924)	(-2.925)		
REER	-3.679 (-2.924)	-9.780 (-2.925)	0.174	0.0267
NEER	-3.799 (-2.924)	-9.771 (-2.925)	0.175	0.0243
grM3_gap	-1.977 (-2.924)	-7.352 (-2.925)	0.589	0.0957

Note:

1. DF-GLS refers to the Elliott et al (1996) efficient test for an autoregressive unit root similar to an (augmented) Dickey-Fuller "t" test, as but has the best overall performance in terms of small sample size and power. DF-GLS hypothesis: H0 is a unit root, HA is stationarity.
2. KPSS refers to the Kwiatkowski, Phillips, Schmidt, Shin test for stationarity of a time series. This test differs from those in common use by having a null hypothesis of stationarity. This test is complementary to other tests such as DF-GLS, Dickey-Fuller and Phillips-Perron; being often used in conjunction with those tests to investigate the possibility that a series is neither I (1) nor I (0). KPSS test hypothesis: H0 is stationarity, H1 is a unit root.
3. Fed funds rate becomes stationary only after the third differentiation (KPSS test statistic: 0.0174); For the KPSS test the maximum lag order was chosen automatically (maxlag=3); and for the DF-GLS the maximum lag order chosen is one (maxlag= 1).

Annex A4: Endogeneity test

	Sargan-Hansen statistics (Chi-sq(1) P-value)		
variables \output gap measures	HP output gap	%IP	CLI
Inflation (gap)	0.853 (0.3556)	3.076 (0.0795)	3.444 (0.0635)
output (gap)	0.684 (0.4084)	0.338 (0.5612)	3.913 (0.0479)

Note: Endogeneity tests employed was implemented by STATA after ivreg2, which is similar to C statistics defined as the difference of two Sargan-Hansen statistics: one for the equation with the smaller set of instruments, where the suspect regressor(s) are treated as endogenous, and one for the equation with the larger set of instruments, where the suspect regressors are treated as exogenous. ***Under the null hypothesis (H0) the specified endogenous regressor(s) can actually be treated as exogenous***, the test statistic is distributed as chi-squared with degrees of freedom equal to the number of regressors tested. Under conditional homoskedasticity, this endogeneity test statistic is numerically equal to a Hausman test statistic.

Annex A5: Tests for heteroskedasticity

Tests\ outputgap measures	HP output gap		IP%		CLI	
	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value
Pagan-Hall general	16.797	0.0049	22.045	0.0005	20.418	0.0010
Pagan-Hall test w/assumed normality	27.208	0.0001	37.223	0.0000	39.711	0.0000
White/Koenker nR2	17.545	0.0036	23.151	0.0003	21.882	0.0006
Breusch-Pagan/Godfrey/Cook-Weisberg	29.096	0.0000	39.062	0.0000	47.009	0.0000

Note: these are standard tests designed to detect any linear form of heteroscedasticity. Under the null hypothesis the error variances are all equal.

Annex A6: Serial correlation test

Test\ outputgap measure	IP%	
	t-statistic	p-value
Cumby-Huizinga test	0.12059892	0.728386

Note: H0: errors non-autocorrelated at order 1; Cumby-Huizinga test is "*especially attractive because it can be used in three frequently encountered cases where alternative such as the Box-Pierce test, Durbin's h test and the Breusch-Godfrey test are not applicable. One of these cases is the presence of endogenous regressors, which renders each of these tests invalid. A second case involves the overlapping data commonly encountered in financial markets where the observation interval is shorter than the holding period, which requires the estimation of the induced moving average (MA) process. The Cumby-Huizinga test avoids estimation of the MA process by utilizing only the sample autocorrelations of the residuals and a consistent estimate of their asymptotic covariance matrix. The third case involves conditional heteroskedasticity of the regression error term, which is also handled without difficulty by the Cumby-Huizinga test*"[14].

[14] http://fmwww.bc.edu/repec/bocode/i/ivactest.html

Annex A7: CROSS-CHECKED RESULTS; ESTIMANTES OF TR IN THE EURO AREA -1994:01-2011:12 – OTHER ESTIMATORS.

	OLS			LMIL		
	HP output gap	%IP	*CLI*	*HP output gap*	%IP	*CLI*
β_π	-0.0016 (0.024)	0.0311 (0.020)	0.057** (0.019)	0.052 (0.051)	0.0792* (0.032)	0.106*** (0.032)
β_x	4.007*** (0.748)	0.0173*** (0.003)	0.0355** (0.010)	2.835* (1.267)	0.0149*** (0.0034	0.0310*** (0.009)
ρ	0.969*** (0.009)	0.979*** (0.008)	0.985*** (0.010)	0.978*** (0.009)	0.989*** (0.008)	0.987*** (0.009)
α	0.0733* (0.024)	0.0225 (0.029)	0.016 (0.029)	0.051 (0.029)	0.0042 (0.029)	0.0151 (0.032)
N	209	209	209	198	198	204
j-test (p-value)	NA	NA	NA	8.544 (0.014)	0.331 (0.847)	4.463 (0.107)
AIC	-117	-123	-110	-132	-144	-115
BIC	-103	-110	-96.92	-119	-131	-102
RMSE	0.181	0.177	0.182	0.170	0.165	0.179
adj. R^2	0.987	0.988	0.988	0.987	0.987	0.986

Note:

1. $i_t = \alpha + \beta_\pi (\pi_{t+6} - \overline{\pi}) + \beta_x x_{t+3} + \rho i_{t-1} + \varepsilon_t$
2. Standard errors in parentheses. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.
3. AIC and BIC stands for the Akaike and Schwarz information criteria, respectively-the lower their value , the better the model; RMSE stands for root mean square error which measures the dispersion in the error term.
4. **Standard HP output gap** stands for t the difference between the logarithm of the annual growth IP index and its HP trend; **%IP** stands for the annual growth rate of the Industrial production index; and **CLI** for the annual growth rate of the amplitude adjusted composite leading indicator (CLIs) of the OCDE.
6. The j-test stands for the Sargan-Hansen test, a test of overidentifying restrictions. The joint null hypothesis is that the instruments are valid instruments (uncorrelated with the error term). The J statistic is consistent in the presence of heteroskedasticity and (for HAC-consistent estimation) autocorrelation. A rejection casts doubt on the validity of the instruments.

Annex A8: CROSS-CHECKED RESULTS; ESTIMANTES OF TR IN THE EURO AREA -1999:01-2011:12 – DIFFERENT SAMPLE.

Estimators	GMM
β_π	0.0889* (0.0439)
β_x	0.0132* (0.0062)
ρ	0.988*** (0.0124)
α	0.00373 (0.0298)
N	150
j-test (p-value)	1,106 (0.5753)
AIC	-156
BIC	-145
RMSE	0.1394
adj. R^2	0.988

Note: See note on Annex A7; except that the output gap is measured by the annual growth rate in the industrial production index (%IP).

Annex A9: CROSS-CHECKED RESULTS; ESTIMANTES OF TR IN THE EURO AREA -1994:01-2011:12. EXCLUD EXPECTED REALIZED OUTPUT GAP AS REGRESSOR.

	OLS	GMM			LMIL		
	#	*HP output gap*	%IP	*CLI*	*HP output gap*	%IP	*CLI*
β_π	0.0924*** (0.022)	0.125*** (0.035)	0.163*** (0.031)	0.150*** (0.030)	0.155*** (0.025)	0.181*** (0.025)	0.167*** (0.028)
ρ	0.978*** (0.008)	0.977*** (0.009)	0.978*** (0.010)	0.976*** (0.009)	0.977*** (0.009)	0.976*** (0.009)	0.976*** (0.009)
α	0.0456* (0.023)	0.049 (0.027)	0.048 (0.031)	0.0592* (0.025)	0.0514* (0.024)	0.0570* (0.025)	0.0539* (0.024)
N	209	204	204	204	204	204	204
j-test (p-value)	NA	3.853 (0.146)	5.611 (0.061)	5.784 (0.056)	5.922 (0.052)	8.506 (0.014)	8.805 (0.012)
AIC	-93	-98	-86	-91	-89	-78	-84
BIC	-83	-88	-76	-81	-79	-68	-74
RMSE	0.191	0.188	0.193	0.191	0.192	0.197	0.194
adj. R^2	0.986	0.985	0.984	0.984	0.984	0.983	0.984

Note:

1. See note on Annex A7, except that now the is equation is as follows : $r_t = {}_\alpha + \beta_\pi (\pi_{t+6} - \overline{\pi}) + \rho r_{t-1} + \varepsilon_t$

2. When implementing the GMM and LMIL , the output gap is included in the set of instrumental variables to reflect the ECB monetary policy overriding mandate which does not respond directly to economic activity, but its effects on inflation

Annex A10: ESTIMATES OF TR IN THE EURO AREA: 1994:01-2011:12 –ADDITIONAL EXPLANATORY VARIABLES

GMM											
	Fed funds rate	Annual growth in the DJ Euro stoxx 50 index	DJ Corr.	REER	NEER	grM3_gap	interest rate spread	GR_Risk Premiun	PT_Risk Premium	GR and PT risk premium	
β_π	0.107** (0.034)	0.0895* (0.040)	0.0766 (0.046)	0.0943* (0.039)	0.0946* (0.039)	0.0810* (0.034)	0.0660** -0.0214	0.097 (0.058)	0.132 (0.069)	-0.0103 (0.041)	
β_x	0.0040 (0.006)	0.0079 (0.008)	0.0136 (0.009)	0.0144** (0.005)	0.0146** (0.005)	0.0158** (0.005)	0.0167** (0.004)	0.0049 (0.007)	0.0001 (0.008)	0.0216*** (0.006)	
β_γ	0.0445*** (0.012)	0.002 (0.001)	0.000 (0.001)	0.003 (0.003)	0.003 (0.003)	-0.003 (0.006)	-0.011 (0.013)	-0.003 (0.006)	-0.007 (0.014)	-0.0759** (0.025)	0.147*** (0.042)
ρ	0.937*** (0.020)	0.987*** (0.010)	0.988*** (0.010)	0.984*** (0.010)	0.985*** (0.010)	0.989*** (0.008)	0.984*** (0.011)	0.962*** (0.028)	0.950*** (0.032)	0.989*** (0.023)	
α	0.025 (0.029)	0.002 (0.031)	0.007 (0.034)	0.018 (0.036)	0.019 (0.037)	0.005 (0.028)	0.030 (0.051)	0.032 (0.057)	0.043 (0.065)	0.0251 (0.056)	
j-test (p-value)	2.945 (0.229)	3.322 (0.190)	2.217 (0.330)	1.894 (0.388)	1.878 (0.391)	3.087 (0.214)	1.732 (0.421)	0.4569 (0.345)	1.567 (0.457)	2.686 (0.261)	
N	198	198	198	198	198	198	198	47	47	47	
adj. R^2	0.988	0.987	0.987	0.987	0.987	0.987	0.988	0.990	0.990	0.992	

Note:

1. $i_t = \alpha + \beta_\pi(\pi_{t+6} - \overline{\pi}) + \beta_x X_t + \beta_\gamma Z_t + \rho i_{t-1} + \varepsilon_t$,
2. Standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$;
3. The output gap measure implemented refers to the annual growth in the industrial production index;
4. The DJ Corr. refers to the difference between the annual changes in the DJ Euro Stoxx 50 and the annual change in the IP index, which allow to measure the growth in the stock prices not explained by real growth;
5. The exchange rates, both Real effective (REER) and Nominal effective (NEER), are measure as annual change rates; grM3 refers to annual growth rate of the monetary aggregate (M3); grM3_gap refers to the difference between the annual growth of the monetary aggregate (M3) and the reference value (4½%) set by the ECB; interest rate spread refers to the difference between the Euro area 10-year Government bond yield and 3-month euribor;
6. GR and PT risk premium refers to a proxy of sovereign risk of Greece and Portugal measured by the difference between 10-year government bond (Greece, Portugal) and 10-year government bond (Germany).When considering the inclusion of sovereign risk, the sample period ranges from August 2007 to December 2011. The risk premium is only significant from the onset of the subprime crisis and when both countries risk premiums are considered in the equation simultaneously.