THE MONETARY POLICY RULES IN EUROPE: HETEROGENEITY AND COMMON PATTERNS

Borek Vasicek

Documents de Recerca del Programa de Doctorado en Economía Aplicada
Universitat Autònoma de Barcelona

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Departament d'Economia Aplicada
Universitat Autònoma de Barcelona
E-08193 Bellaterra (Cerdanyola del Vallès)

www.ecap.uab.es

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Abstract:

The objective of this study is the empirical identification of the monetary policy rules pursued in individual countries of EU before and after the launch of European Monetary Union. In particular, we have employed an estimation of the augmented version of the Taylor rule (TR) for 25 countries of the EU in two periods (1992-1998, 1999-2006). While uniequational estimation methods have been used to identify the policy rules of individual central banks, for the rule of the European Central Bank has been employed a dynamic panel setting.

We have found that most central banks really followed some interest rate rule but its form was usually different from the original TR (proposing that domestic interest rate responds only to domestic inflation rate and output gap). Crucial features of policy rules in many countries have been the presence of interest rate smoothing as well as response to foreign interest rate. Any response to domestic macroeconomic variables have been missing in the rules of countries with inflexible exchange rate regimes and the rules consisted in mimicking of the foreign interest rates. While we have found response to long-term interest rates and exchange rate in rules of some countries, the importance of monetary growth and asset prices has been generally negligible.

The Taylor principle (the response of interest rates to domestic inflation rate must be more than unity as a necessary condition for achieving the price stability) has been confirmed only in large economies and economies troubled with unsustainable inflation rates. Finally, the deviation of the actual interest rate from the rule-implied target rate can be interpreted as policy shocks (these deviation often coincided with actual turbulent periods).

Keywords: Monetary Policy, Monetary Policy Rules, Taylor Rule, European Monetary Union, Panel Data

JEL Classification: E52, E58

1. Introduction

In the last decades, two important (and mutually related) tendencies in the monetary policy conduct have been observed: a promotion of central bank independence and a shift from discretional to rule-based policies.[1] Most central banks in developed countries have consequently adopted some interest-rate arrangement, where the short-term interest rates was a main policy instrument. Thereby the monetary policy rule has been usually understood being an interest-rate rule, linking the interest rate to a set of variables that are considered by the monetary authority when adjusting the instrument.

An intensive research effort in the area of empirics of monetary policy rules started in the 1990's with the seminal paper of Taylor (1993). The empirical studies have consequently sprawled out to describe the monetary policy practice in different countries. The results of these studies are generally hard to compare because of the differences in the model specification, data or estimation methods used.

Our objective is an empirical identification of the interest rate rules that have been pursued by monetary authorities in countries of the European Union before and after the launch of EMU. In particular, we have estimated an augmented version of the Taylor rule (TR), using data of the current 25 EU members.[2] In the pre-EMU period (1992-1999) we have estimated an individual policy rule of each country of EU-15. In the second period (1999-2006) we have carried out a common estimation with data of 12 EMU countries to identify the policy rule of the ECB[3] and individual estimation for each of the present 13 EU member outside of the euro area.

At the very beginning it is fair to admit that the results are conditioned (as for most applied studies) by our subjective choice of the functional form, relevant variables (their actual measures) and the estimation method employed. Therefore, we have not aspired to present the actual rule of each central bank but rather to reveal the way in which the short-term interest rates, as the policy instrument of modern central banks, responded to the main macroeconomic variables. The rest of the paper is organized as follows. The next section reviews some of the relevant empirical studies and points to possible limitations of this empirical approach. In section 3, we discuss the model specification and the estimation method. In Section 4, we present our dataset and the results of basic analysis of the time series. Section 5 contains all the estimation results. Section 6 concludes and suggests some possible extensions.[4]

[1] The rational-expectations revolution and the literature on time-consistent policy represented the principal theoretical inspirations for the monetary policy rules.
[2] We have not considered Bulgaria and Rumania that entered the EU in 2007.
[3] We will assume that Greece joined the EMU in 1999, which is unlikely to influence in a considerable the results way.
[4] All the estimations have been performed by Eviews 5.

2. Survey of the related empirical research

The idea of empirical confirmation of monetary policy reaction function (monetary policy rule) appeared for the first time in Dewald and Johnson (1963). Various empirical studies appeared since then, especially for the US. An important breakthrough was a paper presented by Taylor (1993). The author, using the historical evidence on the decisions of Federal Open Market Committee (FOMC)[5] between 1987 and 1992, identified a very simple form of the FED policy rule. The federal funds rate depends linearly on the deviations of the inflation rate from the target (variable of price stability) and the output from its potential (variable of economic activity). Clarida et al. (1998) proposed augmentation of this Taylor rule that enable it to capture the interest-rate setting in the main economies (interest-rate smoothing, forward-looking nature of the rule, inclusion of additional variables).

The establishment of EMU represented a challenge to identify empirically the policy rule of the European Central Bank (ECB). Most of these studies have used aggregated data that are likely to neglect the existing dispersion of main variables among the EMU members. Early studies used usually meta-data of artificial euro area for the period preceding 1999 (e.g. Gerlach and Schnabel, 2000). The availability of data permitted to study the actual policy rule of the ECB only recently (Fournans and Vranceanu, 2004, Fendel and Frenkel, 2006).

The empiric research for the new 10 EU members has been very limited (Maria-Dolores, 2005). The reasons are several (worse quality of the data, frequency of shock related to the economic transition in the 1990´s etc.). There have been also very few studies of larger samples of countries (one exception is Eleftheriou et al., 2006). Ruth (2004) explored in this context the panel data estimation techniques that permits to capture both country-specific and common effects.

The validity of the empirical monetary policy analysis is subject to various limitations. They come generally from two sources: the historic data, which are often an imperfect approximation of the relevant information actually used for policy decisions (Orphanides, 2001) and the structure of the model that can never represent entirely the reality. Recently there have been given arguments for non-linearity of the rules (Dolado et al., 2005).

The present study features the multi-country focus, it uses the cross-sectional dimension when it is reasonable and includes some countries that have not been focused by this research. The potential problem of data uncertainty is addressed by different measures and

[5] FOMC is the main body of the FED, deciding about its monetary policy.

transformations of a single variable the model uncertainty is reflected by means of different model specifications as well as various estimation methods.[6]

3. Model Specification and Estimation Method

The original Taylor rule in an estimable form can be written:

$$i_t^* = \alpha + \beta\pi_t + \gamma y_t + \varepsilon_t \qquad (1)$$

where the constant term α (contains the real equilibrium exchange rate and the inflation target), π_t is the inflation rate, y_t is the output gap and ε_t is the error term. While the equation (1) has been estimated as a first approximation, we have consequently allowed to reflect **the interest-rate smoothing** by means of a partial adjustment mechanism:

$$i_t = \rho i_{t-1} + (1-\rho) i_t^* + \upsilon_t \qquad (2)$$

where the actual interest rate i_t is a combination of the target interest rate i_t^* and the lagged value of the interest rate (usually one period) i_{t-1} (ρ is the smoothing coefficient). As many of the countries in the sample are small open economies, we have also included additional variables (representing the external constrains) to get **the augmented Taylor rule**:

$$i_t = \rho i_{t-1} + (1-\rho)\left(\alpha + \beta\pi_{t+s} + \gamma y_{t+k} + \delta x_{t+m}\right) + \upsilon_t \qquad (3)$$

While we have allowed this rule to be either backward- ($s \le 0$) or forward-looking ($s \ge 0$) in inflation π_{t+s}, the output gap y_{t+k} and the additional variables x_{t+m} (exchange rate, asset prices, monetary growth and long-term interest rate) have always entered in a present or a past values ($k \le 0, m \le 0$). In all cases we have been interested in the long-term coefficient that could be calculated from the short-term estimated coefficients (once adjusted for the smoothing parameter ρ).

The Taylor principle postulates that β shall be higher than unity, meaning that the central bank must increase the nominal interest rate more than the inflation increase in order to achieve an increase of the real interest rate (therefore effectively fight the inflation and stabilize the price level).[7] The compliance with this principle assures the uniqueness of the equilibrium and both the price and nominal interest rate determinations in stochastic general equilibrium models of closed economy (Clarida et al., 2000). Its interpretation for open economies is less straightforward because of the exchange rate channel. The viability of the Taylor principle in theoretic models of small economy depend on the assumption made about the intensity of the

[6] It is beyond the scope of our study to consider the possibility of rule asymmetry. Therefore, our estimated rules should be always understood as average rules in place for the estimation period.

pass-through effect, in what currency aree set the prices of imported goods, or what price index is considered by the monetary authority (Linnemann and Schabert, 2006).

Our estimation strategy has followed the logic of starting with a simple specification of the rule towards a more complex one and starting with a basic estimation method towards a more robust one. The rules for different countries have been estimated on a common base to make them easily comparable (same estimation periods, measures of variables etc.). At the same time we have allowed for a limited degree of heterogeneity in rule of different countries (the presence of interest rate smoothing, the timing of some variables, and the inclusion of additional regressors). On the other hand, we have not used country-specific temporal dummies in order to improve the fit of the rule[8] but rather used the deviation from the rule (the residual series) for the identification of the monetary policy shocks.

We have estimated first off the same specification for all the countries by OLS: 1. the simple backward-looking Taylor rule (1), 2. the same specification with interest rate smoothing (2) and 3. the rule augmented with foreign interest rate (3).[9]

Recognizing that countries that are similar and geographically close can be exposed to common external shocks, we have reformulated the previous analysis as a system of simultaneous equations and linked them together by their error terms. This system was consequently estimated by Seemingly Unrelated Regression method (SUR) that make used of contemporaneous residual correlation to gain efficiency (compared to individual estimations by OLS). This system allowed us to test the coefficient homogeneity across the countries by the Wald test.

Finally, we have pursued estimation by GMM to get the preferable specification for each country and period. This method permits that some exogenous variables, in particular inflation, enter in expected value (forward-looking rule) and eliminates possible simultaneity bias. We have used 2 lags of endogenous and exogenous variables of each specification as instruments. The weighting matrix was chosen in accordance with the Newey and West (1997) covariance estimator, which is robust to the presence of both heteroskedasticity and autocorrelation of unknown form (HAC Consistent Covariances). Because we have always had more instruments than parameters to estimate, we were able to perform the Sargan test for overidentifying restrictions to confirm the overall validity of the model.

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[7] Clarida et al. (1998) and Taylor (1999) showed that the FED's monetary policy did not comply during the 1960´s and 1970´s with this principle, which was likely the reason for persisting inflation in that period.
[8] The country-specific time dummies have been used by Clarida et al. (1998) and Eleftheriou et al. (2006).
[9] We have tested the autocorrelation by means of Durbin-Watson (DW) and Breusch-Godfrey Lagrange multiplier tests. We report only DW statistic in the results, which is not accurate in the model with lagged dependent variable. However, even in this case the values of DW statistics are illustrative.

For the identification of monetary policy rule of the EMU (1999-2006) we have used individual time series of the 12 countries, pooled them together and estimated the ECB rule in a panel setting.[10] The dynamic panel model of the augmented Taylor rule (3) can be written:

$$i_{it}^{*} = \rho i_{i,t-1} + (1-\rho)\left(\alpha + \beta\pi_{i,t+s} + \gamma y_{i,t+k} + \delta x_{i,t+m}\right) + \upsilon_{it} \qquad (4)$$

where $i = 1,...,N$ is the cross-section dimension, $t = 1,...,T$ is the time dimension and $\upsilon_{i,t}$ follows the one-way error component model:

$$\upsilon_{it} = \mu_i + \zeta_{it} \qquad (5)$$

and $\mu_i \sim IID(0,\sigma_\mu^2)$ represent the cross section fixed effect and $\zeta_{it} \sim IID(0,\sigma_\zeta^2)$ is the error term.

There are some additional econometric issues related to dynamic panels. It has been shown that dynamic panel with fixed effect estimated by traditional methods (OLS) gives biased results because of the correlation between the lagged dependent variable and the error term (Nickel, 1981). Therefore, we have performed specific GMM estimation for dynamic panel (Arellano and Bond, 1991 or Arellano and Bover, 1995), consisting in the transformation of the model (differentiation or forward orthogonal differences) and in the expansion of the instruments. We have also combined the estimation of the transformed equation with untransformed instruments (in levels, not in differences/orthogonal deviations) in order to obtain estimates with the smallest variances (Arellano, 1989). We have used for the panel estimation up to four lags of the endogenous and exogenous variables of each specification as instruments.

4. Data and Basic Time-series Analysis

We have used quarterly data for the analysis; for the original 15 EU members from 1992 to 2006, and for the 10 new EU members from 1999 to 2006. The principal sources were **OECD** (Economic Outlook and Main Economic Indicators), **Eurostat** and the **European Central Bank** (Statistic Data Warehouse). Some data, especially for the non-OECD members, were obtained additionally from the national central banks and national statistic offices.

The inflation rate is measured as a change in harmonized consumption price index (HCPI, calculated by Eurostat) with respect to the same quarter in the previous year. **The short-term interest rate** is an average 3 month interbank interest rates (for robustness check, overnight interbank interest rate has been used). **The long-term interest rate** is government bond yield with 10 years maturity. **Output gap** is the difference between the logarithm of the current

[10] The existence of a single monetary policy (single interest rate) in the Euro area implies a single reaction

value of GDP (for robustness check, industrial production index has been used) and the trend value obtained by HP filter. **The exchange rate change** is represented by the change of real effective exchange rate index (REER) with respect to the same quarter in the previous year, and by the deviation from the sample average. The nominal exchange rate of euro against the US dollar has been additionally used in the panel analysis for the EMU. **The monetary growth** is the change in seasonally adjusted M3 aggregate (common definition by Eurostat) with respect to the same quarter in the previous year. **The asset prices change** is the change in the share index of the local stock exchange with respect to the same quarter in the previous year and with respect to the last quarter.

4.1 Testing for Unit Roots

The first studies on the monetary policy rule were conducted often under untested assumption that all the key variables are stationary. Some recent contributions found that some of the main variables in the rule (inflation, interest rates) were integrated (Gerlach-Kristen, 2003, Ruth, 2004).

We have firstly employed the common **single unit root tests** to identify the type of the generating process of the time series, in particular Augmented Dickey-Fuller test (ADF), Philips-Perron (1988) test (PP) and Kwitkowski-Phillips-Schmidt-Shin (1992) test (KPSS). The very construction of most variables implies their stationarity that has also been confirmed by all tests. The results for the inflation rates, short-term and long-term interest rates have been more ambiguous (depending on the test used and the assumption made about the presence of the constant term and the deterministic trend in the tested equation).[11]

It has been known for some time that the single-equation unit root tests have low power in short samples (we have at most 60 observations). Therefore we have made use of the panel structure of our dataset (25 cross sections) and employed the novel panel unit root tests using the cross-sectional variation to achieve a higher power. We have employed 6 **panel unit root tests**.[12] LLC (Levin, Lin and Chu, 2002), Breitung (2000) and Hadri (2000) tests assume that the unit root process is the same across all cross-sections. IPS test (Im, Pesaran and Shin, 2003) and two Fischer-type tests: Fischer ADF test and Fisher PP test (Maddala and Wu, 1999 and Choi, 2001) are less restrictive and allow that the individual processes differ.

The stationarity of the output gap, exchange rate change, asset price change and change of money stock has been confirmed, as it was expected, by all the tests. All these tests additionally confirmed the stationarity of the inflation rates and both short- and long-term interest rates

function of the ECB.

[11] We do not report these results here.

when we have assumed there was neither individual intercept nor deterministic trend. We believe that these results also correspond to economic logic because if inflation rates or interest rate were integrated processes they could take negative values for infinitely long periods, which is not consistent with the reality. Given these results, we have employed in all cases the estimation in levels, which is also common in most of the studies.[13]

4.2 Testing the Granger Causality in the Interest Rates

Consequently, we have tested **the Granger causality testing** in the interest rates. Although the short-term interest rates of different countries in our sample are highly correlated, it does not guarantee any causal relationship between one and another. Therefore we want to see, whether the interest rate of dominant country (Germany, the US and the euro area) should be reasonably included in the estimated policy rule of other countries.

In the period **1992-98** we have tested whether the German interest rate Granger-caused the interest rates of the remaining 14 EU members (it was confirmed for all EU members except Italy, Portugal, the UK) and whether the US interest rate Granger-caused the interest rates of Germany and the UK (confirmed). In the period **1999-2006** we have tested whether the euro interest rate Granger-caused the interest rates of the countries outside the euro area (confirmed only for all non-EMU member except Cyprus, Hungary and the UK) and whether the US interest rate Granger-caused the interest rates of the euro area and the UK (confirmed). These results are in most cases consistent with the common wisdom and confirms that the foreign interest rates can be reasonably included as exogenous variables in the estimated policy rule.

Finally, we have tested whether the long-term interest rate Granger-caused the short-term interest rates within one country (currency area). It was confirmed in the period **1992-98** only for Denmark, France, Italy and Spain and in the period **1999-2006** only for the Czech Republic, Estonia, Malta, Sweden and the UK. For the 12 countries within EMU we have tested whether the long-term interest rates of the EMU members (different but highly correlated) Granger-caused the euro short-term interest rates (common for all), which was confirmed for all EMU members except Greece. Consequently, the long-term interest rates that are believed to contain information about inflation expectations were included as exogenous variables in the estimated policy rules of some countries.

[12] All the tests assume a cross-sectional independence.

[13] Although the panel unit root tests have confirmed the stationarity of most of the variables, some of the individual time series might appear in a shorter period non-stationary. Therefore, it is possible that some of the static rules we have estimated first could really be spurious regressions. However, once we augmented the dynamic structure of the equation, the serial correlation of the residuals always accompanying the spurious regressions disappears.

5. Estimation Results

5.1 Pre-EMU Period 1992-1998

The OLS estimation results of a simple static backward-looking TR (1) have presented strong serial correlation for all countries except Germany. This is not surprising as the existence of simple TR was previously confirmed only large closed economies.[14] Once we introduced the partial adjustment mechanism (2), the autocorrelation disappeared but the coefficients of relevant variables, in particular inflation β, turned out to be not significant. In the next step, we have augmented the TR by the foreign interest rate as an additional exogenous variable. In most cases, either the coefficient of domestic lagged interest rate variable ρ or the one of the foreign interest rate δ are statistically significant because of the multicollinearity between the lagged domestic interest rate and foreign interest rate. In this case, it is complicated to distinguish between the relative strength of these two effects. Given the overall implausibility of these results we do not report them.

Consequently, we have applied the SUR method to the system of simultaneous equations to exploit the contemporaneous residual correlation (due to common shock or common ommited variables) between the cross sections. The results of SUR estimation of the individual backward-looking TL with the interest rate smoothing are reported in Table 1.[15]

Table 1.: SUR estimates of backward-looking TR with interest-rate smoothing for EU-15

	α *(constant)*	β (π_t)	γ (y_{t-1})	ρ (i_{t-1})	R^2	*DW*
AUT	**0.51** (0.14)	0.04 (0.04)	**0.23** (0.05)	**0.86** (0.03)	0.98	1.29
BEL	0.06 (0.15)	**0.20** (0.07)	0.04 (0.02)	**0.88** (0.04)	0.95	1.88
DEU	**0.31** (0.10)	**0.15** (0.04)	**0.18** (0.05)	**0.84** (0.03)	0.99	1.37
DNK	1.01 (0.77)	-0.17 (0.24)	**0.53** (0.08)	**0.89** (0.08)	0.86	2.37
ESP	0.10 (0.22)	**0.25** (0.11)	**0.23** (0.09)	**0.85** (0.06)	0.96	1.01
FIN	-0.01 (0.27)	**0.33** (0.15)	0.14 (0.11)	**0.89** (0.07)	0.93	1.73
FRA	**1.47** (0.49)	0.19 (0.17)	**0.67** (0.18)	**0.70** (0.10)	0.91	2.23
GBR	**1.04** (0.20)	**0.19** (0.06)	**0.28** (0.07)	**0.78** (0.05)	0.88	1.49
GRC	1.23 (0.85)	**0.19** (0.08)	-0.04 (0.05)	**0.78** (0.08)	0.97	1.38
IRE	1.84 (1.04)	**0.95** (0.40)	0.39 (0.31)	**0.52** (0.12)	0.50	1.53
ITA	-0.08 (0.43)	**0.61** (0.12)	0.12 (0.10)	**0.73** (0.08)	0.88	1.56
LUX	**0.54** (0.17)	**0.45** (0.08)	**0.06** (0.03)	**0.71** (0.04)	0.96	1.80
NLD	**0.25** (0.14)	**0.16** (0.05)	**0.19** (0.03)	**0.85** (0.02)	0.99	1.60
PRT	**0.11** (0.30)	**0.42** (0.14)	-0.10 (0.13)	**0.73** (0.07)	0.95	2.47
SWE	**3.34** (0.45)	**0.43** (0.07)	**0.81** (0.14)	**0.38** (0.08)	0.96	1.13

Note: Standard errors in parenthesis. The coefficients statistically significant at 5% in bold. DW is the Durbin-Watson statistic.

[14] We estimate this basic TR also with overnight interbank interest rate as a dependent variable (instead of 3 month interest rate) and with output gap calculated from industrial production (instead of GDP). The main results do not vary substantially.

[15] In the whole text we use the following abbreviations: AUT – Austria, BEL – Belgium, DEU – Germany, DNK – Denmark, ESP – Spain, FIN – Finland, FRA – France, GBR – the United Kingdom, GRC – Greece, IRE – Ireland, ITA – Italy, LUX – Luxembourg, NLD – the Netherlands, PRT – Portugal, SWE – Sweden.

Compared to the previous OLS estimation, we have found in many cases statistically significant reaction to inflation rate, which in long-term (when adjusted for the short-term interest rate smoothing) took values close to unity and in some cases even exceeded 1.5 (Belgium, Spain, Finland, Ireland or Italy). The reaction to the output gap has been also positive and significant. There is distinct heterogeneity of all the coefficients across the sample (homogeneity rejected in all cases by the Wald test).

Given the coefficient heterogeneity as well as the autocorrelation that has been still present for some countries in the previous results, we have abandoned the common specification of the policy rule for all countries and continued with an independent estimation for each country. We have used the GMM estimator. The example of the identification procedure that has been carried out for each country of EU-15 is given in Table 2.

Table 2.: GMM estimates of different specification of policy rule (example of Austria)

Austria	α *(const)*	β (π_{t-1},π_{t+1}^*)	γ (y_{t-2},y_{t-1}^*)	ρ (i_{t-1})	δ (i_t^{for})	ζ (x_{t-1},x_t^*)	R^2	*DW*	*J-sta*
BL	1.39 (1.26)	**1.57** (0.39)	**1.62** (0.46)				0.76	0.72	0.28
FL + SMT	**1.06** (0.20)	**0.28*** (0.13)	**0.54*** (0.12)	**0.68** (0.07)			0.98	0.95	0.55
FL + SMT + FIR	-0.10 (0.29)	**-0.28*** (0.13)	-0.08* (0.12)	**-0.55** (0.25)	**1.69** (0.31)		0.98	1.21	0.45
FL + FIR	**0.59** (0.09)	**-0.26*** (0.12)	**0.17** (0.05)		**1.01** (0.06)		0.99	1.13	0.83
FL + FIR + REER	**0.19** (0.09)	**-0.21*** (0.05)	**0.17** (0.04)		**1.05** (0.02)	**-0.06*** (0.01)	0.99	1.51	0.69
FL + FIR + SHI	**0.25** (0.11)	-0.12* (0.10)	0.04 (0.05)		**1.00** (0.06)	**-0.01*** (0.00)	0.99	1.10	0.69
FL + FIR + MA	0.31 (0.17)	**-0.47*** (0.08)	**0.15** (0.06)		**1.05** (0.04)	**0.13*** (0.05)	0.99	1.47	0.71
FL + FIR + LTIR	-0.98 (0.52)	**-0.39*** (0.10)	**0.04** (0.07)		**1.02** (0.04)	**0.27** (0.09)	0.99	1.41	0.84

Note: Standard errors in parenthesis. The coefficients statistically significant at 5% in bold. DW is the Durbin-Watson statistic. J-stat is the p-value of the overidentification test. Best rule is in bold. BL – backward-looking rule, FL – forward-looking rule, SMT – interest rate smoothing, FIR – foreign interest rate, additional variables *x*: REER - real effective exchange rate, SHI – asset prices, MA – monetary growth, LTIR – long-term interest rate.

First, we have estimated again the basic backward-looking TR (BL) (1) and consequently specified the rule as forward-looking in inflation (FL), introduced the interest rate smoothing (SMT) (2), and added the foreign interest rate (FIR). Of these four specification, we have chosen the one with the better fit and augmented it with additional variables x_{t+m} (exchange rate – REER, asset prices - SHI, monetary growth – MA, and long-term interest rate – LT-IR). The best rule adjusting to the data has been chosen from these 8 specifications on the base of a reasonability of the results, an overall fit, a lack of autocorrelation, and the compliance with the overidentifying restriction test. The rules with the best adjustment for each country are reported in Table 3.

Table 3.: GMM estimates of the best-adjusting policy rule for each country of EU-15

	α (const)	β (π_{t-1},π_{t+1}*)	γ (y_{t-2},y_{t-1}*)	ρ (i_{t-1})	δ (i_t^{for})	ζ (x_{t-1},x_t*)	R^2	DW	J-sta
DEU	**0.82** (0.32)	**0.60*** (0.17)	**0.43*** (0.13)	**0.55** (0.11)			0.97	1.64	0.75
GBR (REER)	**0.69** (0.22)	**0.27** (0.04)	**0.15*** (0.07)	**0.78** (0.04)		**0.04** (0.01)	0.89	1.98	0.68
AUT (REER)	**0.19** (0.09)	**-0.21*** (0.05)	**0.17** (0.04)		**1.05** (0.02)	**-0.06*** (0.01)	0.99	1.51	0.69
BEL	**-0.52** (0.18)	**0.46** (0.15)	**-0.21*** (0.08)		**0.95** (0.05)		0.96	1.74	0.82
DNK	-1.08 (0.71)	0.49 (0.36)	0.11* (0.17)	**0.58** (0.09)	**0.50** (0.09)		0.90	2.52	0.78
FIN (LTIR)	-1.47 (0.54)	-0.05 (0.11)	**0.34*** (0.09)	**0.48** (0.11)	**0.61** (0.20)	**0.19** (0.05)	0.95	1.60	0.96
IRE (MA)	-3.65 (1.51)	0.58 (0.48)	**1.08*** (0.17)		**1.95** (0.16)	**0.10*** (0.03)	0.73	0.98	0.51
NLD	-0.23 (0.38)	**0.38** 0.14	**0.24*** (0.10)		**0.84** (0.02)		0.99	1.61	0.90
ESP (LTIR)	**-0.97** (0.41)	0.05 (0.21)	**0.32*** (0.06)	**0.38** (0.09)	**0.35** (0.10)	**0.44** (0.13)	0.98	1.21	0.93
FRA (MA)	0.10 (0.27)	**1.02*** (0.11)	-0.02* (0.16)		**0.79** (0.03)	**0.09*** (0.02)	0.95	2.02	0.77
LUX	**0.83** (0.21)	0.32* (0.19)	**0.18*** (0.05)	**0.49** (0.11)	**0.27** (0.09)		0.97	2.06	0.80
ITA (REER)	0.05 (0.38)	**0.69*** (0.15)	**0.32*** (0.11)	**0.54** (0.06	**0.28** (0.07)	**0.04** (0.01)	0.93	1.90	0.90
SWE (REER)	**3.64** (0.38)	**0.49*** (0.15)	**1.35*** (0.11)		**0.55** (0.11)	**0.04** (0.01)	0.96	1.88	0.94
GRC (SHI)	-2.10 (1.25)	**0.49*** (0.10)	**-0.45*** (0.15)	**0.81** (0.09)		**0.05*** (0.01)	0.95	1.45	0.60
PRT (REER)	0.38 (0.41)	**0.90*** (0.27)	**-0.84*** (0.27)	**0.41** (0.15)		**0.21** (0.07)	0.94	2.13	1.00

Note: Standard errors in parenthesis. The coefficients statistically significant at 5% in bold. DW is the Durbin-Watson statistic. J-stat is the p-value of the overidentification test. Best rule is in bold. Additional variables *x*: REER - real effective exchange rate, MA – monetary growth, LTIR – long-term interest rate.

In principle we have identified **four different type of rules** marked by the importance of the foreign interest rate, and the countries are grouped in the Table 3. accordingly. The interest rate rules of **Germany** and **the UK** represented typical rules of large economies, where domestic variables played the major role and which resembles the original Taylor rule.

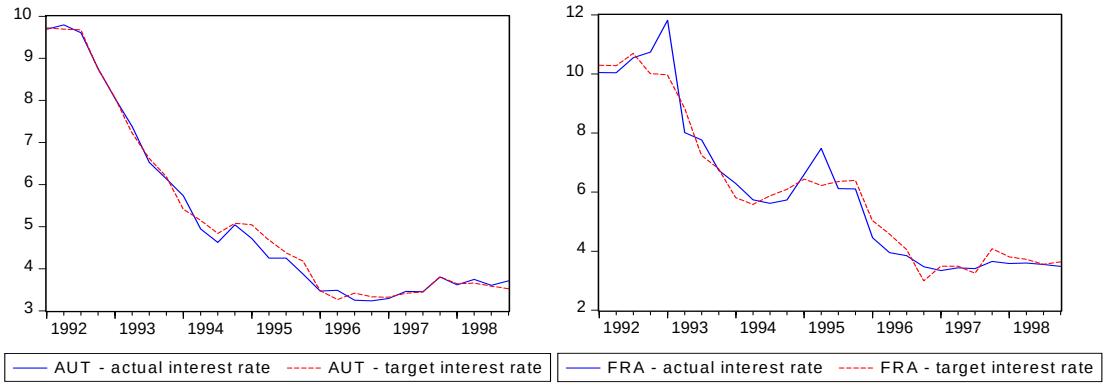
The countries in the second group (**Austria, Belgium, Denmark, Finland, Ireland,** and **the Netherlands**) seem to have followed the monetary policy of Bundesbank very rigidly. The response to the German interest rate is close to unity and the response to main domestic variables is very limited.

In the third group of countries (**France, Spain, Italy, Luxembourg and Sweden**) we have found positive reaction to the German interest rates, which is lower than unity (in the long-term) and the response to domestic variables is more substantial. Some of the rules are forward-looking in inflation.

In the countries of the last group (**Portugal** and **Greece**) we have not found any statistically significant reaction to the German interest rate and the interest-rate rules are defined in terms of domestic variables, in particular the inflation rate. The response to domestic inflation (that was during this period at significantly higher level than in other EU countries) is very strong and there is statistically significant but negative reaction to the output gap, which must be caused by some error of the construction of the variable.

The correlation of the actual interest rate with the target interest rate is very decent in all cases. However, in some countries we have found short periods of their significant deviation. These periods can be considered as monetary policy shocks. In Graph 1. we plot these series for Austria, which did not experience any periods of deviation from the rule (to our knowledge Austria was really not exposed to any turbulences during this period, and for France, where we can find two periods of significant deviation (1993 – crisis of the ERM).

Graph 1.: Target interest rate from the best rule and the actual one for Austria and France



5.2 EMU Period 1999-2006

5.2.1 The ECB Policy Rule

In the second estimation period we had to reformulate the problem for the 12 countries that had formed the EMU in 1999.[16] These countries ceased their autonomous monetary policies to a common authority – the European Central Bank (ECB). Therefore we have been searching for policy rule of the ECB. We have employed first as the previous studies a uniequational estimation with aggregated data of the euro area. The results are reported in Table 4. The preferred specification is forward-looking rule but we can see that the inflation coefficient β varies too much across the specifications.

Table 4.: GMM estimates of policy rule for the euro area based on aggregated data

	α *(const)*	β (π_{t+1})	γ (y_{t-2}, y_{t-1}^*)	ρ (i_{t-1})	δ (i_t^{for})	ζ (x_t)	R^2	*DW*	*J-sta*
ECB	**1.10** (0.39)	**-0.56** (0.21)	0.07* (0.11)	**0.92** (0.09)	**0.12** (0.02)		0.95	1.44	0.42
ECB (NER)	**0.35** (0.19)	**0.44** (0.16)	0.06* (0.05)	**0.35** (0.09)	**0.13** (0.02)	**-0.05** (0.01)	0.97	1.58	0.66
ECB (REER)	**0.53** (0.19)	**0.36** (0.15)	0.02* (0.05)	**0.37** (0.10)	**0.10** (0.02)	**-0.06** (0.01)	0.96	1.40	0.68
ECB (SHI)	0.07 (0.25)	0.07 (0.09)	0.07* (0.05)	**0.83** (0.05)	**0.06** (0.02)	**0.00** (0.00)	0.94	1.15	0.55
ECB (MA)	**1.90** (0.39)	**-0.66** (0.18)	0.28* (0.15)	**0.84** (0.09)	**0.16** (0.02)	**-0.06** (0.02)	0.95	1.32	0.73
ECB (LTIR)	**-0.70** (0.22)	0.01 (0.11)	0.00* (0.03)	**0.66** (0.05)	**0.14** (0.01)	**0.29** (0.03)	0.98	1.98	0.70

Note: Standard errors in parenthesis. The coefficients statistically significant at 5% in bold. DW is the Durbin-Watson statistic. J-stat is the p-value of the overidentification test. Best rule is in bold. Additional variables *x*: NER - nominal exchange rate EUR/USD, REER - real effective exchange rate, SHI – asset prices, MA – monetary growth, LTIR – long-term interest rate.

[16] We have assumed that Greece joined the EMU in 1999 instead of 2001 and confirmed the results are not significantly affected by this decision.

Consequently we have used the panel analysis instead with data of individual EMU countries. We believe that this focus actually better corresponds to the two-pillar monetary strategy of the ECB proposing large set of variables that are supposedly taken into about for monetary policy decision. The panel analysis has also important econometric advantages over the time-series regression with averaged variables (more observations and variability, elimination of multicollinearity, unequivocal stationarity of the panel etc.). However, the estimation of dynamic panel faces some other potential econometric problems that we have already briefly outlined. On this account, we have used not only various specifications of the model but also applied to each model specification various estimation methods. The results of different specification of the dynamic panel (4) are reported in Table 4. The estimation method is 2-step Arellano and Bover (1995) GMM estimator (forward orthogonal deviations transformation of the model) accompanied with untransformed instruments (in levels). The instruments are up to 4 lags of endogenous and exogenous variables of each specification.[17]

Table 5.: GMM panel estimates of policy rule for the euro area

Specification	α *(const)*	β (π_{t-1},π_{t+1}^*)	γ (y_{t-1},y_t^*)	ρ (i_{t-1})	δ (i_t^{for})	ζ (x_t)	R^2	*J-sta*
ECB		**0.28*** (0.02)	**0.01** (0.02)	**0.73** (0.02)	**0.12** (0.01)		0.90	0.15
ECB (LTIR)		**0.19*** (0.02)	**0.07** (0.03)	**0.68** (0.01)		**0.25** (0.01)	0.88	0.15
ECB (NER1)		**0.16*** (0.01)	0.03 (0.02)	**0.76** (0.01)		**-0.02** (0.00)	0.91	0.15
ECB (REER1)		**0.18*** (0.01)	0.01 (0.01)	**0.80** (0.02)		**-0.03** (0.00)	0.92	0.15
ECB (REER1)		**0.24*** (0.01)	0.00 (0.02)	**0.76** (0.02)	**0.07** (0.01)	**-0.01** (0.00)	0.92	0.15
ECB (REER1 +LTIR)		**0.27*** (0.02)	-0.02 (0.02)	**0.64** (0.02)	**0.12** (0.01)	**0.00** (0.00) **0.22** (0.02)	0.92	0.10

Note: Standard errors in parenthesis. The coefficients statistically significant at 5% in bold. DW is the Durbin-Watson statistic. J-stat is the p-value of the overidentification test. Best rule is in bold. Additional variables *x*: NER - nominal exchange rate EUR/USD, REER - real effective exchange rate, SHI – asset prices, MA – monetary growth, LTIR – long-term interest rate.

We have confirmed in the panel analysis that the ECB monetary policy rule is forward-looking. Compared to the analysis with aggregated data here we have obtained much more stable inflation coefficient β across its different specifications. The long-term coefficient is lower then unity (not in conformity with the Taylor principle) but there is similar response to the long-term interest rate that is believed to carry information about inflation expectations. The sum of both coefficients in long-term is above unity signaling that the ECB policy shall have stabilizing effect (the EMU can be considered as a large and closed economy and therefore the Taylor principle shall apply). There is not response to the economic activity as

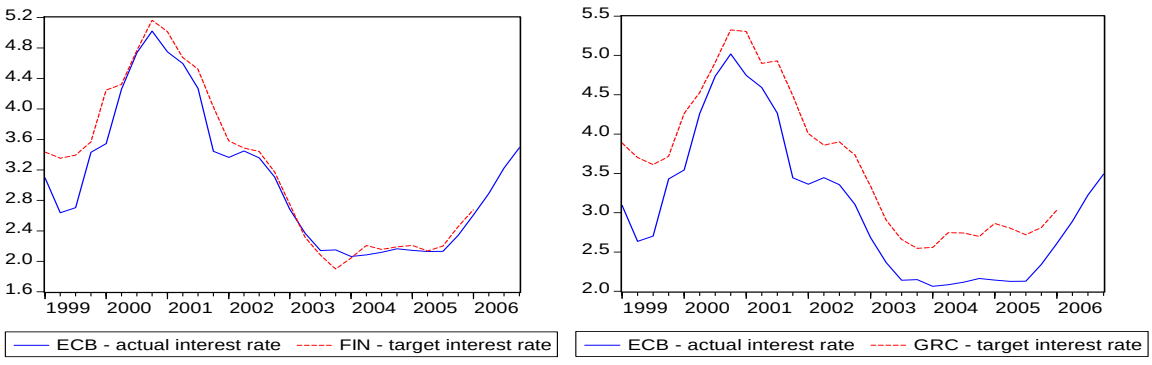
[17] These results of the same estimation with transformed instruments (by the forward orthogonal differences transformation) are noted by higher standard errors. However, Arellano (1989) proposed the previous approach being preferable. The estimation with 2-step Arellano and Bond (1991) estimator GMM (differentiation of the model) with both untransformed (in levels) and transformed (differentiated) instruments does not give substantially different results.

represented by the output gap and there are additionally small but significant responses to the US interest rate (positive) and to the exchange rate appreciation (negative, both for nominal and real effective exchange rate). We have also included the measures of monetary growth and asset prices but these variables were not statistically significant in any specification.[18] The irrelevance of output gap and the monetary growth is rather surprising, given the presence of specific economic activity goal and "the monetary pillar" in the ECB strategy.

The estimated policy rules can be used for so-called "counterfactual experiment". The previous studies usually substituted the aggregated data for the actual euro area into the estimated historic pre-EMU policy rule (of Bundesbank or an artificial euro area) to get the implied interest rate path. The comparison with the actual interest rate allowed to reject that the ECB followed the Bundesbank rule and confirmed that the ECB rule is rather similar to historic rule of artificial euro area.

We have used the logic of this experiment but substituted the data of individual EMU members into the estimated ECB rule for the same period (1999–2006). The idea is to see whether the actual euro interest rate path adjusts better to the rule-predicted interest rate path from the data of country than another. In the Graph 2 we plot the actual euro interest rate (3-month Euribor) and the implied one with data of Finland (representing the low inflation countries like Austria, Belgium or Germany) and Greece (similar path was obtained with Spanish or Portuguese data).

Graph 2.: Counterfactual experiment



At first glance, it is obvious that the fit is decent both countries (the correlation between the actual and the target series around 0.97 in all cases). Therefore, it can not be said that the ECB disregarded the developments in some country at all. However, we can see that while the actual interest rate has overlapped most of the time with the fitted series obtained from the Finish

[18] We do not report these results here. We have used the same measures of the variables as in previous sections. The information about monetary growth was available only for the whole euro area, therefore we used this as a common regressor.

data, it has been lower than the fitted values from the Greek data. Still it does not mean necessary that the ECB disregarded the inflation pressures in the latter group of countries but rather that the low-inflation countries represent major part of the euro area GDP and therefore weight more. Nevertheless, this policy-making might be to the detriment of the price stability in countries with systematically higher inflation rates, especially if the inflation differentials were to widen in the future.

5.2.2 Individual Policy Rules for Denmark, Sweden and the UK

The launch of Euro might have represented a structural change in monetary policy even in countries that did not adopt the common currency, notably in Denmark and Sweden, where the German interest rate entered the best specification of the policy rule in the previous period. The structural stability of the estimated policy of Denmark, Sweden and the UK has been rejected by the Chow breakpoint test therefore we estimated the rules separately for each period.

Graph 6.: GMM estimates of the best-adjusting policy rule for Denmark, Sweden and the UK

	α *(const)*	β (π_{t-1})	γ (y_{t-2}, y_{t-1}^*)	ρ (i_{t-1})	δ (i_t^{for})	ζ (x_t)	R^2	*DW*	*J-sta*
DNK	0.58 (0.50)	**0.39** (0.17)	**0.35*** (0.14)	**0.55** (0.12)			0.92	1.31	0.75
GBR (LTIR)	-1.46 (1.27)	**0.42** (0.15)	**0.55*** (0.16)	**0.63** (0.06)		**0.54** (0.20)	0.90	1.61	0.65
SWE (LTIR)	**-0.46** (0.13)	**0.12** (0.04)	**0.18*** (0.03)	**0.60** (0.05)		**0.33** (0.05)	0.97	1.40	0.54

Note: Standard errors in parenthesis. The coefficients statistically significant at 5% in bold. DW is the Durbin-Watson statistic. J-stat is the p-value of the overidentification test. Additional variable *x*: LTIR – long-term interest rate.

The monetary policy rules of these three EU member that did not joint the EMU in 1999 share certain similarities. All rules backward-looking with interest rate smoothing. The response of short-term interest rate to inflation rate is lower then unity in the long-term (but in case of Sweden and the UK is additionally very strong response to long-term interest rates that are believed to proxy for inflation expectation) and relatively strong response to output gap. For Denmark we found also similarly good fit for a rule containing the euro interest rate, where is in the contrary no response to domestic variables. This country would likely the least effected by the adoption of common monetary policy as its short-term interest rate has been very similar to the euro interest rate.

5.2.3 Individual Policy Rules for New 10 EU Members

For the estimation of the policy rules of the new 10 EU members, we have followed the same logic as previously in the analysis of individual policy rules of EU-15 (sect. 5.1), i.e. common approximation of the rules by OLS, SUR and detailed specification for each country by GMM.

The estimation of basic static backward-looking Taylor rule by OLS and SUR did not yield any reasonable results. The overall fit of the model is very low and there is a very strong serial correlation in all cases.[19] This problem has been solved by the introduction of the interest rate smoothing and the Euro interest rates as additional regressors. There are again important differences between the coefficient of different countries, reflecting without any doubt a very different nature of their exchange rate arrangement and, consequently different degrees of actual monetary policy autonomy.

To concretize the individual monetary policy rules of the 10 new EU members more precisely, we have again resumed a uniequational estimation by GMM for each country. The rules with the best adjustment for each country are reported in Table 7.[20]

Table 7.: GMM estimates of the best-adjusting policy rule for each country of EU-10

	α *(const)*	β (π_{t-1},π_{t+1}^*)	γ (y_{t-2},y_{t-1}^*)	ρ (i_{t-1})	δ (i_t^{for})	ζ (x_{t-1},x_t^*)	R^2	*DW*	*J-sta*
CYP	0.15 (0.19)	-0.04* (0.04)	-0.11* (0.07)	**0.82** (0.14)	**0.24** (0.09)		0.94	1.42	0.79
MAL	**0.73** (0.22)	-0.06 (0.06)	-0.01* 0.01	**0.52** (0.06)	**0.38** (0.05)		0.97	1.44	0.85
EST (REER)	1.01 (0.52)	**0.18*** (0.04)	0.03* (0.04)	**0.57** (0.02)	**0.33** (0.13)	**-0.10*** (0.03)	0.94	2.03	0.59
LAT (REER)	0.56 (0.56)	-0.04 (0.07)	0.03* (0.08)	**0.49** (0.05)	**1.08** (0.24)	**-0.13** (0.04)	0.79	1.61	0.69
LIT (REER)	1.50 (0.91)	**-0.06** (0.03)	0.07* (0.06)	**0.35** (0.03)	**1.20** (0.08)	**-0.14*** (0.05)	0.98	1.63	0.76
CZE	**-0.51** (0.09)	**0.15*** (0.06)	**-0.18** (0.05)	**0.62** (0.03)	**0.42** (0.08)		0.97	1.37	0.90
HUN	**2.35** (0.60)	**0.54*** (0.12)	**-1.62*** (0.47)	**0.92** (0.05)			0.89	1.35	0.85
POL (REER)	**-3.87** (1.04)	**1.11*** (0.25)	**-0.86*** (0.29)	**0.32** (0.14)	**1.99** (0.45)	0.03* (0.03)	0.98	1.54	0.57
SLO	0.12 (0.26)	**0.26*** (0.10)	0.01* (0.17)	**0.77** (0.08)			0.95	1.87	0.46
SVK	**1.06** (0.39)	-0.12 (0.09)	-0.31* (0.24)	**0.89** (0.06)			0.93	1.79	0.89

Note: Standard errors in parenthesis. The coefficients statistically significant at 5% in bold. DW is the Durbin-Watson statistic. J-stat is the p-value of the overidentification test. Additional variable *x*: REER - real effective exchange rate.

We have again identified **three different type of rules** marked by the importance of the foreign interest rate that has been linked to the degree of flexibility of the exchange rate regime and the countries are grouped accordingly in the Table 7.

The fist group is made of **Cyprus** or **Malta** that are very small economies with rigid exchange rate regimes. Both countries lack any autonomous monetary policy aimed at domestic developments. Their policy rules consist of mimicking the euro interest rate but in the short-term there their interest rates were very persistent (as demonstrated by the smoothing parameter ρ).

[19] These basic result are again confirmed when use output gap derived from industrial production (instead of GDP) and overnight interest rates (instead of 3 month interest rates).

[20] In all the test we use these abbreviations: CYP – Cyprus, CZE – the Czech Republic, EST – Estonia, HUN – Hungary, LAT – Latvia, LIT – Lithuania, MAL – Malta, POL – Poland, SLO – Slovenia, SVK – Slovakia.

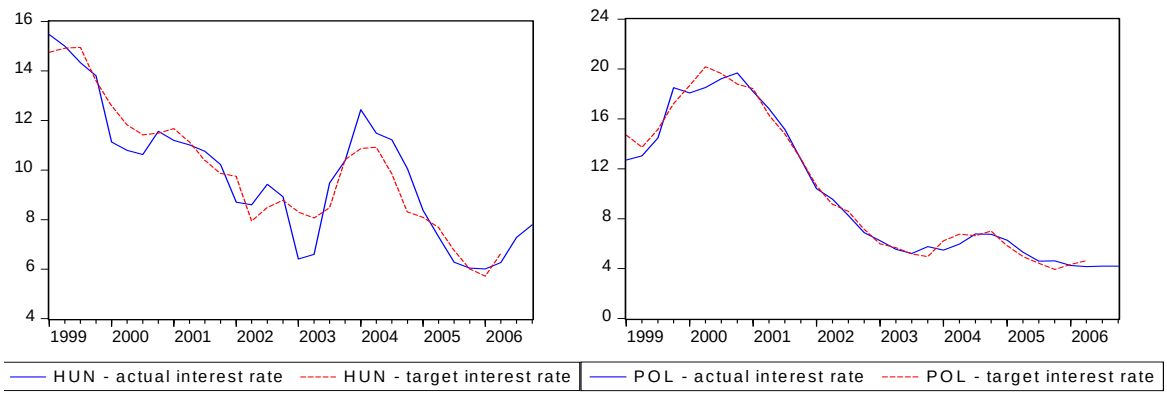
The Baltic countries (**Estonia, Latvia and Lithuania**) represent another homogenous group. They all maintained very inflexible exchange rate regimes. Therefore the policy rules are defined by strong response to the euro interest rate but this time also to other variables. In particular in all there countries has been confirmed a negative response to real effective exchange rate appreciation.[21]

The policy rules of the Central European inflation-targeting countries (**Czech Republic, Poland,** and **Hungary**) and of **Slovenia** share again similar features. All the rules are forward-looking (with interest rate smoothing) because the inflation-targeting central banks are always concerned with the inflation forecast as an intermediate policy target. Additionally, there has been significant and positive response to the euro interest rate in the Czech Republic and Poland. The output gap has entered in all three countries as significant with negative sign, which is likely related to the problems inherent in the construction of the variable.

Finally, **Slovakia** is the only country in the whole sample where we did not find any reasonable interest-rate rule at all. The short-term interest rate has been steadily decreasing with no relation at all to the domestic inflation rate but surprisingly nor to the euro interest rates.[22]

We have again compared the actual interest rate with the target interest rate to get the monetary policy shocks. In Graph 3. we plot these series for Poland, which did not experience any significant deviation from the rule, and Hungary, where we have found two significant deviation (2003 – high speculative demand of forint obliged the central bank to cut the interest rate, which resulted in significant inflation increase and subsequent disproportional interest rate increase).

Graph 3.: Target interest rate from the best rule and the actual one for Hungary and Poland



[21] We used in all cases the euro interest rate as the measure of foreign interest rate, although Latvia had until 2005 peg against SDR and Lithuania maintained currency board with USD until 2002.

[22] The intuition is that the data are of very poor quality. We have compared the basic series obtained from different sources but the overall features are very similar.

6. Conclusions and Possible Extensions

The objective of this study was an empirical confirmation of the monetary policy rules pursued in countries of EU before and after the launch of common currency in 1999 by means of estimation of the augmented version of the Taylor rule. We were able to identify reasonable form of a interest rate rule in case of most central banks. However, the preferred specification usually differ from the form originally proposed by Taylor (1993) and there is a lot heterogeneity between the countries.

In the pre-EMU period we were able to identify four classes of rules (groups of countries) according to the importance of a foreign (German) interest rate in the domestic monetary policy rules and therefore also the degree of dependence on the German monetary policy.

In the second period commencing with the euro introduction in 1999 we have applied two different procedures to identify the monetary policy rule of the ECB. The panel data analysis has showed to have clear advantages over the uniequational analysis with aggregated data, which has been carried out in the literature so far. We have again applied country by country estimation for the identification of policy rules in countries outside the euro area. The policy rules of Denmark, Sweden and UK that were not structurally stable over 1999 shared in this period certain similarities. Finally, within the new 10 EU members we have identifies three classes of rules in line with the degree of foreign exchange rate flaxibility.

The famous Taylor principle (the short-term interest rate must respond by more than unity to the inflation increase in order to achieve the price stabilization) has been confirmed to apply only in large economies and economies with unsustainable inflation rates. The price stability of small economies has been assured by response of the domestic interest rates to additional variables, in particular the foreign interest rate.

The deviations of the actual interest rate from the implied target rate can be interpreted as monetary policy shocks. Episodes of significant deviations have been found in some countries and as long as these coincide with actual turbulent periods, the rule might be considered a good description of monetary policy. The deviation have been usually related to actual exchange rate turbulences.

Unlike previous studies we have extended the sample, provided the results for countries that have not been subject to this analysis yet, and confirmed the coherence of the panel analysis, still more popular in macroeconomic studies, in the field of empirical analysis of monetary policy rules.

The present study is opened to extensions in various directions, concerning the data used (monthly frequency, longer estimation periods, other sensitivity checks), the model specification (consideration of non-linearities), or the estimation method (consideration of cross-section dependencies in the panel analysis). In additional, the sample of countries could be amplified (emerging markets with flexible exchange rate like various countries in South America) and the empirical analysis of closely related issues could be carried out (pass-through effects of exchange rate to domestic prices and inflation in open economies, the asymmetries in the transmission mechanism of the monetary union).

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