Assessing Monetary Rules Performance across EMU Countries.

by

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DISCUSSION
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Assessing Monetary Rules Performance across EMU Countries

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Abstract

The topic covered in this paper is the performance of di¤erent monetary policy rules used as guidelines in practical policymaking. To this end, di¤erent rules are evaluated using alternative econometrics techniques. A comparative analysis is made of the ability of the rules to correspond to the historical central bank behaviour and of the volatility of the output, in‡ation and interest rate changes that they imply. The study is conducted of the EMU countries. The results suggest that simple rules perform quite well and that the advantages obtained from adopting an optimal control-based rule are not so great. Moreover, the addition of a forward-looking dimension and of an interest rate smoothing term in the reaction function seems to improve the performance of the rules.

Keywords: In‡ation targeting, Monetary Rule, ECB

JEL Classi…cation: C52, E52

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1 Introduction

The paper analyses the performances of di¤erent reaction functions to be used as possible guidelines for the establishment of monetary policy in the EMU. The reaction function, summarising how the central bank alters monetary policy in response to economic development, can be useful in predicting actual monetary actions and, therefore, in assessing the current stance and the future direction of monetary policy. The econometric evidence resulting from this kind of study can also suggest which monetary rule the ECB should adopt in order to achieve its primary institutional goal, namely, price stability. The monetary rules analysed di¤er in their method of expectation formation, some being backward-looking, others being forward looking and in the variables they allow to enter into the monetary policy reaction functions. The rules studied include di¤erent speci…cations of the Taylor rule, an open-economy version of the Rudebusch and Svensson targeting rule and the forward-looking rule proposed by Clarida, Gali and Gertler.

In order to evaluate the various results a central bank obtains from adopting a particular rule, a preliminary de…nition of what constitutes rule-based monetary policy in practice has to be given. As no central bank will be bound to the prescription of any simple rule (or any optimal control algorithm), the distinction between rule-based and discretionary monetary policy is crucial. As stressed in McCallum (2000), while a discretionary monetary policy takes into account current macroeconomic condition, ignoring past development in the economic system, a rule-based monetary policy is based on a "timeless perspective", i.e. the rule is constructed as if the current conditions were not known. According to this de…nition, when following a discretionary policy, the central bank re-optimises its decision-making process periodically, while in a rule-based policy, monetary authorities implement a contingency formula chosen to be applied for an in…nite number of time periods. Nevertheless, in the rule-based framework the possibility of revising the rule is also contemplated, once the central bank gets new information on the state of the economy. In this sense, the in‡ation-targeting regime, although not restricting monetary authorities to select instrument settings according to a particular rule, can be considered an example of rule-based policymaking.

The reason why a central bank should adopt a monetary rule, instead of having a discretionary behaviour, has a theoretical basis in time-consistency literature. In this literature, to which the seminal contribution was made by Kydland and Prescott (1977) and Barro-Gordon (1983), it is shown that if a central bank does not commit itself to a rule, the policymakers will be tempted to choose a suboptimal in‡ation policy[1]. The contribution of Barro and Gordon is of particular interest for the issues analysed in the paper because the "rules vs. discretion" dichotomy was separated from the debate on "activist vs. non-activist" central bank policy. This separation has resulted in the possibility for monetary policymaking to concentrate on the issue of policy rules. Moreover,

[1] For an exposition on the relationship between ECB conduct and the concept of credibility see Marani-Altavilla (1999).

there are other advantages the central bank can obtain by limiting the range of possible policies, i.e. adopting a rule. The first is an increase in monetary policy credibility. The second is a decrease in market participants' uncertainties deriving from a better forecast of future policy actions.

The remainder of the paper proceeds as follows. In Section 2, an open-economy model is presented which is designed to show the main channel through which monetary policies affect inflation and output. In Section 3, the Rudebush and Svensson (1998) technique is applied to recover an optimal feedback rule in a context of open-economy. In Section 4, various specifications of the Taylor rule, including terms for interest rate smoothing and lagged output gap, are presented as examples of instrument rules. In Section 5, the forward-looking rule proposed by Clarida et al. (1998) is studied in order to account for the more realistic behaviour of monetary authorities. In Section 6, the results obtained from applying the different rules to each European country are compared. Section 7 concludes the paper.

2 The Model

In the literature, several types of models have been used for evaluating monetary policy rules, including an optimising model with representative agents, closed and open economy models, rational expectations models[2]. The model used to analyse central bank behaviour is a backward-looking open-economy model[3]. Relations between variables are considered to be representative of the major effects that monetary policy has on inflation and output.

The model consists of an aggregate supply equation of the form:

$$\pi_{t+1} = \sum_{i=0} \alpha_i \pi_{t-i} + \alpha_4 y_t + \alpha_5 q_t + \alpha_6 Pcom_t + u^{\pi}_{t+1} \quad (1)$$

This open-economy autoregressive Phillips curve relates inflation to a lagged output gap (y), measured as a percentage gap between actual real industrial production and potential industrial production, to a change in the commodity price index (Pcom), to a lagged real exchange rate (q) and to four lags of a CPI inflation. The underlined structure of the aggregate supply is consistent with an adaptive representation of inflation expectations. The inclusion of the commodity price index is due to its specific features. Indeed as commodity prices are determined in auction markets they react much faster to news about future inflation than industrial or consumer prices. For this reason, they have been included in the system to control for expected future inflation. Moreover, recent empirical

[2] As observed in Taylor (1998), despite differences in the models used for studying monetary policy, they share some important peculiarities. See also Taylor (1999) for a comprehensive review of the different models used in recent literature.

[3] The main features of the model I presented here are consistent with the structure and timing of the model obtained from a VAR analysis conducted in Altavilla(2000). In this paper is shown that such specification gives raise to a reasonably well behavior in the movement of the variables, once they are subjected to a monetary policy shock.

evidence coming from the Vector Autoregression (VAR) literature on monetary transmission mechanisms suggests that conducting policy analysis without using commodity prices as a leading indicator of inflation leads to the so-called Price Puzzle: a contractionary monetary policy shock result in an increase in the price level. The absence of forward-looking variables in the equation (1) is in line with the analysis of Fuhrer (1997) on the importance of future price expectations in explaining price and inflation behaviour. He finds that the performance of a model buildt for pure forecasting purposes with a forward-looking specification of inflation is no better than a backward-looking model. Moreover, if the model is used for policy simulation, only mixed backward/forward-looking price specification leads to acceptable long-run behaviour of inflation.

Equation (2) identifies the aggregate demand equation:

$$y_{t+1} = \sum_{i=0} \beta_i (y_{t-i}) - \beta_2(\bar{i}_t - \bar{\pi}_t) + \beta_3 q_t + u^y_{t+1} \qquad (2)$$

According to the above equation the output gap is related to its own lags, to a lagged real interest rate and to the real exchange rate. In the above equation $\bar{i}_t$ is the four-quarter average short-term interest rate, typically an interbank lending rate for overnight loans, and $\bar{\pi}_t$ is the four-quarter inflation, i.e. $\frac{1}{4}\sum_{j=0} \pi_{t-j}$; q_t is the (log) real exchange rate the equation of which is specified below. From Equation (2) we can see that an increase in q_t, representing a depreciation of the home currency, shifts aggregate demand to the home country ($\beta_3 > 0$).

The commodity prices are assumed to follow a stationary univariate AR (2) process:

$$Pcom_{t+1} = \eta_0 Pcom_t + \eta_1 Pcom_{t-1} + u^{Pcom}_{t+1} \qquad (3)$$

The foreign interest rate equation evolves according to a generalized lagged Taylor-rule of the form:

$$i^*_{t+1} = \gamma_0 \pi^*_t + \gamma_1 y^*_t + \gamma_2 i^*_t + u^{i^*}_{t+1} \qquad (4)$$

In other words, the foreign interest rate is assumed to be a linear function of a lagged foreign output gap, lagged inflation rate and of its own lag.

The foreign output gap and inflation are modeled in a way similar to the home country equations; however the real exchange rate does not enter the specification. More specifically, the aggregate demand and supply take the following form:

$$y^*_{t+1} = \varphi_0 y^*_t + \varphi_1 y^*_{t-1} + \varphi_2 (i^*_t - \pi^*_t) + u^{y^*}_{t+1} \qquad (5)$$

$$\pi^*_{t+1} = \sum_{i=0} \rho_i \pi^*_{t-i} + \rho_4 y^*_t + u^{\pi^*}_{t+1} \quad (6)$$

The (log) nominal exchange rate process fulfils the uncovered interest parity condition:

$$e_t = E_t e_{t+1} - i_t + i^*_t + u^e_t \quad (7)$$

Moreover, specifying the real exchange rate equation as a function of the nominal exchange rate e, the domestic price level (p), and the foreign price level (p^*) we get:

$$q_t \equiv e_t + p^*_t - p_t \quad (8)$$

By rearranging equations (7) and (8), it is possible to write an expression for the real exchange rate of the form[4]:

$$q_{t+1} = q_t + i_t - i^*_t - \pi_{t+1} + \pi^*_{t+1} + u^q_{t+1} \quad (9)$$

For all countries analysed in the paper the exchange rate is that of the national currency against the US dollar. Moreover, with this specification of the model, the interest rate is considered as an exogenous variable under the perfect control of the monetary authorities.

The transmission of monetary impulses operates through two main channels: an interest rate channel and an exchange rate channel. Precisely, the effects of a monetary contraction are a decrease in output, and thus through the Phillips curve in inflation, and an appreciation of the exchange rate. The timing of the model can be summarised as follows: an increase in the monetary policy instruments i in period t immediately affects the real exchange rate. This contractionary policy takes one quarter to influence output and another quarter, i.e. at time t+2, for output to affect inflation. At the same time, a change in the exchange rate also influences output and inflation but both at time t+1. This feature is consistent with the common view according to which the direct exchange rate effect is the fasteest channel through which monetary policy influences inflation.

The model has been estimated by applying the Seemingly Unrelated Regression (SUR) technique and using quarterly data[5] for the period 1979-1998. All variables of the model were de-meaned prior to estimation. The length of the sample period is justified by the need to have a single monetary policy regime involved in the estimations.

[4] For estimation purposes, the specification of the exchange rate used is: $q_{t+1} = \delta_0 q_t + \delta_1 i_t - \delta_2 i^*_t - \delta_3 \pi_{t+1} + \delta_4 \pi^*_{t+1} + u^q_{t+1}$

[5] The data used in the empirical analysis are taken from the IFS statistics.

A preliminary issue to resolve before estimating the models is the de-trending method used to measure the output gap. Three alternative techniques used to measure the cycle are analysed. The first is obtained from the difference between the log of industrial production and a quadratic trend[6]. The second relies on the deviation of the log of industrial production from a potential output derived by applying a Hodrick-Prescott filter with the smoothing parameter set to 1600[7].

Finally, a third measure of the cycle is derived by taking the residuals of an OLS regression of the (log) industrial production on a constant and a linear trend. The three alternative measures are reported in Figure 1.

Insert Figure 1

Consistently across the countries the different measures do not show large discrepancies. For this reason, as suggested from recent literature on the measurement of the output gap, the second measure, i.e. the one obtained with the Hodrick-Prescott filter, will be used in the remainder of the paper.

Nevertheless, there is an increasing literature[8] aimed at stressing the high uncertainty involved in the measurement of the indicators of aggregate capacity utilization such as the output gap. Many authors, underline that the likely effect of the measurement error in the output gap can be retrieve in the larger response coefficients of the estimated optimal feedback rules with respect to the size of the parameters suggested by Taylor(1993). According to Orphanides (1998) the problem implied by the measurement error might be mitigate by attenuation. This strategy implies the monetary authorities reduce the coefficient on the output gap in the policy rules that the central banks actually respond. The attenuation can be a useful strategy to counterbalance the problems in the real-times estimates of the output gap.

Moreover, as stressed in Cecchetti (1997), the parameter uncertainty is only one of the possible source of uncertainty involved in the estimation of the monetary reaction function. More specifically, the model uncertainty, related to the non-agreement over the true structural model, has also to be taken into account once a policy rule is estimated. The problem of the model uncertainty, which could be handled with a robustness analysis of the policy rules, is not considered in the paper.

3 Targeting Rules

The first class of rules considered are the targeting rules. In the targeting rule framework, a central bank is assigned to minimise a loss function that has a

[6] This measure of the output gap has been used, among others, by Clarida et al.(1998).

[7] The value of the penalty parameter λ affects the variability of the trend component. Larger values of λ are associated with a smaller variability of its trend component. Therefore, choosing an extremely high number for the smoothness parameter is equivalent to taking a linear trend as a measure of the potential output.

[8] See Cecchetti (1997), Smets (1998) and Orphanides (1998) among others.

positive relation with the deviation between a target variable and the target level for this variable. Following the dynamic optimisation algorithm provided by Rudebush and Svensson (1998) and Svensson (1998a,b) to obtain a targeting rule, the central bank is supposed to minimise an intertemporal loss function of the form:

$$E_t \sum_{\tau=0} \delta^{\tau} L_{t+\tau} \tag{10}$$

where E_t refers to expectations conditional upon the available information set at time t, while δ is a given discount factor, with $0 < \delta < 1$.

The specific features of the loss function that have to be considered raise some problems. Several authors have stressed the perverse attitude to risk of the quadratic loss function; by utilising such a function we are implicitly assuming the central bank treats symmetrically both positive and negative deviations from the target. Even so, as shown in Chadha and Shellekens (1999), conducting the analysis with a different attitude to risk through the introduction of an exponential (CARA) or isoelastic (CRRA) loss function does not produce, in a context of additive uncertainty, a richer description of policymaking behaviour. In fact, also in those cases certainty equivalence applies, provided the alternative loss function is symmetric. Thus, in the rest of the paper a quadratic loss function is used of the form:

$$L_t = \hat{\pi}_t^2 + \lambda y_t^2 + \nu (i_t - i_{t-1})^2 \tag{11}$$

Following the terminology introduced in Svensson (1997), the above expression describes a flexible inflation target where the goal variables describing central bank preferences are $\hat{\pi}_t$, i.e. the deviation of actual inflation from a constant given inflation target, y_t, i.e. the output gap and $i_t - i_{t-1}$, an interest rate smoothing term. Moreover, λ and ν are non-negative weights that the central bank attaches to output stabilisation and interest rate smoothing, respectively. If λ and ν are set to zero, we are in a situation of strict inflation targeting. Some words must be spent on the variables that enter into the loss function. In real monetary policy-making, the inflation rate is usually preferred to the output gap as a formal target for monetary policy. The reasons are related to the specific features the inflation rate has in comparison with the output gap. From a theoretical point of view, the long-run neutrality of monetary policy on output capacity suggests that central banks should concentrate on the variables, like inflation, that they can influence on a long-term basis. From a practical point of view, the difficulty in measuring the output gap and public familiarity with the concept of inflation supports the choice of inflation for central bank communication and econometrics estimation purposes, respectively. Nevertheless, even if the central bank official target is expressed in terms of inflation, it is believed that output stabilisation is still important to monetary authorities. Finally, the inclusion of the objective of interest rate smoothing is proposed to account for two phenomena. The first is the aversion that the central banks have to frequently changing the direction of their strategy. The second is related to the idea that central banks also care about financial stability: interest rate instability can lead to a destabilisation of the financial system.

As shown in Rudebush and Svensson (1998), for $\delta = 1$, the optimisation problem can be rewritten interpreting the intertemporal loss function as the unconditional mean of the period loss function; it means that the intertemporal loss function can be written as the weighted sum of the unconditional variances of goal variables:

$$E[L_t] = Var[\pi_t] + \lambda Var[y_t] + \nu Var[i_t - i_{t-1}]. \tag{12}$$

In the following, this loss function will be used, assuming, therefore, the limiting case $\delta = 1$.

3.1 State-Space Representation

The State space representation of the estimated model is :

$$X_{t+1} = AX_t + Bi_t + v_{t+1} \tag{13}$$

This compact form is helpful in summarising the structure underlined by the dynamic model. More precisely, in the above equation the 19×1 vector X contains the state variables, the 19×19 matrix A and the 19×1 column vector B contains the estimated parameters, and the 19×1 column vector v_t is the disturbance term. This representation summarises the dynamic structure of the economy and the uncertainty that the central banks face regarding this structure. The matrix A and the vector B govern the dynamics of the state vector. Uncertainty enters through the additive stochastic vector v_{t+1}. The terms in equation (13) can be written as:

$$
A = \begin{bmatrix}
\sum_{i=0} \alpha_i e_{i+1} + \alpha_4 e_7 + \alpha_5 e_9 + \alpha_6 e_5 \\
e_1 \\
e_2 \\
e_3 \\
\eta_0 e_5 + \eta_1 e_6 \\
e_5 \\
\beta_2 e_{1:4} + \beta_0 e_7 + \beta_1 e_8 + \beta_3 e_9 - \beta_2 e_{17:19} \\
e_7 \\
-\delta_3 \sum_{i=0} \alpha_i e_{i+1} - \delta_3 (\alpha_6 e_5 + \alpha_4 e_7 - \delta_0 \alpha_5 e_9) + \delta_4 (\rho_0 e_{10} + \rho_1 e_{11}) - \delta_2 e_{14} \\
\sum_{i=0} \rho_i e_{i+10} + \rho_4 e_{14} \\
e_{10} \\
e_{11} \\
e_{12} \\
-\varphi_2 e_{10} + \varphi_0 e_{14} + \varphi_1 e_{15} + \varphi_2 e_{16} \\
e_{14} \\
\gamma_0 e_{10} + \gamma_1 e_{14} + \gamma_2 e_{16} \\
e_0 \\
e_{17} \\
e_{18}
\end{bmatrix}
$$

where e_i $(i = 0, 1, \ldots, 19)$ denotes a 1×19 row vector with all element equal to zero and with the elements $i = 1, \ldots, 19$ equal to unity; and where $e_{i:k}$ $(i < k)$ denotes 1×19 row vector with elements $i, i+1, \ldots, k$ equal to $\frac{1}{4}$ and all other elements equal to zero. Notice that all variables entering in the state-space representation are expressed as a function of lagged data only. This condition comes from the particular model considered in the analysis which is, in fact, a backward-looking model[9].

[9] A forward-looking open economy model was used in Svensson (1998b). In this case, the state-space representation is much more complicated to derive.

$$X_t = \begin{bmatrix} \pi_t \\ \pi_{t-1} \\ \pi_{t-2} \\ \pi_{t-3} \\ Pcom_t \\ Pcom_{t-1} \\ y_t \\ y_{t-1} \\ q_t \\ \pi^*_t \\ \pi^*_{t-1} \\ \pi^*_{t-2} \\ \pi^*_{t-3} \\ y^*_t \\ y^*_{t-1} \\ i^*_t \\ i_{t-1} \\ i_{t-2} \\ i_{t-3} \end{bmatrix}; \qquad B = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ -\frac{\beta_2}{4} \\ 0 \\ \delta_1 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{bmatrix} \qquad \text{and} \qquad \varepsilon_t = \begin{bmatrix} u^{\pi}_t \\ 0 \\ 0 \\ 0 \\ u^{Pcom}_t \\ 0 \\ u^{y}_t \\ 0 \\ u^{q}_t \\ u^{\pi^*}_t \\ 0 \\ 0 \\ 0 \\ u^{y^*}_t \\ 0 \\ u^{i^*}_t \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

Writing the target variables, $\bar{\pi}_t; y_t$ and $i_t - i_{t-1}$ as a function of the state variable X_t we get:

$$Y_t = \begin{bmatrix} \bar{\pi}_t \\ y_t \\ i_t - i_{t-1} \end{bmatrix} = C_X X_t + C_i i_t; \text{where } C_X = \begin{bmatrix} e_{1:4} \\ e_7 \\ -e_{17} \end{bmatrix} \text{ and } C_i = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

The loss function can now be expressed as:

$$L_t = E[Y_t' K Y_t]; \text{where } K = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \lambda & 0 \\ 0 & 0 & \nu \end{bmatrix}: \tag{14}$$

The class of linear feedback rules considered here takes the following generic form:

$$i_t = f X_t \tag{15}$$

where f denotes a 1×19 vector. Using the foregoing relations, the dynamics of the model follows:

$$X_{t+1} = M X_t + v_{t+1}; \; M = A + B f \tag{16}$$

$$Y_t = CX_t; \; C = C_X + C_i f. \tag{17}$$

The optimal linear feedback rule is then supposed to be an interest rate rule that, given the economic structure implied by the rule, is able to minimize the central bank loss function. Thus, the optimal linear feedback rule can be expressed as:

$$f = -(R + B'VB)^{-1}(U' + B'VA)X_t \tag{18}$$

where the matrix V satisfies the Riccati equation:

$$V = Q + Uf + f'U' + f'Rf + M'VM \tag{19}$$

and where:

$$Q = C_X' K C_X; \; U = C_X' K C_i \text{ and } R = C_i' K C_i$$

As stressed in De Grauwe et al. (1998), the specific features of the optimal linear feedback rule f in equation (18) underline that there are at least three factors affecting the particular form of the rule the central bank should follow. In fact, these factor: different values of the state variable, X, different impacts of monetary policy, A and B, and different central bank preferences over inflation, output and interest rate smoothing, K, may result in a different interest rate policy, i.e. a different optimal linear feedback rule. Those differences emerge in Figure 2, where the actual versus the estimated interest rates for each EMU country are plotted.

Insert Figure 2

Additionally in Figures 8 to 11, the optimal feedback rule coefficients for inflation, interest rate smoothing, output gap and exchange rate are presented.

Insert Figure 8 to 11

Consistent with a-priori beliefs, the coefficients for the exchange rate are all negative and, in general not very high. The first interest rate smoothing coefficients are near the value one, 0.7 on the average, while the third and fourth lag coefficients are approximately nought. The estimated coefficients for inflation are quite small. However, these coefficients present a certain degree of persistence; contrary to the values of the lag coefficients for interest rate smoothing, in this case, the second to the fourth lags do not show small values.

4 Instrument Rules

In this section, different specifications of instrument rules will be estimated. Within this class of rules, the monetary policy instrument is expressed as a function of the available information. As an example of the instrument rule, different types of Taylor rules are analysed. Since the Taylor (1993) seminal paper, a great amount of literature has been written which aims at explaining the stabilising power of active interest rate rules. Recently, several authors including Taylor (1998) and Gerlach and Schnabel (1999) have underlined the usefulness of the Taylor rule as an informal benchmark for setting interest rates in the EMU area. In the following, three versions of the Taylor rule are studied. The first referred to as the classic Taylor rule (henceforth TR), assumes that the interest rate is a function of the current values of both inflation and the output gap:

$$i_t = k + a\pi_t + by_t + v_t \qquad (20)$$

By adding an autoregressive term to the previous specification, thus allowing the central bank to react to a lagged interest rate, we get the Generalised Taylor Rule (GTR):

$$i_t = k + a\pi_t + by_t + ci_{t-1} + v_t \qquad (21)$$

Finally, the Lagged Taylor Rule (LTR) is derived considering the lagged values of both inflation and the output gap plus the autoregressive term:

$$i_t = k + a\pi_{t-1} + by_{t-1} + ci_{t-1} + v_t \qquad (22)$$

The above reaction functions have been estimated using OLS.

Figures 3 to 5 show the estimated versus the actual interest rate. The ability of the rule to correspond to the historical behaviour of the interest rate, i.e. of the central bank, varies across the different specifications of monetary policy reaction function. Both the generalised and the lagged Taylor rule outperform the simple Taylor rule.

Insert Figure 3 to 5

However, an analysis of the estimated coefficients in Table 1 shows that only the coefficients in the TR have an unambiguous theoretical meaning; they suggest that the central banks of the EMU countries have risen nominal interest rates by more than any increase in inflation, so that inflation has never spun out of control.

Insert Table 1

In any case, it seems that the inclusion of the lagged interest rate in the GTR and the LTR artificially brings the estimated rules near historical records of the interest rates. The high value, nearly one, of the interest rate smoothing coefficients in the GTR and the LTR confirms this conclusion.

5 Forward Looking Rules

In analysing the targeting rule, it has been stressed that, in the case of a purely backward-looking linear model with a quadratic loss function, certainty-equivalence applies. The only difference with the full information case is that the optimal policy is not calculated on the actual value of the state vector; the reaction function responds to an efficient estimation of state variables[10]. In monetary policy literature, there has been a great debate on the information set that the central banks should use to fix the interest rate. More precisely, the discussion has focused on the possibility and the relevance for monetary authorities to include some forward-looking variables in the reaction function specification. The need for a forward-looking dimension in monetary policymaking has been stressed by several authors, among others Batini-Haldane (1998) and Svensson-Woodford (2000), as a necessary condition for a better representation of central bank behaviour. Nevertheless, many economists are sceptical about the improvement that can be obtained from the inclusion of a forward-looking variable in a macroeconomic model of monetary policy and, in any case, they stress the need to incorporate a sort of history-dependence in a rule to be considered as optimal[11]. This scepticism is based on the consideration that by allowing a central bank to react to forecasts of future inflation we are not eliminating the backward-looking component in central bank behaviour: as the forward-looking components are recovered from current and lagged data of the related variables, they are, in fact, backward-looking. The main advantage of the forward-looking rule then is the inclusion of other variables besides the output gap and inflation that can help to forecast monetary actions.

In the following, an example of a forward-looking monetary rule is presented. Generalized Methods of Moments (GMM) is the econometric approach used to conduct estimation in the context of a framework of intertemporal optimisation-rational expectation. This method, developed by Hansen (1982) and initially used in the consumption theory for the estimation of the Euler equation, has recently been employed by several authors to estimate central bank reaction function. Following Clarida et al. (1998), the empirical model specified for the GMM estimation of the monetary rule is:

$$i_t^* = \bar{i} + \beta(E[\pi_{t+n} | \Omega_t] - \pi^*) + \gamma(E[y_t | \Omega_t] - y_t^*) \qquad (23)$$

In addition, to take into account the tendency of central banks to smooth interest rates, a partial adjustment mechanism is introduced as follows:

[10] See Svensson and Woodford(2000).
[11] See Woodford (2000) on this point.

$$i_t = (1 - \rho) i_t^* + \rho r_{t-1} + \nu_t \tag{24}$$

where i_t^* is the target interest rate, $\bar{i}$ is the long-term equilibrium nominal interest rate, y_t is the real industrial production, π_{t+n} is the inflation rate between the periods t and $t+n$, π^* and y_t^* are the equilibrium values for inflation and output[12] respectively. Finally, E_t denotes expectation formed conditionally upon the information set, Ω, available at time t.

The monetary rule emerging from equation (23) and (24) underlines the central bank ability to have direct information about the current value of both output and inflation when setting the target interest rate. Another important feature of the above monetary rule is the inclusion of expected inflation in the reaction function; this characteristic may be useful in trying to disentangle the connection between the estimated coefficient and central bank objectives. Again following Clarida et al. (1998), equation (23) is rearranged as:

$$i_t^* = \alpha + \beta E[\pi_{t+n} \mid \Omega_t] + \gamma E[\tilde{y}_t \mid \Omega_t] \tag{25}$$

where $\alpha \equiv \bar{i} - \beta \pi^*$ and $\tilde{y}_t \equiv y_t - y_t^*$. Taking into account the partial adjustment mechanism yields:

$$i_t = (1 - \rho)\alpha + \beta E[\pi_{t+n} \mid \Omega_t] + \gamma E[\tilde{y}_t \mid \Omega_t] + \rho i_{t-1} + \nu_t \tag{26}$$

Rewriting the last equation in terms of realized variables in order to eliminate the unobserved forcast variables we get:

$$i_t = (1 - \rho)\alpha + (1 - \rho)\beta \pi_{t+n} + (1 - \rho)\gamma \tilde{y}_t + \rho i_{t-1} + \varepsilon_t \tag{27}$$

where the error term is now:

$$\varepsilon_t = -(1 - \rho)\{\beta(\pi_{t+n} - E[\pi_{t+n} \mid \Omega_t]) + \gamma(\tilde{y}_t - E[\tilde{y}_t \mid \Omega_t])\} + \nu_t \tag{28}$$

the set of orthogonality condition implied by equation (27) is:

$$E[r_t - (1 - \rho)\alpha - (1 - \rho)\beta \pi_{t+n} - (1 - \rho)\gamma \tilde{y}_t - \rho i_{t-1} \mid u_t] = 0 \tag{29}$$

where u_t includes all the variables in the central bank information set at the time the interest rate is fixed.

[12] For comparison purposes, a quadratic trend is not used to derive the output gap as done in Clarida-Gali-Gertler (1998); as in deriving the optimal feedback rule, the potential output is calculated, instead, using the Hodrick and Prescott filter with a penalty parameter set to 1600.

In the estimated model, the constant, the first four lags of the output gap, the first four lags of inflation and the first four lags the of commodity price index have been taken as instruments. Since the number of instruments exceeds the parameter vector, the model is over-identified. The validity of the over-identifying restriction can be tested by using the Hansen (1982) J-statistic. This statistic, distributed as an χ^2, can be useful in assessing if the above specification omits significant variables which, in fact, enter into the central bank information set. In other word, the choice of the instruments, reflecting the monetary authority information set, is crucial in specifying the monetary rule.

The results are shown in Figure 6 and Table 2.

Insert Figure 6 and Table 2

In almost all the models, the interest rate response coefficients of the inflation rate, i.e. β, are above the stability threshold of one. This evidence, as stressed by Taylor (1998), is a crucial feature for a dynamically stable monetary policy. In his paper, Taylor also gives a theoretical basis for this result. Essentially, he argues that having a response coefficient lower than one results in a positively-sloped aggregate demand curve and causes the output to decrease in response to an inflation shock, which is destabilising. From Table 2, we can also see that Finland is the country where a rise in expected inflation produces the largest response from the central bank in terms of real interest rate reaction; an increase of one percent induces the monetary authorities to raise the real rates by 155 basis point. More generally, in all the EMU countries the central banks have responded to inflationary pressures by raising the real rates.

Another interesting result regards the output gap estimated coefficients, i.e. γ. In all countries a rise in the output gap induces central banks to increase interest rates. A one percent increase in the output gap in Italy, for example, induces the Bank of Italy to increase nominal (and thus real) rates by 47 basis point. We can conclude that over the sample period, the central banks of the EMU countries reacted to real economy pressures independently of their concern about inflation. Finally, the p-values of the J-statistics reported in Table 2 imply that the overidentifying restrictions are not rejected and thus that the estimated reaction functions are not badly specified.

6 Comparative Analysis

In this section, the performance of the analysed rules is considered. In the previous sections, some results which come from the values of the estimated coefficients entering into the reaction functions have already been stressed. This section embodies a comparative analysis of the estimated monetary rules.

The ability of the various rules to reproduce the actual interest rate is shown in Figures 2 to 6. From this analysis, it is shown that all the rules perform quite well in replicating actual interest rate movements. In particular, the generalised

Taylor rule and the forward-looking rule seem to be consistently the most successful across the countries in describing historical central bank behaviour. The inclusion of a smoothing term for interest rates and the possibility for the central bank to respond to forecasts about future inflation are then to be considered as realistic features of policy-making.

However, a comparative analysis of alternative policy rules cannot rely on the differences experienced between actual and estimated reaction functions. Following the definition of Taylor (1994), a policy rule has to be considered optimal if it minimises a weighted sum, where the weights are set by the policymakers' tastes, output variance and inflation variance. In our case, given the specification of the loss function in equation (??), a term in interest rate smoothing is also taken into account. In other words, the efficiency of a rule results from its ability to stabilise output, inflation and interest rate changes around their target values for an infinite number of periods.

Table 3 and Table 4 provide the results for the volatility of goal variables, measured as the unconditional standard deviations, implied by the five estimated rules under the hypothesis that $\lambda = 1$ and $\nu = 0.5$. With this assumption, the analysis is implicitly carried out under the hypothesis that, for the central bank, the volatility of output and inflation are equally undesirable ($\lambda = 1$) while the variability of nominal interest rate changes are much less costly ($\nu = 0.5$).

These tables also report the loss implied by the rules and the relative ranking in terms of loss in the fourth and fifth columns of Table 3 and 4, respectively.

Insert Table 3 and Table 4

The unconditional variances are calculated using the method developed in Rudebush and Svensson (1998). More precisely, the 3x3 covariance matrix of the goal variables is given by:

$$\sum_{YY} \equiv E\left[Y_t Y_t'\right] = C \sum_{XX} C' \tag{30}$$

where the 19×19 matrix $\sum_{XX}$ represents the unconditional covariance matrix of the state variables and satisfies the following relationship:

$$\sum_{XX} \equiv E\left[X_t X_t'\right] = M \sum_{XX} M' + \sum_{vv} \tag{31}$$

In order to recover the covariance matrix of the state variables we can use[13]:

$$\begin{aligned} \text{vec}\left(\sum_{XX}\right) &= \text{vec}\left(M \sum_{XX} M'\right) + \text{vec}\left(\sum_{vv}\right) \\ &= (M \otimes M)\,\text{vec}\left(\sum_{XX}\right) + \text{vec}\left(\sum_{vv}\right) \end{aligned}$$

[13] The relationships used are: $\text{vec}(A + B) = \text{vec}(A) + \text{vec}(B)$ and $\text{vec}(ABC) = \text{vec}(C' \otimes A) + \text{vec}(B)$.

Finally we can solve for $(\sum_{xx})$:

$$\operatorname{vec}\left(\sum_{xx}\right) = [I - (M \otimes M)]^{-1} \operatorname{vec}\left(\sum_{vv}\right) \tag{32}$$

The results obtained by applying this technique suggest several conclusions. In all countries, the variability of optimal feedback rules outperforms, in terms of minimum losses, the other rules. It means that the volatility of the goals variables is minimised once the central bank adopts an optimal feedback rule. Moreover, the simple forward-looking Taylor-type rule is consistently, across the countries, the second top-performing rule; the results in terms of the volatility of target variables and, therefore, in terms of losses are very close to those of the optimal feedback rule. We can conclude that the inclusion of a forward-looking dimension in a monetary authority decision process seems to improve the performance of the simple rule.

The generalised and the lagged Taylor rules outperform, with the exceptions of France and the Netherlands, the classic Taylor rule. This is mainly thought to be due to the inclusion of an autoregressive term in the GTR and LTR. This result corroborates the evidence emerging from the comparative analysis between actual and estimated rules; an interest rate smoothing term then improves not only the ability of the rule to give a better representation of central bank behaviour, but also the efficiency, measured in terms of volatility, of the rules. Nevertheless, for many models the volatility of interest rate changes is higher in the rule that reacts to the lagged interest rate.

Finally, the similar results of the GTR and the LTR underline that the use of lagged rather than contemporaneous values of the output gap is not helpful in reducing the volatility of goal variables and, therefore, in stabilising the economy.

7 Concluding Remarks

This paper attempts to analyse different rules capable of modelling how the central banks of the EMU countries have made policy choices affecting interest rates. In particular, the study focuses on five different rules relating the interest rate, which the central banks are assumed to control, to a set of variables thought to affect monetary authority behaviour. This kind of study provides insight for how the new European monetary institution should conduct and characterise its policy strategy. In other words, it can suggest how the ECB should move interest rates once a change in real output, inflation or the exchange rate occurs.

The first step of the analysis is the construction of a macroeconomics model to use as a basis for the comparison of estimated reaction functions. The features of the model are very important because the conclusions obtained depend, of course, on the belief that the economic structure implied by the proposed model is not grossly incorrect.

Two preliminary problems are considered prior to recovering the alternative reaction functions. The first is related to the measurement of the business cycle;

the second concerns the number of variables that enter into the monetary policy loss function.

The econometrics analysis considers the main properties of five different rules: three different specifications of the Taylor rule, an optimal feedback rule and a forward-looking rule. These rules are estimated using different econometrics techniques. The estimated coefficients of the rules form a preliminary basis to detect the main differences they imply in terms of monetary policy strategy.

Once the interest rate rules are estimated, a comparison of the alternative rules is performed.

The first question considered in the comparative analysis is the ability of the rules to replicate historical interest rate movements, i.e. central bank behaviour. The results emerging from the paper stress that simple rules perform quite well in following interest rates historical records. The ability to mimic increases once an interest rate smoothing term is included in the reaction function. This suggests that central bank behaviour can be better explained by adding a lagged interest rate. Moreover, considering a forward-looking dimension that takes into account expectations of future inflation movements, seems to give further improvement.

The second issue is related to the ability of the rules to reduce the volatility of the variables the central bank considers as targets and, therefore, to stabilise the economy. The analysis suggests that even if the rule obtained by solving an optimal control algorithm is consistently, across the EMU countries, the top-performing rule, the performance of a simple forward-looking rule with a smoothing term for the interest rate is almost as stabilising as the optimal feedback rule. Then, it can be concluded that the gains a central bank can obtain by following a complicated rule are not so great. In addition, the easier communicability of the simple rule can also increase the transparency and thus the credibility of the central bank. The problem of transparency is of particular interest, once the problem of the possible rules the European Central Bank should adopt is considered. In fact, the inability of the ECB to communicate with the agents about its strategy is one of the main problems the new monetary institution is facing[14]. It follows that the ECB should use simple rules as guidelines for its monetary strategy.

[14] In Marani-Altavilla (1999), this conclusion is supported by the evidence emerging from the analysis of the term structure of interest rates.

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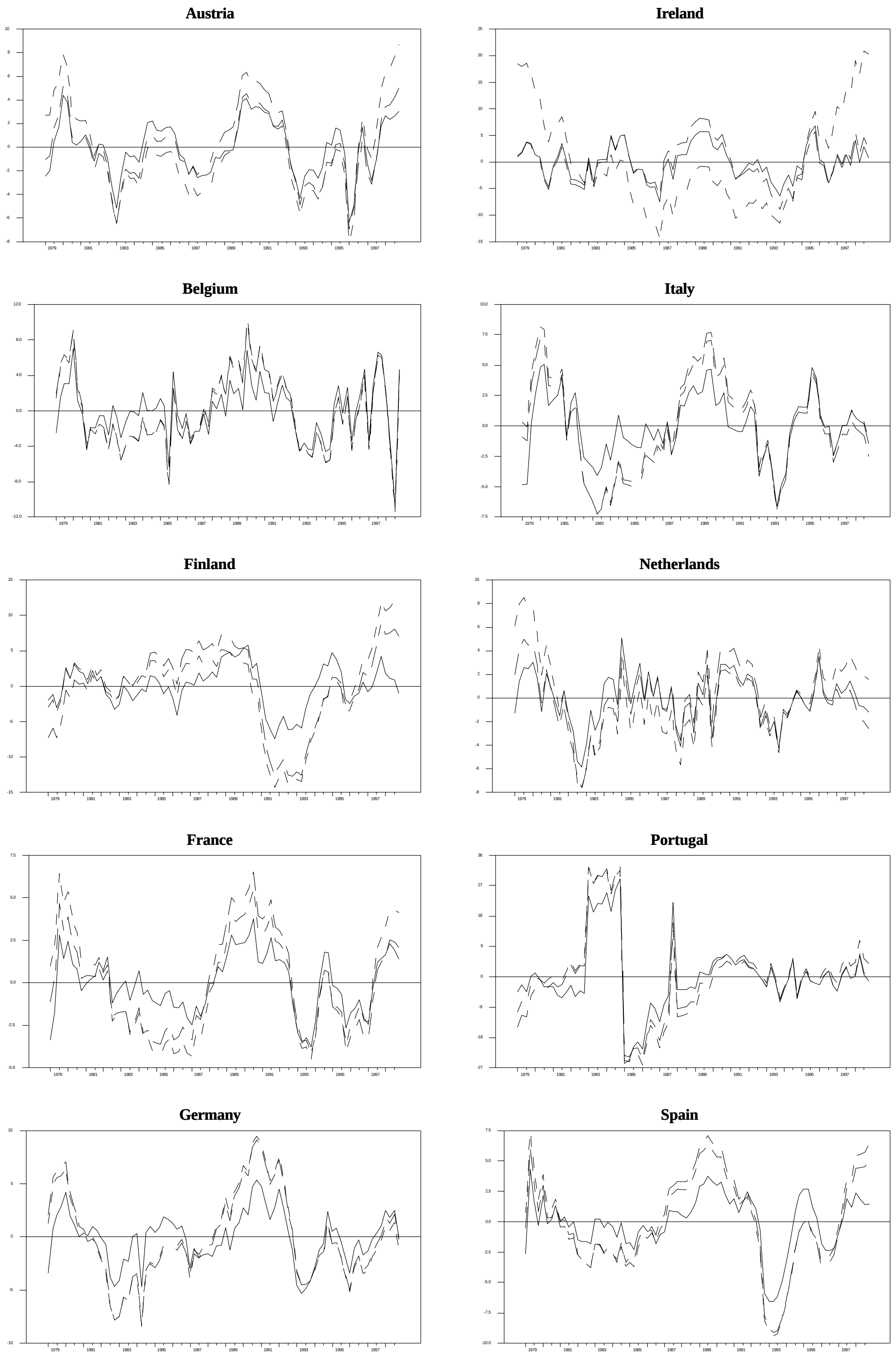
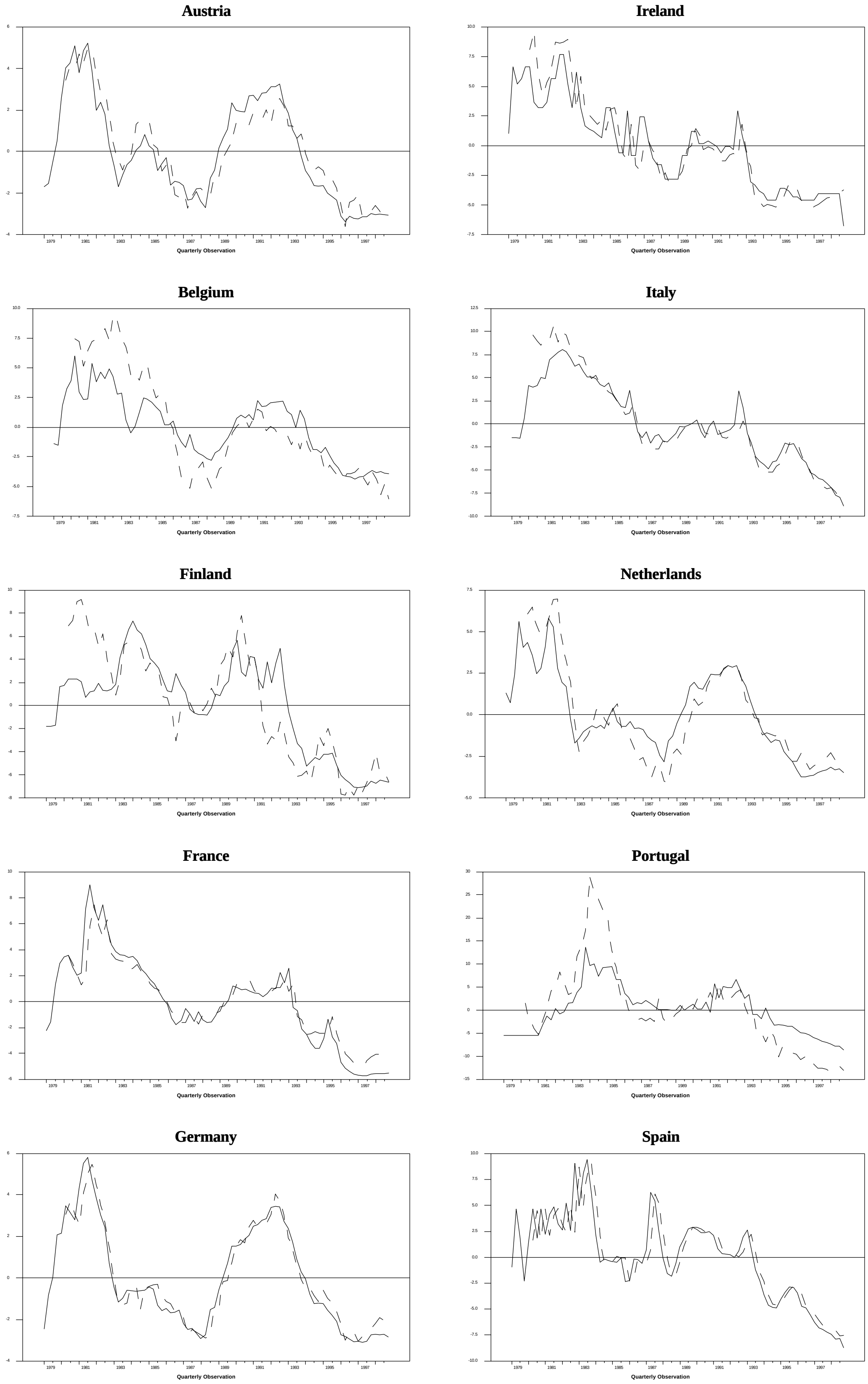
Figure 1: Alternative Measures of Output Gap



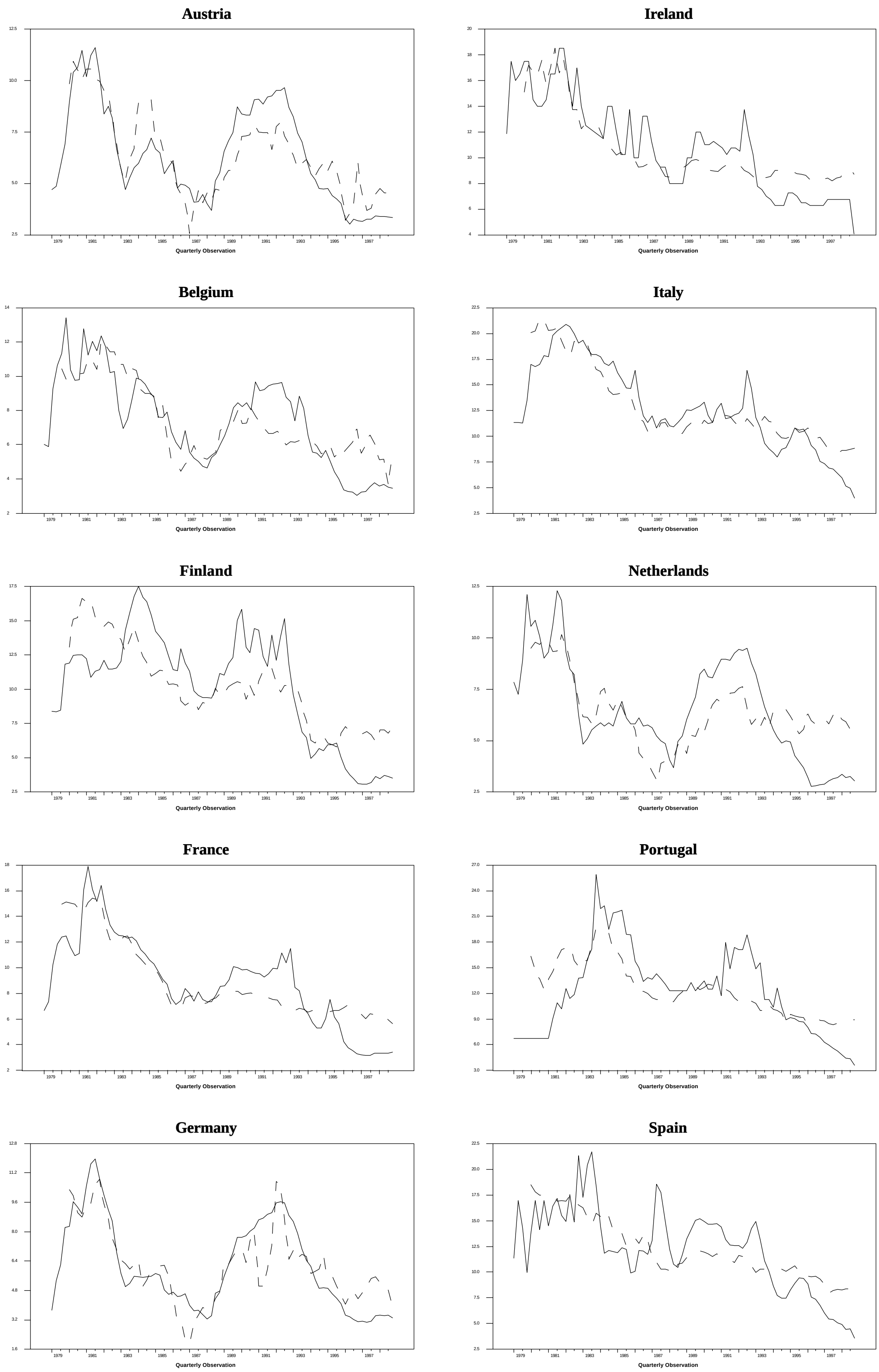
Notes: The output gaps recovered through the Hodrick-Prescott filter are shown as the solid line.
The gaps had by using a linear trend are shown as long-dashed lines;
the output gaps obtained from applying a quadratic trend are shown as short-dashed lines.

Figure 2: Estimated Optimal Feedback Rules vs. Actual Interest Rates



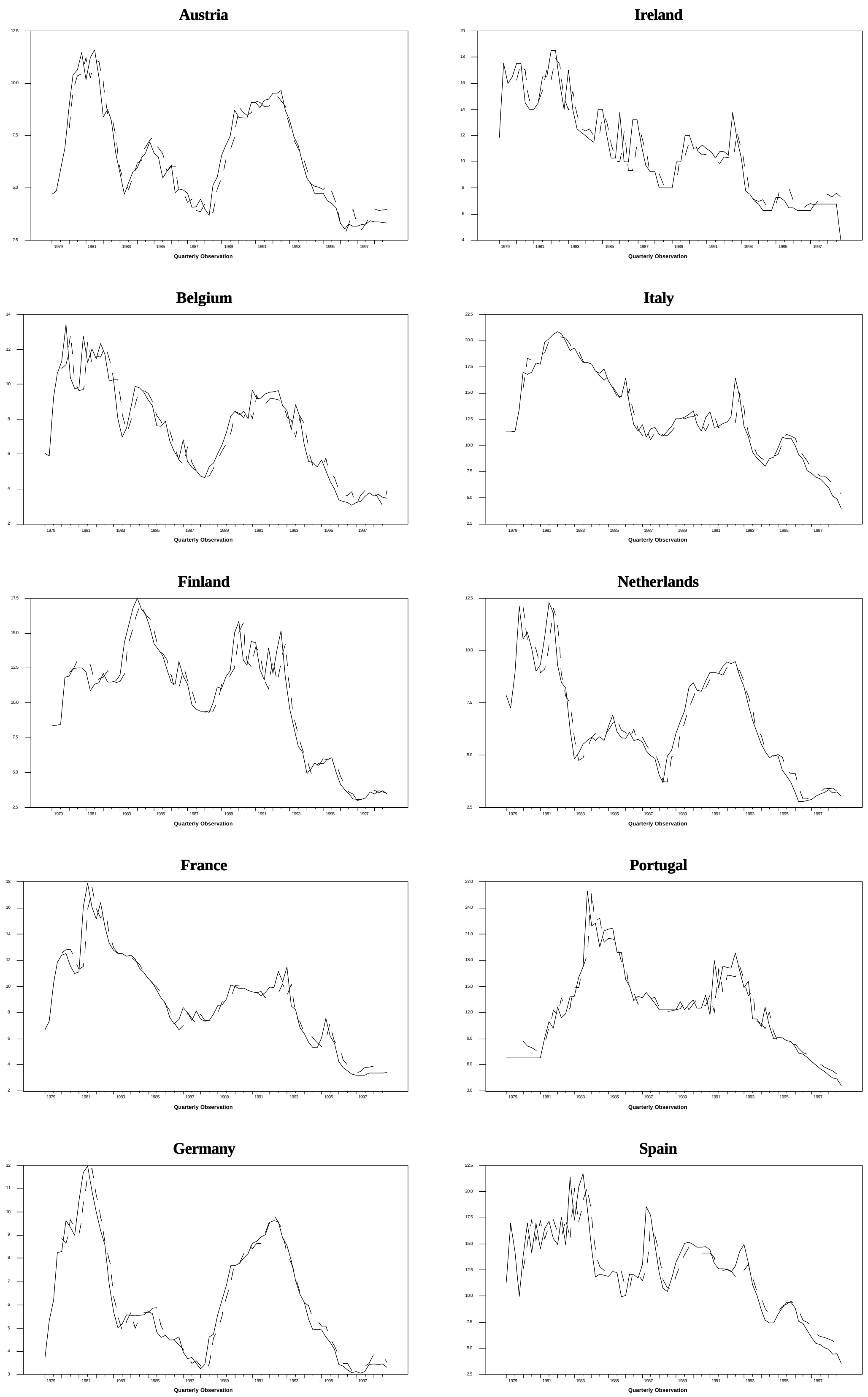
Note: the actual interest rates are shown as the solid line. The dashed lines represent the estimated monetary policy reaction functions.

Figure 3: Estimated Taylor Rules vs. Actual Interest Rates



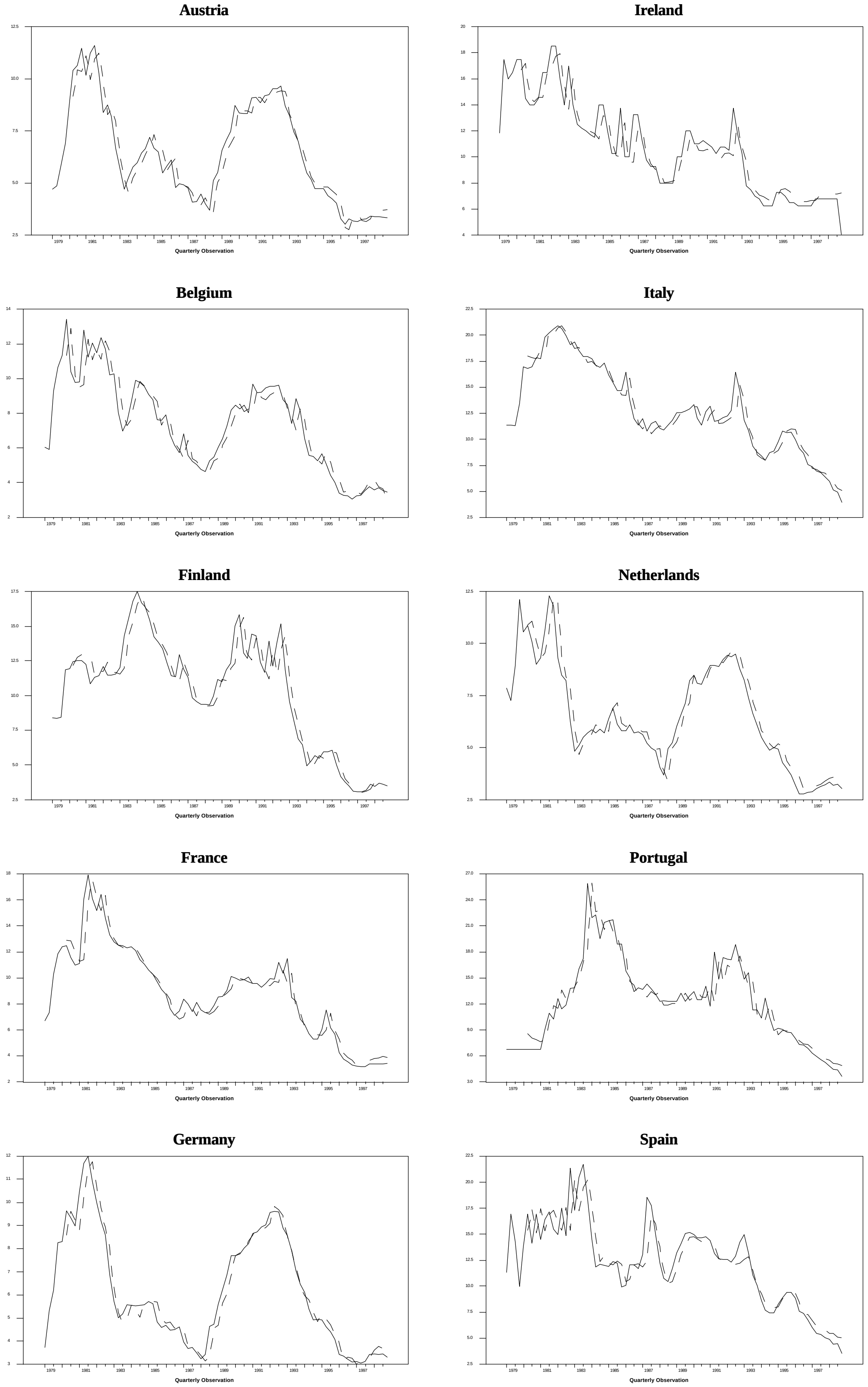
Note: the actual interest rates are shown as the solid line. The dashed lines represent the estimated monetary policy reaction functions.

Figure 4: Estimated Generalized Taylor Rules vs. Actual Interest Rates



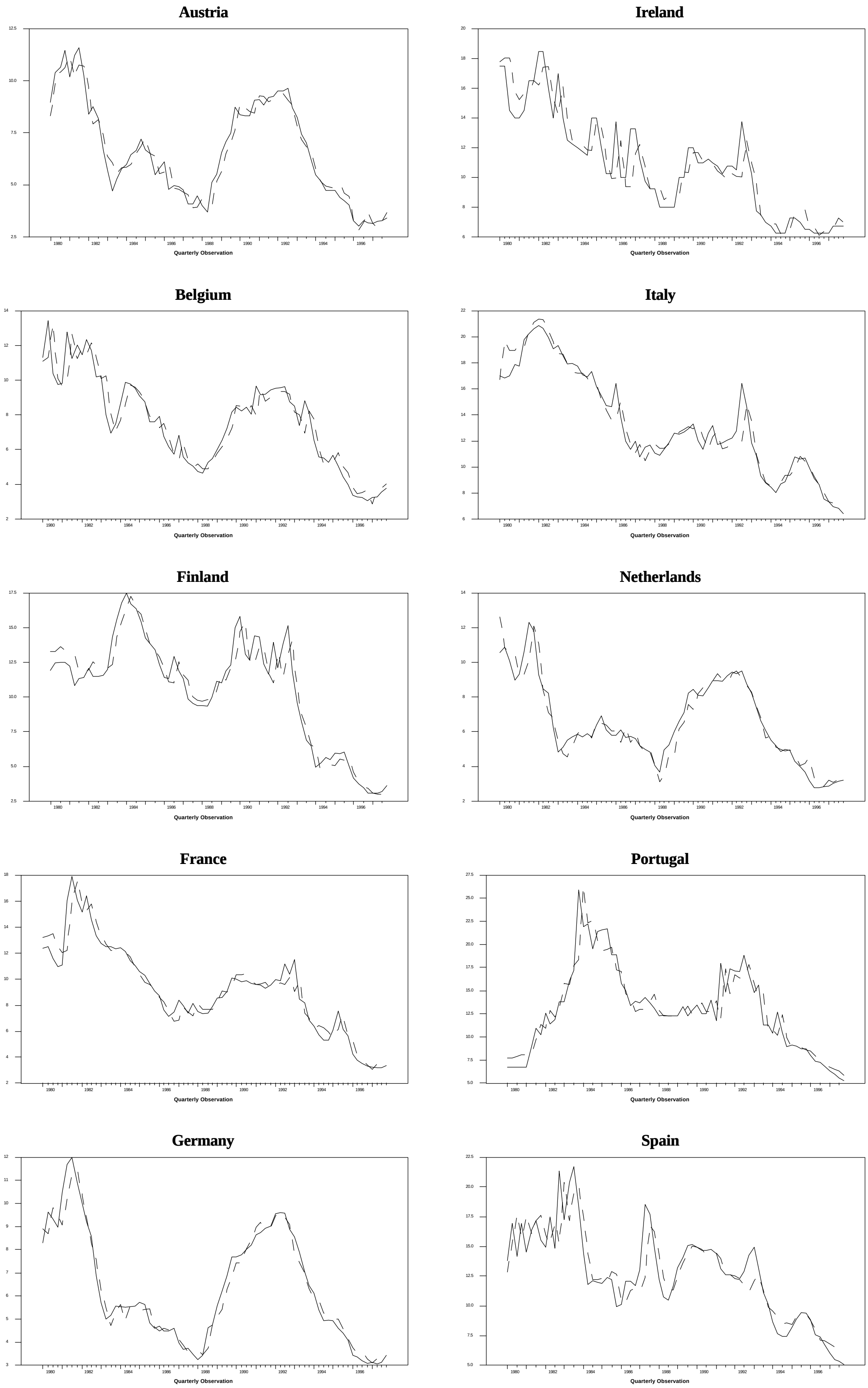
Note: the actual interest rates are shown as the solid line. The dashed lines represent the estimated monetary policy reaction functions.

Figure 5: Estimated Lagged Taylor Rules vs. Actual Interest Rates



Note: the actual interest rates are shown as the solid line. The dashed lines represent the estimated monetary policy reaction functions.

Figure 6: Estimated Forward-Looking Rules vs. Actual Interest Rates



Note: the actual interest rates are shown as the solid line. The dashed lines represent the estimated monetary policy reaction functions.

Figure 7: Optimal Feedback Rule Coefficients for Inflation

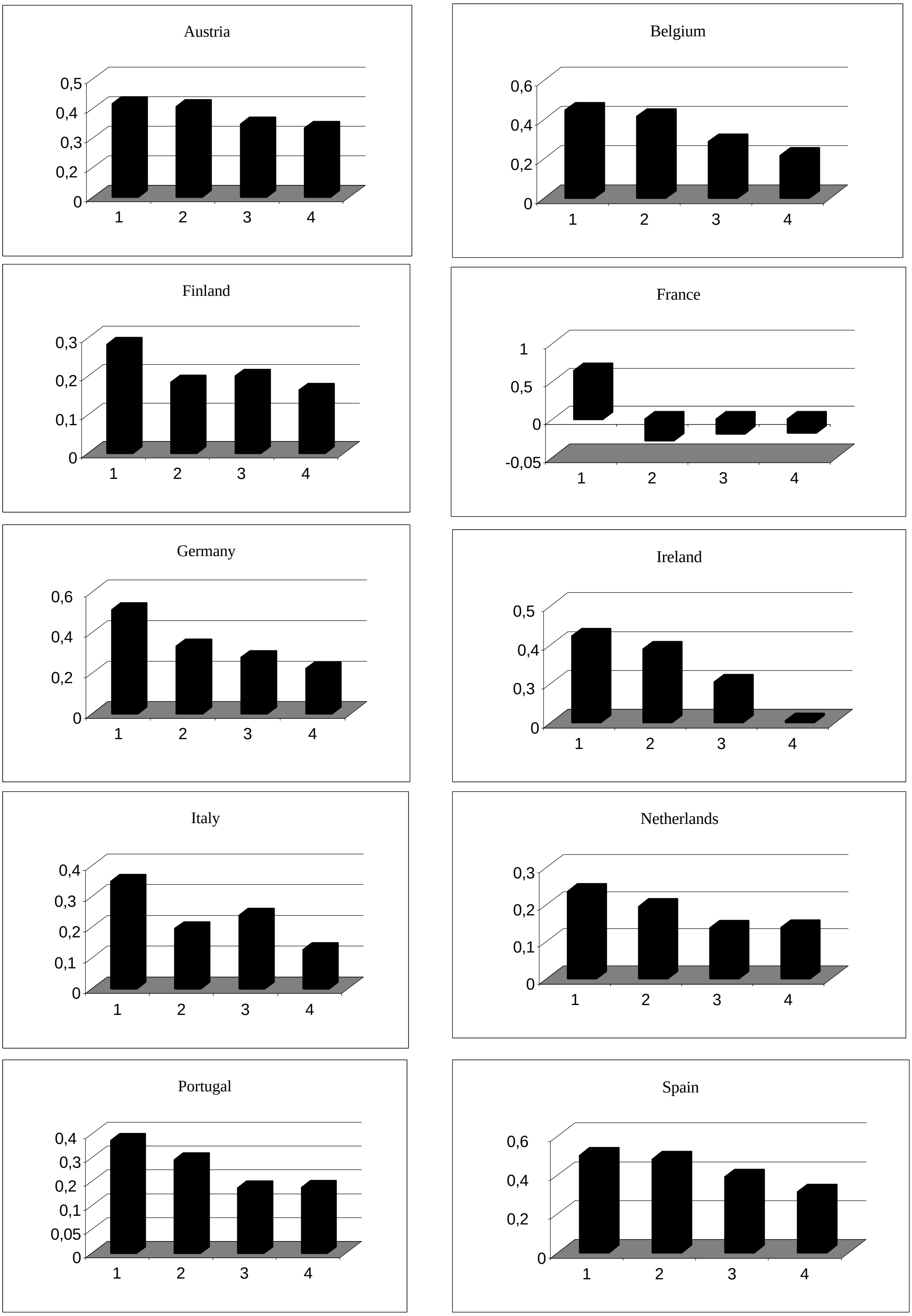


Figure 8: Optimal Feedback Rule Coefficients for Interest Rate Smoothing

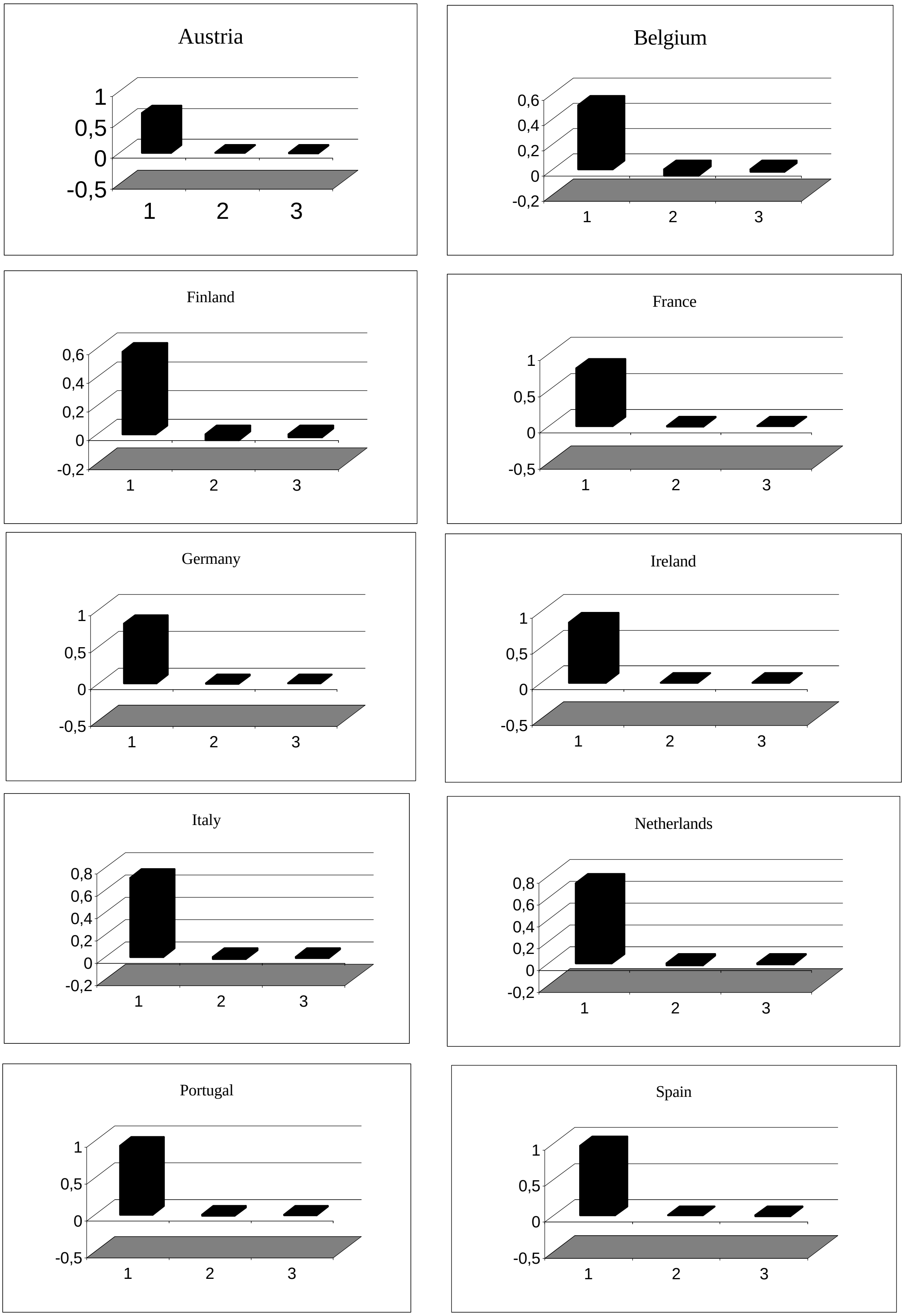


Figure 9: Optimal Feedback Rule Coefficients for Output Gap (first lag)

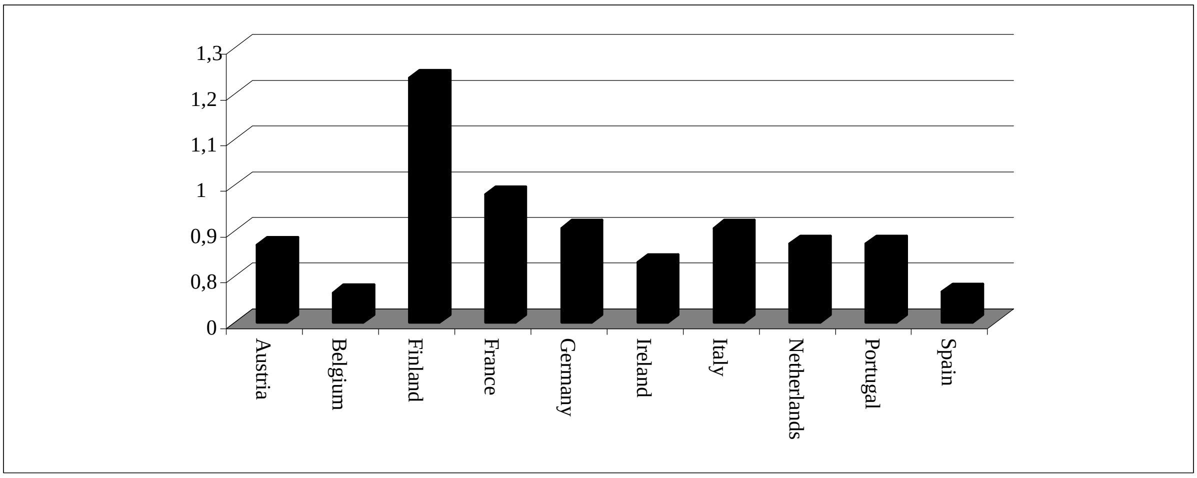


Figure 10: Optimal Feedback Rule Coefficients for Output Gap (second lag)

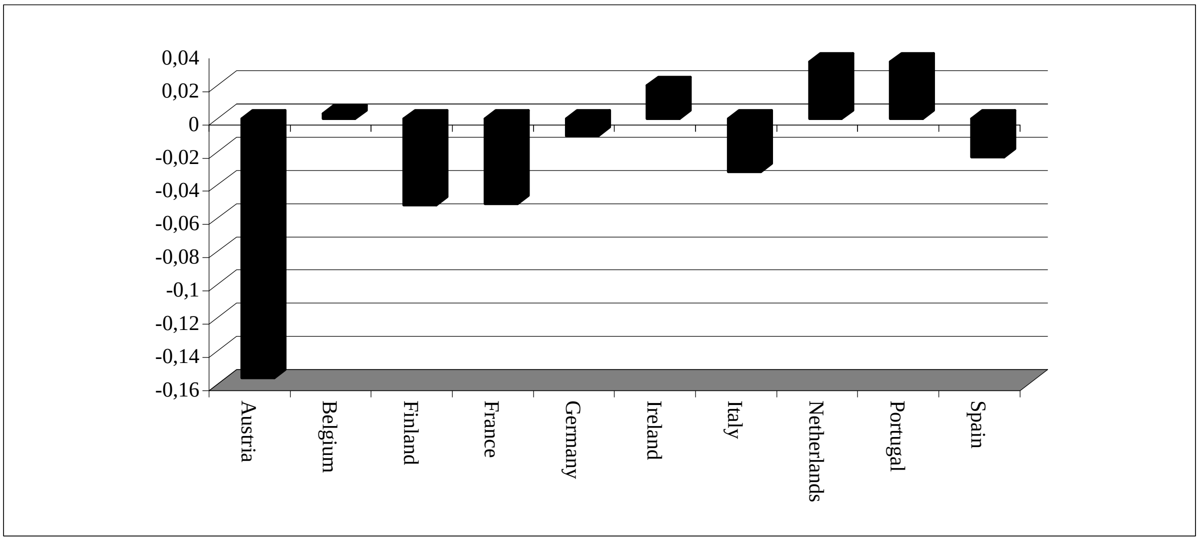


Figure 11: Optimal Feedback Rule Coefficients for Exchange Rate

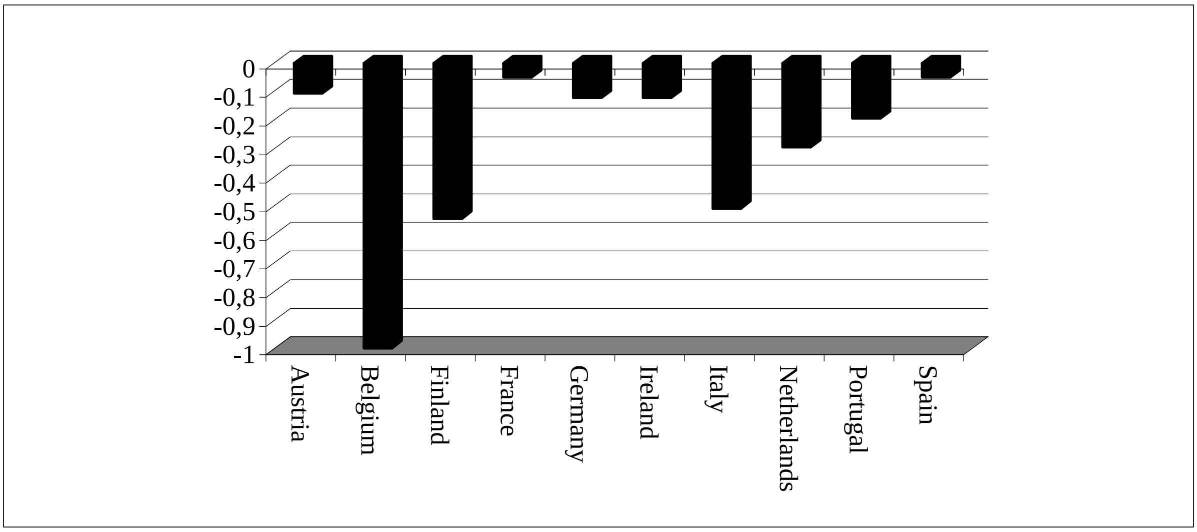


Table 1: Estimated Coefficients of Different Rules

	Aus	Bel	Fin	Fra	Ger	Irl	Ita	Net	Por	Spa
Taylor Rules										
const.	2,816	4,250	6,010	5,383	3,280	7,580	7,263	4,180	7,600	6,860
p_t	1,130	0,880	0,893	0,756	1,087	0,523	0,740	0,839	0,430	0,754
y_t	0,275	0,115	0,339	0,050	0,274	0,017	0,208	0,175	0,006	0,002
Generalized Taylor Rules										
const.	0,615	0,447	0,104	0,730	0,364	1,925	1,203	0,292	0,873	1,414
p_t	0,180	0,120	0,101	0,110	0,096	0,139	0,169	0,010	0,106	0,215
y_t	0,160	0,065	0,046	0,160	0,132	0,089	0,058	0,098	0,022	0,106
i_{t-1}	0,813	0,871	0,933	0,849	0,900	0,739	0,803	0,942	0,834	0,760
Lagged Taylor Rules										
const.	0,359	0,484	0,136	0,553	0,233	1,708	0,432	0,210	0,212	0,100
p_{t-1}	0,037	0,100	0,095	0,093	0,007	0,119	0,097	0,036	0,936	0,888
y_{t-1}	0,089	0,049	0,025	0,147	0,101	0,016	0,106	0,084	0,030	0,120
i_{t-1}	0,915	0,873	0,932	0,877	0,949	0,759	0,895	0,967	0,835	0,790

Table 2: Estimated Coefficients of Different Rules

	Aus	Bel	Fin	Fra	Ger	Irl	Ita	Net	Por	Spa
Forward-looking Rule										
r	0,803	0,960	0,925	0,846	0,850	0,822	0,799	0,930	0,886	0,748
a	3,067	0,966	1,819	4,655	3,230	6,436	4,312	1,697	6,027	5,738
b	1,108	1,070	2,555	1,038	1,035	0,872	1,283	1,308	0,562	1,031
g	0,785	1,790	0,133	1,517	0,883	0,538	0,472	2,959	0,391	0,755
c^2	0,569	0,756	0,950	0,895	0,925	0,845	0,846	0,609	0,322	0,814

The c^2 rows refers to the p-values for the J statistic used to test the overidentifying restrictions
The instruments are 1, four lags of interest rate, four lags of inflation rate, four lags of commodity price, four lags of real exchange rate and four lags of output gap.
Estimates are obtained by GMM with correction for MA(4) autocorrelation.

Table 3: Results on Inflation and Output Volatility

Rules	$Std\,[p_t]$	$Std\,[y_t]$	$Std\,[i_t - i_{t-1}]$	***Loss***	***Rank***
Austria					
Optimal Feedback Rule	0,876	1,699	0,577	2,864	**1**
Forward-looking Rule	0,902	1,746	0,608	2,952	**2**
Taylor Rule	1,192	1,757	0,780	3,340	**5**
Generalized Taylor Rule	0,915	1,762	0,655	3,004	**4**
Lagged Taylor Rule	0,914	1,716	0,665	2,962	**3**
Belgium					
Optimal Feedback Rule	2,016	1,058	0,729	3,439	**1**
Forward-looking Rule	2,113	1,135	0,903	3,699	**2**
Taylor Rule	3,114	1,033	0,596	4,445	**5**
Generalized Taylor Rule	2,781	1,109	0,842	4,311	**3**
Lagged Taylor Rule	2,964	1,024	0,845	4,410	**4**
Finland					
Optimal Feedback Rule	2,771	2,565	1,099	5,885	**1**
Forward-looking Rule	2,882	2,662	1,025	6,057	**2**
Taylor Rule	3,255	2,641	0,693	6,242	**5**
Generalized Taylor Rule	2,988	2,661	1,047	6,173	**4**
Lagged Taylor Rule	2,967	2,644	1,066	6,144	**3**
France					
Optimal Feedback Rule	3,044	1,205	0,879	4,689	**1**
Forward-looking Rule	3,248	1,241	0,839	4,909	**2**
Taylor Rule	3,298	1,399	0,640	5,017	**3**
Generalized Taylor Rule	3,277	1,406	0,868	5,117	**4**
Lagged Taylor Rule	3,278	1,384	0,914	5,120	**5**
Germany					
Optimal Feedback Rule	1,086	1,683	0,626	3,082	**1**
Forward-looking Rule	1,101	1,843	0,546	3,218	**2**
Taylor Rule	1,172	1,838	0,901	3,460	**5**
Generalized Taylor Rule	1,151	1,842	0,569	3,278	**3**
Lagged Taylor Rule	1,166	1,806	0,590	3,267	**4**

Table 4: Results on Inflation and Output Volatility

Rules	$Std\left[p_t\right]$	$Std\left[y_t\right]$	$Std\left[i_t - i_{t-1}\right]$	***Loss***	***Rank***
Ireland					
Optimal Feedback Rule	4,378	2,011	1,346	7,063	**1**
Forward-looking Rule	4,515	2,185	1,102	7,251	**2**
Taylor Rule	4,962	2,178	0,670	7,474	**4**
Generalized Taylor Rule	4,716	2,185	1,076	7,439	**3**
Lagged Taylor Rule	4,832	2,181	1,133	7,579	**5**
Italy					
Optimal Feedback Rule	3,876	1,783	0,801	6,060	**1**
Forward-looking Rule	4,117	1,890	0,910	6,462	**2**
Taylor Rule	4,722	1,866	0,582	6,878	**4**
Generalized Taylor Rule	4,512	1,863	0,882	6,817	**3**
Lagged Taylor Rule	4,621	1,816	0,886	6,880	**5**
Netherlands					
Optimal Feedback Rule	1,522	1,138	0,717	3,018	**1**
Forward-looking Rule	1,574	1,148	0,757	3,100	**2**
Taylor Rule	1,659	1,215	0,503	3,126	**3**
Generalized Taylor Rule	1,716	1,171	0,668	3,221	**5**
Lagged Taylor Rule	1,594	1,194	0,693	3,135	**4**
Portugal					
Optimal Feedback Rule	5,929	7,282	1,742	14,081	**1**
Forward-looking Rule	6,060	7,315	1,766	14,258	**2**
Taylor Rule	6,409	7,531	0,753	14,317	**4**
Generalized Taylor Rule	6,062	7,144	1,664	14,038	**3**
Lagged Taylor Rule	6,060	7,464	1,706	14,378	**5**
Spain					
Optimal Feedback Rule	2,872	2,004	1,745	5,748	**1**
Forward-looking Rule	3,006	2,037	1,345	5,716	**2**
Taylor Rule	3,305	2,019	1,650	6,148	**5**
Generalized Taylor Rule	3,106	2,026	1,445	5,855	**3**
Lagged Taylor Rule	3,211	2,012	1,460	5,953	**4**