

Empirical Estimates of Reaction Functions for the Euro Area

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1. Introduction

The modelling of the central banks' reaction functions, i.e. the systematic relationship between economic developments and the central banks' response to them, has recently attracted increasing attention by macroeconomists who often describe the strategy or the rule followed by a monetary authority by an interest rate reaction function. The reasons which might explain the large interest for estimating the central banks' reaction function could be described as follows. First, such a rule can provide a basis for forecasting changes in the central bank's policy instrument. Second, within the context of a macro model, the reaction function could represent an important element to evaluate the central bank's policy and the effects of other policy actions or of economic shocks. Third, when rational expectations are assumed in macro models, knowing the correct reaction function is an important element in estimating the entire model.

A simple rule which has become rather popular both in academic literature and among professional central bank watchers in recent years is the so-called "Taylor rule". This rule specifies that the central bank sets its instrument – the interest

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rate – in order to react to two key goal variables: the deviations of contemporaneous inflation from an inflation target and the deviations of real output from its long-run potential level.¹ Therefore, by focusing on policy responses to these key variables, the Taylor rule implicitly captures the policy responses to the economic factors that affect the evolution of those key variables.

This study fits into the literature which focuses on deriving a reaction function for a “fictitious” central bank in the euro area which may be able to explain its systematic behaviour. It also investigates the explanatory power of additional variables and tests the robustness of the estimated reaction functions to the modelling of the inflation term. One of the main features which distinguish our study from the literature is the monthly data set which, *inter alia*, includes a series of monthly real GDP.² Thus it may better represent the decision-making problem a central bank is facing. Given that, since the early 1980s, many European countries have taken a concerted effort to reign in inflation, the estimation of policy rules for the euro area would allow to identify the features of monetary policy which prevailed during an era where policy-making was considered to be effective in terms of bringing down inflation to levels consistent with price stability and which continued with the management of the European Central Bank (ECB henceforth).

The present study is organised as follows. Section 2 provides a short review of the main findings of some recent studies on the estimations of Taylor rules while Section 3 describes the key features of the Taylor rule and some potential estimation problems. The estimation methodology and the main specifications of the monetary policy reaction functions considered in this study are described in Section 4. Estimates of these functions are also presented and discussed in that context. The main findings and caveats to the empirical estimations of these reaction functions are summarised in the conclusions.

1 Despite its simplicity, the academic literature has shown that Taylor rules have to be interpreted with a grain of salt. It is easy to show that, *inter alia*, “... the fitted parameters represent a convolution of parameters describing the central banks preferences and those describing the structure of the economy ...” (see FAVERO, 2001, p. 236).

2 For the details on the method adopted to convert real GDP from quarterly into monthly frequency, see GERDESMEIER and ROFFIA (2003).

2. A Brief Review of the Literature

With regard to the euro area, a number of authors have already discussed the potential usefulness of Taylor rules. In this study we will, therefore, only shortly illustrate specific aspects of some recent studies which have explored the issue of estimating single-equation reaction functions either similar to the original Taylor rule or modified variants of that rule.

To begin with, there are some studies which have focused on estimating monetary policy reaction functions for single European countries. This type of analysis has been based on the assumption that, for some periods of time, it would not be appropriate to estimate policy rules for the euro area as a whole because of the evolving commitment to the ERM that central banks of the member states had for some time and the collapse of the ERM in 1992 (with the exception of Germany which had always had more control over its domestic monetary policy).

For instance, CLARIDA, GALÍ and GERTLER (1998) (CGG henceforth) estimate forward-looking reaction functions for the G3 countries (US, Japan and Germany) and for three main European countries (Italy, France and UK, denoted as E3).³ The authors argue that the central banks of the G3 countries have pursued a form of inflation targeting⁴ by raising nominal (and thereby also real) interest rates when expected (rather than lagged) inflation exceeded its long-run target. The E3 countries seem instead to have been influenced by German monetary policy.⁵ The authors also focus on more complex specifications of the rule which

3 The evaluation of the E3 countries answers the question on how each of those countries would have set its target interest rate if it had applied the same rule as the Bundesbank. This assessment relies on the fact that the Bundesbank had a strong influence on monetary policy within the E3 countries and that these countries were clearly constrained by their ERM commitments before the euro.

4 More explicitly, the authors call it “soft-hearted inflation targeting”.

5 The authors argue that the assessment of the G3 policy would “... *not only supply lessons for future policy-making in the G3, but it would also provide insight for how the new ECB should manage policy.*” (p. 1034). Moreover, the evaluation of the policy rules for the E3 countries, using the Bundesbank rule as a benchmark, would provide a sense of whether the level of interest rates for each country was reasonable from the perspective of their domestic economic conditions. In this respect, the authors analyse how the E3 countries would have set their target interest rate if they were following the rule of the Bundesbank, i.e. setting a target interest rate based on (domestic) inflation and output gaps using the coefficients estimated for the Bundesbank. Such an historical analysis is of interest as it has been often argued that the Bundesbank could be seen as a model for the ECB.

allow the central bank to respond to variables other than output and inflation.⁶ The main conclusion is that, with regard to Germany, lagged inflation and the development of monetary aggregates are insignificant, while the coefficients on the US Federal Funds rate and on the real Deutsche Mark/US dollar exchange rate are significant but small and leave the estimates of the other coefficients basically unchanged.

Another contribution is the paper by FAUST, ROGERS and WRIGHT (2001) (FRW henceforth) who focus on the estimation of a (forward-looking) monetary policy reaction functions for the Bundesbank which is subsequently used as a benchmark to assess the stance of the monetary policy of the ECB since 1999.⁷ Comparing the ECB's policy with the one followed by the Bundesbank, the authors find that the euro area interest rate is lower than the benchmark. This leads them to conclude that the ECB has put a higher weight on the output gap relative to the corresponding weight set by the Bundesbank.

Other studies have also been carried out for the euro area using aggregated euro area data previous to the start of Stage Three of EMU, thus investigating the conduct of a "fictitious" central bank in the euro area prior to the establishment of the ECB. In this respect, PEERSMAN and SMETS (1998) (PS henceforth) confirm the results found by CGG in so far as a forward-looking version of the Taylor rule is able to track German and European short-term interest rates quite well since 1979. They also analyse the stabilisation properties of the Taylor rule in a model of the euro area economy using aggregated data for five euro countries and the German policy rate. Finally, they also compare the performance of the Taylor rule with an optimal rule and find that the former behaves quite well, although the optimal rule would be characterised by a higher output gap coefficient. In another study, GERLACH and SCHNABEL (1998) (GS henceforth) find that the original Taylor rule is able to explain quite well the fall in the average euro area interest rate in the last decade. In particular, they demonstrate that during the period 1990–98, with the exception of the period of the exchange market turmoil in 1992–93, the interest rate in the euro area countries moved closely with the output gap and inflation as would be suggested by the Taylor rule. Moreover, GS – along the lines of CGG – find that additional explanatory variables in an expanded Taylor rule do not significantly affect the weights on

6 These include lagged inflation, a measure of the gap between actual money stock and the official Bundesbank target or the US Federal Funds rate within the first set of countries and the German short-term interest rate for the E3 countries.

7 This is based on the fact that, in the past, many euro area central banks were following the Bundesbank's policy already before the start of Stage Three of EMU.

inflation and the output gap. In this context, only the coefficient on the US Federal Funds rate is found to be significant (but negative), while the coefficients related to the growth rate of M3 and the real euro/US dollar exchange rate turn out to be insignificant.

Interestingly, most studies on the subject are based on a slightly modified version of the original simple Taylor rule which includes an element of inertia on the right-hand side of the equation in the form of a lagged interest rate term. Its significance is generally explained, *inter alia*, by optimal monetary policy inertia or interest rate smoothing behaviour by central banks in their conduct of monetary policy (WOODFORD, 1999), data uncertainty (ORPHANIDES, 1998) or, according to a recent study by RUDEBUSCH (2002), by the fact that monetary policy inertia is just an illusion and reflects the misspecification of the empirical policy rules which fail to take into account serially correlated shocks and, instead, display substantial partial adjustment.⁸

With regard to the issue of the data used for estimating monetary policy rules, the standard practice in empirical macroeconomics is to employ *ex-post* revised data for this type of investigation both for the measure of inflation expectations and the output gap.⁹ However, this procedure ignores the difficulties associated with the accuracy of the initial data and their subsequent revisions. In this respect, ORPHANIDES (2001) shows that real-time policy recommendations may differ considerably from those obtained with *ex-post* revised data. This underlines the importance of the information available to policy makers in real time for the analysis of monetary policy rules. This issue is not dealt with in our present study and is left for future research. In relation to this, an additional potential source of complication in these types of investigation is represented by the difficulty surrounding the estimation of the equilibrium real interest rate.

Finally, Taylor rules can also be calibrated to investigate their explanatory power with respect to the euro area interest rate. For instance, GALÍ (2001) calibrates a simple benchmark rule for the euro area and he finds that the ECB has remained substantially below the level implied by the benchmark rule, thus concluding that ... *ECB policy over the period considered may have violated the so-called Taylor principle.*

8 Smoothing interest rates might also be consistent with the behaviour of the central bank being subject to a learning process or might result from the fear that *ex abrupto* changes in interest rates might be regarded as being too disruptive to the economy.

9 In a forward-looking specification of the Taylor rule, it is quite common to use realised inflation rates as proxies for the expected inflation rates.

3. Taylor's Original Rule and Related Estimation Issues

The monetary policy rule advocated by TAYLOR (1993) postulates that the central bank sets the short-term interest rate on the basis of the current situation regarding inflation and the business cycle. More precisely, his rule specifies that the level of the nominal US Federal Funds rate is set equal to the rate of inflation plus an "equilibrium" real funds rate (which is consistent with full employment) and an equally weighted average of two gaps, a deviation of inflation from its target and the percent deviation of real GDP from an estimated potential level:¹⁰

$$i_t = \pi_t + \bar{r} + 0.5(\pi_t - \bar{\pi}) + 0.5(y_t - \bar{y}), \quad (1)$$

where i_t represents the policy rate of the central bank (Federal Funds rate in the case of the United States), π_t is the inflation rate, $\bar{r}$ is the equilibrium real interest rate, $\bar{\pi}$ is the inflation target and $(y_t - \bar{y})$ represents the output gap.

In his seminal paper, Taylor did not estimate the equation, but he assumed that the weights of the two gaps were equal to 0.5, while the equilibrium real interest rate and the inflation target were both equal to 2%. He also regarded this rule as being very simple, but, at the same time, capable of capturing the essential elements of regimes in which the central bank looks at a wider range of variables and relates the policy instrument to current economic conditions. Although estimating the Taylor rule may appear to be a very simple task, in fact it can raise a number of practical and theoretical problems.

First, the weights to inflation and output gap must be estimated and, therefore, they are both method- and sample-dependent. Second, central banks appear to adjust interest rates gradually, by approaching a desired setting. Consequently, many authors have introduced an interest rate smoothing in the original specification of the Taylor rule. Third, broadly-based indices such as the Consumer Price Index and the GDP deflator are generally suitable for calculating inflation: given that their developments often differ, the choice of the price index may matter. Besides, a measure of "underlying inflation" may allow to eliminate purely transitory price movements and capture more long-term price trend.

Fourth, different options exist to estimate the output gap. The different methods used – for example, log-linear/quadratic trend, Hodrick-Prescott filter –

10 This specification seems to appear, from a certain perspective, more consistent with the Fed's than the ECB's mandate.

and the variable considered – real GDP or industrial production – may have an impact on the level and the behaviour of the Taylor interest rate rule. Related to this argument, as already mentioned the central bank has to base its monetary policy decisions completely on real-time data and not on the final revised data which are instead normally used to estimate the historical Taylor rule interest rate. As a matter of fact, some of the series are not only subject to subsequent major statistical revisions, but are also released with some time delay with respect to the other series.

Finally, the Taylor rule has also some shortcomings in its design. In its original formulation, it does not model the forward-looking behaviour of a central bank. Due to the existence of a lag in the transmission mechanism of monetary policy, the monetary policy decision-makers should be guided by the outlook, rather than the current developments, for inflation.

The simple Taylor rule illustrated above serves as a starting point for our present investigation. In the subsequent section, we will also estimate some alternative specifications.

4. Estimates of Reaction Functions for the Euro Area

This section presents some estimations of a wide range of reaction functions focusing on euro area as done in some parts of the literature. This choice can be justified on several grounds. First, since the early 1990s the process of monetary convergence in the euro area countries accelerated, so that the investigation of the average interest rate behaviour in these countries could be interpreted as an indicator of the monetary policy stance in the euro area.¹¹ Second, the use of euro area data implicitly assumes that, before the start of Stage Three of EMU, every country was only looking at its domestic economic conditions, which might seem to be inconsistent with the implementation of the ERM. However, as explained by the CGG study mentioned in Section 2, some countries imposed, for some time, strict capital controls which, in essence, provided the respective central banks with some leeway to pursue domestic policy objectives. Third, the institutional changes since the monetary convergence and the subsequent establishment of a single monetary policy might render the single-country past evidence no longer informative. Finally, there is not sufficient evidence to analyse the euro area as a whole given the limited period of time which has passed after the start

11 See, for instance, PEERSMAN and SMETS (1998).

of Stage Three of EMU. Against this background, the solution chosen in this study – fully recognising the problems that are implicit in this procedure – is to construct measures of aggregate variables at the euro area level starting from the countries forming the euro area for the period before 1999.

The present section is organised as follows. Sub-section 4.1 contains a description of the Taylor-like rule specifications while sub-section 4.2 describes the estimation technique adopted and some diagnostic tests. The main findings of the exercise are discussed in sub-section 4.3, while sub-section 4.4 deals with the derivation of the equilibrium real interest rate from the estimated reaction functions.

4.1. Reaction function specifications

Following the Taylor rule specification used by CGG and PS, the central bank behaviour can be described by the following forward-looking version of the Taylor rule with interest rate smoothing:¹²

$$i_t = (1 - \rho)[\bar{i} + \beta(E(\pi_{t+n}|I_t) - \bar{\pi}) + \gamma E(y_t - \bar{y}|I_t)] + \rho i_{t-1} + \mu_t, \quad (2)$$

where $\bar{i}$ is the equilibrium nominal interest rate (i.e. the equilibrium real interest rate plus the inflation objective), π_{t+n} is the annual inflation rate at time $(t+n)$, E is the expectation operator and I_t stands for the information available to the central bank when it sets the policy interest rate.^{13,14} With an inflation parameter larger than unity, the rule indicates that the short-term real interest rate should be increased whenever inflation rises, thus exerting a stabilising effect on inflation. In order to estimate this reaction function, we re-write eq. (2) in terms of realised variables as follows:

$$i_t = (1 - \rho)\alpha + (1 - \rho)\beta\pi_{t+n} + (1 - \rho)\gamma(y_t - \bar{y}) + \rho i_{t-1} + \varepsilon_t, \quad (3)$$

where

$$\alpha = (\bar{i} - \beta\bar{\pi})$$

12 This specification contains the interest rate smoothing term on the basis that central banks appear to adjust interest rates in a gradual fashion, slowly bringing the rate towards its desired setting or “target” level.

13 The other variables have been already introduced in Section 3.

14 Of course, the dynamics of adjustment of the interest rate with respect to its recommended level can take different forms (see, for instance, JUDD and RUDEBUSCH, 1998).

and

$$\varepsilon_t = -(1 - \rho)[\beta(\pi_{t+n} - E(\pi_{t+n} | I_t)) + \gamma(y_t - \bar{y} - E(y_t - \bar{y}))] + \mu_t.$$

The exercise presented in this section focuses on the following three main aspects.

First, the simple Taylor rule for the euro area as specified in eq. (3) is estimated empirically and not calibrated. This rule is denoted as the “baseline specification”. Second, we investigate the robustness of the above results to various forms of uncertainties, which can be divided into two main groups.

In relation to the first group, the baseline specification is modified to take into account the impact on the interest rate due to the inclusion of a wide range of additional explanatory variables, e.g. various exchange rate measures, the monetary policy in the United States and the deviation of M3 growth from its reference value.¹⁵ In this case, denoting with x_t and z_t two additional explanatory variables, eq. (3) can be re-written as follows:

$$i_t = (1 - \rho)\alpha + (1 - \rho)\beta\pi_{t+n} + (1 - \rho)\gamma(y_t - \bar{y}) + (1 - \rho)\delta x_t + (1 - \rho)\lambda z_t + \rho i_{t-1} + \varepsilon_t. \quad (4)$$

where, in some specifications, either x_t or z_t or both are included.

Within the second group, alternative measures of the output gap and the inflation term are investigated:

1. Potential output cannot be observed and must be estimated, so we use different techniques – fitting a trend to the data (both in linear and quadratic terms) and employing the HP filter method – to derive it, for both industrial production and real GDP.¹⁶
2. With regard to inflation measures, apart from the commonly used HICP index, we also use the GDP deflator, given that in times of lower prices for imported goods the inflation rate based on consumer prices would be lower compared to the one based on the GDP deflator. Moreover, when oil price shocks are mainly transitory and do not have a permanent impact on inflation, then monetary policy may not react to those changes in the same way as

15 A detailed description of all the variables used in this study is provided in Annex A and Annex B in GERDESMEIER and ROFFIA (2003).

16 Structural approaches could also be followed, like for instance estimating potential output in terms of a relationship with future inflation similar to the way a time-varying NAIRU is estimated within the context of a Phillips curve (see JUDD and RUDEBUSCH, 1998).

to changes in, for instance, services or non-energy good prices. In this case, a measure of inflation based on the HICP index excluding unprocessed food and energy prices should be used. Finally, backward-looking and forward-looking Taylor rules will also be analysed as well as a specification containing the deviation of inflation from its estimated objective.

A robustness check with respect to the results obtained over different sample periods or different estimation techniques is carried out.

The data set used for the estimations includes monthly data generally spanning the period 1985:01–2002:02.¹⁷ The values of the coefficients (together with the standard errors¹⁸) of α , ρ , β and γ (and δ , λ for the additional explanatory variables whenever it applies) are reported in the tables in Section 4.3. When the n -period ahead inflation is used as explanatory variable, the ending point is n months prior to the latest available data.¹⁹ In the same tables we also report the value of the equilibrium real interest rate (see column 6). Its derivation is carried out taking into account the definition of price stability of the ECB. On this basis, we assume a constant value of the inflation objective equal to 1.5% and thus calculate the implicit value which is also based on the estimated coefficients related to the different policy rules.²⁰ Finally, in Section 4.4 we follow a different method by relaxing the assumption of a constant inflation objective and thus deriving a time-varying equilibrium real interest rate using time-varying/recursive methods.

4.2. *The estimation technique and diagnostic tests*

In the literature, Taylor rules of the kind of eq. (1) in Table 1 are sometimes estimated by running a simple Ordinary Least Squares (OLS) regression. However, in case not all the right-hand side variables were exogenous, OLS estimates would be biased and inconsistent. Therefore, it seems advisable to test whether, in the baseline specification of the Taylor rule, the interest rate is not endogenously determined by inflation and the output gap. For this purpose, we run

17 The cut-off date of the data set is end of April 2002.

18 The standard errors of the coefficient estimates are consistent with those which would be obtained using the delta method.

19 It should be noted that the values of future inflation are not determined by means of a model but are chosen assuming perfect foresight.

20 The formula for calculating the equilibrium real interest rate can be derived by eq. (3) and is equal to $[(\beta - 1)\bar{\pi} + \alpha]$.

the Hausman and the LM tests which clearly rejected the hypothesis of consistent OLS estimates.²¹ On this basis, all the estimations are carried out adopting the GMM methodology. This technique nests many common estimators and is chosen in order to avoid a possible correlation between the right-hand variables and the residuals (so-called simultaneity bias).

With regard to the choice of the instruments, they need to be predetermined, i.e. being dated t or earlier. In this context, lagged values of the explanatory variables appear to be natural candidates although one should be careful not to use too many lags or many instruments. Good instruments have two properties. First, the set of instruments should be detected by choosing a vector of variables within the central bank's information set that is orthogonal to the error term. Second, at the same time, they should not only be uncorrelated with the residual term, but they should also be strongly correlated with the right-hand side variables. Possible elements include any lagged variables that help forecast inflation and output as well as any contemporaneous variables that are uncorrelated with the current interest rate shock. The instrument set used in this study includes up to 6 lagged values of the output gap and the inflation rate for the baseline specification and, in addition, up to 6 lagged values of additional explanatory variables when applicable.²² The weighting matrix is chosen using the method suggested by NEWEY and WEST (1987), who have proposed a general covariance estimator that is consistent in the presence of both heteroskedasticity and autocorrelation of unknown form (so-called HAC Covariances).²³

It should be noted that GMM requires no information about the exact distribution of the error term which implies that the normality assumption – being a crucial precondition for many other estimation procedures – is not required. All that is required is that the orthogonality conditions hold.²⁴

21 The null hypothesis of no bias in the OLS estimates can be rejected with a probability of 0.003 in the case of the Hausman test and 0.001 in the case of the LM test.

22 With regard to the choice of the set of Instrumental Variables (IV) used in this study, our selection is in line with the literature. On the one hand, using a large number of instruments would increase the number of overidentifying restrictions and lead to a smaller asymptotic covariance while, on the other hand, bad instruments would lead to seriously biased estimates especially in small samples. The impact on the coefficients estimates following a selection of different sets of instruments is illustrated in Table 5 in GERDESMEIER and ROFFIA (2003), where it is shown that additional instruments easily tend to widen the standard errors of the coefficients thus making the tests more imprecise.

23 Using the Newey-West HAC consistent covariance estimates does not change the point estimates of the parameters, but only the estimated standard errors.

24 *"The key advantage of GMM is that it requires specification only of certain moment conditions rather than the full density"*, see HAMILTON (1994), p. 409.

In the tables below we also report the results related to the J-statistic (see column 7) which is used to test the validity of overidentifying restrictions (i.e. when the number of instruments is greater than the number of parameters to be estimated). Under the null hypothesis that the overidentifying restrictions are satisfied, the J-statistic times the number of regression observations is asymptotically χ^2 distributed with degrees of freedom equal to the number of overidentifying restrictions.²⁵ The tables also contain the results of the Wald test which assesses whether the coefficients on inflation and the output gap are jointly not significantly different from the original values suggested by Taylor, namely 1.5 and 0.5 respectively.²⁶

4.3. Estimation results

This sub-section presents and discusses the results of the estimations of the policy rules specifications which have been described in sub-section 4.1. Looking at the figures reported in the tables below, the following results are worth mentioning.

4.3.1. Inflation and output gap weights in the baseline specification

With regard to eq. (1) in Table 1, the weights on inflation and the output gap are estimated to be 1.93 and 0.28, respectively. The results of the Wald test suggest that these coefficients are in line with the original coefficients proposed by Taylor. The corresponding value for the equilibrium real interest rate is 3.2 % (3.7 %) if an inflation objective of 1.5 % (2 %) is assumed.

However, the coefficient values do not seem to be fully robust with respect to the measurement of the output gap. For instance, when the HP filter method is applied to industrial production (and also to real GDP), the coefficients of inflation and the output gap are jointly significantly different from the original values advocated by Taylor (see eq. (2) and eq. (5)). Finally, it can be shown that the estimated interest rate nicely tracks the behaviour of the actual interest rate.²⁷

25 For further detail, see JOHNSTON and DiNARDO (1997), pp. 337 ff.

26 With regard to testing the parameter constancy, see the results for the Cusum and Cusum of Squares tests of the residuals reported in Annex C in GERDESMEIER and ROFFIA (2003). Although these tests seem to indicate the presence of parameter and variance instability at some points of time, they are suggestive of no movements outside the critical lines towards the major part of the sample, thus suggesting that the residual variance is somewhat stable.

27 See Figure 4 in GERDESMEIER and ROFFIA (2003).

Table 1:
Estimates of Taylor rules in the euro area – sample period 1985:01–2002:02

No. of eq.	Specification	α (1)	ρ (2)	β (3)	γ (4)	δ (5)	$\bar{r}$ (6)	$\bar{R}^2$	J-test (7)	Wald Test ^a
Baseline specification										
1	Simple Taylor GMM rule	1.80 (0.67)	0.87 (0.05)	1.93 (0.25)	0.28 (0.13)	(–)	3.20	0.99	0.024	1.93 (0.15)
Alternative measures of the output gap										
2	HP-filter on GMM ind. prod. ^b	1.21 (0.53)	0.82 (0.07)	2.17 (0.19)	0.28 (0.21)	(–)	2.97	0.98	0.015	12.4 (0.00)
3	Linear trend GMM of ind. prod.	1.31 (0.59)	0.85 (0.06)	2.13 (0.22)	0.13 (0.10)	(–)	3.01	0.98	0.018	14.5 (0.00)
4	Quadratic GMM trend on real GDP	1.50 (0.56)	0.84 (0.06)	2.07 (0.23)	0.21 (0.14)	(–)	3.11	0.98	0.037	3.58 (0.03)
5	HP-filter on GMM real GDP	1.18 (0.54)	0.84 (0.06)	2.16 (0.20)	0.53 (0.64)	(–)	2.92	0.98	0.019	11.1 (0.00)
6	Linear trend GMM on real GDP	1.89 (0.71)	0.86 (0.05)	1.89 (0.28)	0.38 (0.23)	(–)	3.23	0.99	0.025	2.34 (0.31)

Notes to Table 1:

The equations are estimated using the Generalised Method of Moments. When not specified otherwise, the instrument set includes lagged values (up to 6 lags) of inflation and the output gap. Industrial production is used to capture output developments on a monthly frequency, apart from the cases when the use of real GDP is explicitly mentioned. In the baseline case, a quadratic trend is used to calculate potential output (and, therefore, the output gap).

a *p-value, null hypothesis that the coefficients on the output gap and the inflation term are jointly not statistically different from 0.5 and 1.5, respectively.*

b *When potential output is computed using the Hodrick-Prescott filter, the smoothing parameter is set equal to 14400 for monthly data and 1600 for quarterly data.*

Table 2:
Estimates of Taylor rules in the euro area – sample period 1985:01–2002:02

No. of eq.	Specification	α (1)	ρ (2)	β (3)	γ (4)	δ (5)	$\bar{r}$ (6)	$\bar{R}^b$	J-test (7)	Wald Test ^a
Additional explanatory variables										
7 GMM	Nom. euro eff. exchange rate ^b	0.88 (0.81)	0.95 (0.02)	1.59 (0.37)	0.72 (0.28)	-0.17 (0.11)	1.78	0.99	0.091	0.86 (0.42)
8 GMM	Real euro eff. exchange rate	0.80 (0.80)	0.95 (0.02)	1.70 (0.37)	0.68 (0.25)	-0.18 (0.10)	1.85	0.99	0.092	0.77 (0.46)
9 GMM	Nominal euro exchange rate vis-à-vis US \$	2.13 (1.29)	0.95 (0.03)	1.57 (0.61)	0.87 (0.59)	-0.02 (0.04)	2.99	0.99	0.096	1.09 (0.34)
10 GMM	Real euro exchange rate vis-à-vis US \$	2.13 (1.29)	0.95 (0.03)	1.55 (0.59)	0.87 (0.58)	-0.02 (0.04)	2.96	0.99	0.096	0.95 (0.39)
11 GMM	Commodity prices	1.58 (2.16)	0.98 (0.03)	1.31 (1.43)	1.24 (1.54)	0.22 (0.30)	2.05	0.99	0.056	0.29 (0.75)
12 GMM	Money growth gap (a) ^c	2.05 (0.59)	0.87 (0.04)	1.50 (0.27)	0.24 (0.10)	0.49 (0.16)	2.80	0.99	0.035	3.45 (0.03)
13 GMM	Money growth gap (b) ^d	1.51 (0.69)	0.92 (0.03)	1.86 (0.30)	0.26 (0.18)	0.41 (0.17)	2.80	0.99	0.050	1.21 (0.30)
14 GMM	Federal Funds rate	1.54 (1.41)	0.92 (0.02)	1.81 (0.28)	0.41 (0.18)	0.04 (0.20)	2.78	0.99	0.056	0.59 (0.55)
15 GMM	DJ Euro Stoxx 50 ^e	-1.71 (1.04)	0.95 (0.02)	2.39 (0.32)	0.53 (0.28)	0.06 (0.03)	0.38	0.99	0.065	4.65 (0.01)
16 GMM	DJ Euro Stoxx 50 corrected for ind. prod. growth	-1.29 (0.93)	0.95 (0.02)	2.30 (0.34)	0.54 (0.28)	0.06 (0.03)	0.67	0.99	0.068	3.89 (0.02)
17 GMM	DJ Euro Stoxx 50 corrected for real GDP growth	0.07 (0.70)	0.91 (0.02)	2.31 (0.25)	1.34 (0.67)	0.01 (0.01)	1.90	0.99	0.050	12.06 (0.00)
18 GMM	Real DJ Euro Stoxx 50 cor- rected for ind. prod. growth	-1.29 (0.93)	0.95 (0.02)	2.36 (0.33)	0.54 (0.28)	0.06 (0.03)	0.76	0.99	0.068	4.27 (0.02)
19 GMM	Real DJ Euro Stoxx 50 cor- rected for real GDP growth	0.07 (0.70)	0.91 (0.02)	2.31 (0.26)	1.84 (0.67)	0.01 (0.01)	2.03	0.99	0.050	11.40 (0.00)

Notes to Table 2:

The equations are estimated using the Generalised Method of Moments. When not specified otherwise, the instrument set includes lagged values (up to 6 lags) of inflation and the output gap. Industrial production is used to capture output developments on a monthly frequency, apart from the cases when the use of real GDP is explicitly mentioned.

- a *p-value, null hypothesis that the coefficients on the output gap and the inflation term are jointly not statistically different from 0.5 and 1.5, respectively.*
- b *All exchange rate variables used in the estimations are measured in terms of annual changes. In all the equations which include the exchange rate as an additional right-hand variable, the list of instruments is expanded by adding lagged values of M3 growth and the commodity prices.*
- c *The money growth gap (a) indicator is measured by the deviation of annual M3 growth from the ECB's reference value for monetary growth (4½% per annum).*
- d *The money growth gap (b) indicator is measured by the deviation of the annual M3 growth from a time-varying reference value based on the ECB's definition of price stability, the growth rate of potential output and the medium-term velocity trend based on the Calza-Gerdesmeier-Levy (CGL) money demand model (see Annex B for further detail).*
- e *The DJ Euro Stoxx 50 in eq. (15) is measured as annual growth rates in nominal terms. In eq. (16) and eq. (17) the additional indicators are derived as the differences between the annual changes in the DJ Euro Stoxx 50 and in industrial production, while eq. (18) and eq. (19) refer to the differences between annual changes in the DJ Euro Stoxx 50 and real GDP growth.*

4.3.2. Sensitivity of the results to the addition of other explanatory variables

The baseline specification is amended to include some additional variables which might have played, at least in certain periods, an important role in the interest rate setting of a central bank (see Table 2).

Firstly, when including the *euro effective exchange rate* and the *euro exchange rate vis-à-vis the US dollar* – both in nominal and real terms (see eq. (7) – eq. (10)) – it turns out that, as expected, the short-term interest rate has positively responded to a depreciation of these measures of the exchange rate. However, the coefficients of these variables are not found to be significant on a statistical basis, a result which is consistent with the earlier findings by GS. Along the same lines, also the *world commodity prices* and the US monetary policy (the latter measured by the *US Federal Funds rate*) are not found to have any additional significant influence on the level of the euro area interest rates.

Secondly, a very interesting result is represented by the significance of the (positive) coefficient of the deviation of M3 growth from its reference value, denoted as *money growth gap indicator*. This result is valid not only when the reference value for monetary growth is set to be equal to 4½% over the whole sample period (*cf.* money growth gap (a) in eq. (12)), but also when the reference value prior to 1999 is calculated as time-varying and derived as the sum of

the estimated annual inflation objective and potential output growth minus the medium-term velocity trend over the whole sample period (*cf.* money growth gap (b) in eq. (13)).²⁸ This finding would imply that, prior to 1999, a fictitious central bank in the euro area can be portrayed as having responded to an excess monetary growth by increasing the interest rate.

Thirdly, we consider whether some measures of stock prices might have influenced the response of the monetary authority. For this purpose, we use the *DJ Euro Stoxx 50* index both in nominal and real terms, and also corrected for the growth of the economic activity.²⁹ It turns out that changes in nominal and real stock prices corrected for industrial production growth are also significant and enter the Taylor rule with a positive sign (see eq. (16) and eq. (18)). However, in this case the implied equilibrium real interest rate decreases to a rather low level, thus suggesting a need for further investigation.

Finally, as a general conclusion, it can be noticed that the parameter estimates for inflation and the output gap are basically unaffected by the inclusion of the additional variables and remain, in general, strongly significant.

4.3.3. Sensitivity of the results to a different modelling of the inflation term

In Table 3 we allow for a different modelling of the inflation term by hypothesising that the central bank may react (a) either to past inflation (i.e. it is backward-looking, see eq. (21))³⁰ or (b) that central banks can only affect inflation with some lags (i.e. adopting a forward-looking Taylor rule, see eq. (20)). In both cases, the coefficient on the inflation term turns out to be significantly different from zero and not statistically different from 1.5. Moreover, these results are robust to the choice of modelling the inflation term as the difference between the euro area inflation rate and the central bank's average implicit "inflation objective" (see eq. (22)).³¹

28 See Annex B in GERDESMEIER and ROFFIA (2003) for further detail on the construction of this indicator.

29 The correction of the DJ Euro Stoxx 50 for the growth in the economy is done in order to construct a measure for the growth in stock prices not explained by real growth.

30 However, one could argue that the backward-looking behaviour is a little implausible, given that is inconsistent with the fact that central banks, usually facing long and variable lags of transmission, need to respond in due time.

31 In this case the formula for calculating the equilibrium real interest rate is equal to $(\alpha - \bar{\pi})$.

In the same table the robustness of the Taylor rule is also tested with respect to the measurement of the inflation variable, namely based on the HICP index excluding unprocessed food and energy prices or on the GDP deflator. The use of the HICP index excluding unprocessed food and energy prices inflation measure is based on the hypothesis that rises in oil prices combined with a depreciation of the euro exchange rate have been an important source of increase in the HICP inflation in the euro area. The results we obtain using this measure of inflation suggest a weight on the inflation term higher than the one for the headline HICP index (see eq. (23) and eq. (24)).³² Moreover, it is interesting to note that the coefficient on the output gap is lower. The same applies when the GDP deflator is used as a price measure (see eq. (25)).³³

4.3.4. Sensitivity of the results to the exclusion of the smoothing term and a change in the frequency of the data

We also investigate the performance of the original Taylor rule which omits the smoothing of the interest rate. In this case, the coefficient of inflation is approximately 2 and significantly different from 1.5 while the response to output is almost negligible (see eq. (26)).

The results of the baseline specification are not significantly affected when quarterly data are used (*cf.* eq. (27) and eq. (28)). In this case, the coefficient on inflation (output gap) is slightly higher (lower) when using industrial production compared to real GDP.

As a general observation, the explanatory power of all the models is rather high. In the literature this is usually attributed to the inclusion of the smoothing in interest rates. Our results confirm this view. Indeed, it can be noted that, irrespectively of the estimation method employed (see also the results in Table 5), the explanatory power of the equation decreases substantially when the lagged interest rate is omitted.

32 However, it must be noted that the regressions for inflation measured in terms of the HICP index excluding unprocessed food and energy prices are run on a shorter sample period (starting in January 1991) due to the lack of data for the euro area. This might have influenced the final estimates.

33 For the GDP deflator, only a backward-looking equation is found to perform satisfactorily. In the case of a forward-looking specification, convergence problems arise.

Table 3:
Estimates of Taylor rules in the euro area – sample period 1985:01–2002:02

No. of eq.	Specification	α (1)	ρ (2)	β (3)	γ (4)	δ (5)	$\bar{r}$ (6)	$\bar{R}^2$	J-test (7)	Wald Test ^a
Alternative specifications										
20	Forward-looking	1.73	0.97	1.82	0.77	(-)	2.95	0.99	0.051	0.55
GMM	inflation (t+6)	(2.34)	(0.01)	(0.99)	(0.55)					(0.58)
21	Backward-	1.79	0.98	1.53	1.39	(-)	2.59	0.99	0.042	0.67
GMM	looking inflation (t-12)	(2.57)	(0.02)	(1.08)	(1.10)					(0.51)
22	Deviation of infl. from its target	5.50	0.93	1.91	0.38	(-)	4.00	0.99	0.029	0.41
GMM		(0.48)	(0.04)	(0.45)	(0.24)					(0.66)
23	HICP (excl. unpr. food & energy prices) forward-look. infl. (t+12)	0.04	0.90	2.57	0.13	(-)	2.40	0.99	0.027	29.7
GMM		(0.52)	(0.02)	(0.20)	(0.13)					(0.00)
24	HICP (excl. unpr. food & energy prices) backward-look. infl. (t-12)	0.64	0.93	2.05	0.90	(-)	2.22	0.99	0.039	3.73
GMM		(0.58)	(0.01)	(0.29)	(0.15)					(0.03)
25	GDP deflator backward-look. infl. (t-12)	0.58	0.86	2.09	0.51	(-)	2.22	0.99	0.036	9.17
GMM		(0.42)	(0.03)	(0.14)	(0.07)					(0.00)
26	No lagged interest rate	1.61	(-)	2.08	0.06	(-)	3.23	0.67	0.031	66.2
GMM		(0.55)		(0.18)	(0.05)					(0.00)
1	Simple Taylor rule (monthly)	1.80	0.87	1.93	0.28	(-)	3.20	0.99	0.024	1.93
GMM		(0.67)	(0.05)	(0.25)	(0.13)					(0.15)
27	Baseline spec. (quarterly data) – ind. prod.	1.33	0.71	2.11	0.30	(-)	3.00	0.95	0.001	3.23
GMM		(0.94)	(0.18)	(0.34)	(0.34)					(0.20)
28	Baseline spec. (quarterly data) – real GDP	1.99	0.75	1.79	0.77	(-)	3.18	0.96	0.014	1.26
GMM		(1.02)	(0.16)	(0.42)	(0.91)					(0.53)

Notes to Table 3:

The equations are estimated using the Generalised Method of Moments. When not specified otherwise, the instrument set includes lagged values (up to 6 lags) of inflation and the output gap. Industrial production is used to capture output developments on a monthly frequency, apart from the cases when the use of real GDP is explicitly mentioned.

^a *p-value, null hypothesis that the coefficients on the output gap and the inflation term are jointly not statistically different from 0.5 and 1.5, respectively.*

4.3.5. Sensitivity of the results to different sample periods

In Table 4 we relax the assumption of parameter constancy by estimating the baseline specification over different sample periods. While the response coefficient of the central bank to the inflation term seems to have decreased over time since 1990, the coefficient of the output gap remains always below 0.6 but does not show any clear pattern.³⁴ Moreover, the value of the implied equilibrium real interest rate is always lower when estimated over more recent sample periods compared to its equivalent for the whole sample period.

Table 4:
Estimates of Taylor rules in the euro area – sample period 1985:01–2002:02

No. of eq.	Specification	α (1)	ρ (2)	β (3)	γ (4)	δ (5)	$\bar{r}$ (6)	$\bar{R}^b$	J-test (7)	Wald Test ^a
Eq. (1) estimated over different sample periods										
1	1985:01–	1.80	0.87	1.93	0.28	(-)	3.20	0.99	0.024	1.93
GMM	2002:02	(0.67)	(0.05)	(0.25)	(0.13)		(3.7)			(0.15)
29	1988:01–	0.75	0.91	2.20	0.33	(-)	2.55	0.99	0.046	4.43
GMM	2002:02	(0.59)	(0.04)	(0.25)	(0.17)					(0.01)
30	1990:01–	0.17	0.96	1.89	0.57	(-)	1.51	0.99	0.059	0.83
GMM	2002:02	(1.10)	(0.02)	(0.54)	(0.31)					(0.44)
31	1992:01–	0.89	0.95	1.59	0.55	(-)	1.78	0.99	0.074	0.03
GMM	2002:02	(1.06)	(0.02)	(0.58)	(0.36)		(2.1)			(0.97)
32	1995:01–	2.19	0.90	1.02	0.01	(-)	2.22	0.97	0.152	46.70
GMM	2002:02 ^b	(0.38)	(0.01)	(0.21)	(0.06)					(0.00)
33	1999:01–	2.60	0.72	0.45	0.30	(-)	1.78	0.97	0.148	145.5
GMM	2002:02	(0.20)	(0.04)	(0.10)	(0.03)					(0.00)

Notes to Table 4:

The equations are estimated using the Generalised Method of Moments. When not specified otherwise, the instrument set includes lagged values (up to 6 lags) of inflation and the output gap. Industrial production is used to capture output developments on a monthly frequency, apart from the cases when the use of real GDP is explicitly mentioned.

- a *p-value, null hypothesis that the coefficients on the output gap and the inflation term are jointly not statistically different from 0.5 and 1.5, respectively.*
- b *The instrument list includes: lagged values (1 up to 6 lags) of the monthly annualised inflation rate and the output gap; lagged values rate (2 up to 3) of the short-term interest rate, the monthly annualised changes in nominal M3 and the annual changes in commodity prices.*

³⁴ However, it should be noted that the time span of three to five years is basically too short to reliably estimate the coefficients.

4.3.6. Sensitivity of the estimates to different estimation techniques

We also cross-check the results of some selected reaction function specifications obtained with the GMM estimation method with those estimated using the Ordinary Least Squares (OLS) and the Two Stage Least Squares (TSLS) estimation methods. When considering OLS estimates (with the exception of eq. (34b)), the coefficient on the output gap seems to be upward biased whereas the coefficient on inflation seems to be downward biased compared to GMM estimates. Conversely, it turns out that the TSLS coefficient estimates (based on the same set of IV used for the GMM method) resemble closely those obtained with the GMM method. This result can be interpreted as an indication of the relative superiority of the Instrumental Variables approach.

Table 5:
Estimates of Taylor rules in the euro area – sample period 1985:01–2002:02

No. of eq.	Specification	α (1)	ρ (2)	β (3)	γ (4)	δ (5)	$\bar{r}$ (6)	$\bar{R}^b$	J-test (7)	Wald Test ^a
GMM, OLS and TSLS estimations										
1a	Simple Taylor	1.80	0.87	1.93	0.28	(-)	3.20	0.99	0.024	1.93
GMM	rule	(0.67)	(0.05)	(0.25)	(0.13)					(0.15)
1b	"	2.41	0.98	1.03	1.78	(-)	2.46	0.99	(-)	0.54
OLS		(3.10)	(0.01)	(1.25)	(1.27)					(0.58)
1c	"	1.77	0.88	1.94	0.26	(-)	3.18	0.99	(-)	2.28
TSLS		(0.59)	(0.04)	(0.23)	(0.12)					(0.10)
26a	No lagged	1.61	(-)	2.08	0.06	(-)	3.23	0.67	0.031	66.2
GMM	interest rate	(0.55)		(0.18)	(0.05)					(0.00)
26b	"	1.88	(-)	1.97	0.06	(-)	3.34	0.66	(-)	82.5
OLS		(0.31)		(0.11)	(0.03)					(0.00)
26c	"	1.25	(-)	2.24	0.01	(-)	3.11	0.68	(-)	86.47
TSLS		(0.34)		(0.12)	(0.04)					(0.00)
13a	Money growth	1.51	0.92	1.86	0.26	0.41	2.80	0.99	0.050	1.21
GMM	gap (b)	(0.69)	(0.03)	(0.30)	(0.18)	(0.17)				(0.30)
13b	"	4.39	0.99	-0.01	2.18	0.28	2.92	0.99	(-)	0.25
OLS		(5.31)	(0.01)	(2.71)	(2.35)	(0.85)				(0.78)
13c	"	2.843	0.96	1.18	0.71	0.36	3.11	0.99	(-)	0.05
TSLS		(2.16)	(0.03)	(1.05)	(0.73)	(0.29)				(0.95)
34a	No lagged	2.18	(-)	1.77	-0.02	0.40	3.34	0.74	0.068	52.90
GMM	interest rate & money growth gap (b)	(0.53)		(0.21)	(0.05)	(0.11)				(0.00)

No. of eq.	Specification	α (1)	ρ (2)	β (3)	γ (4)	δ (5)	$\bar{r}$ (6)	$\bar{R}^b$	J-test (7)	Wald Test ^a
34b	“	1.34	(-)	2.04	-0.10	0.42	2.90	0.75	(-)	149.90
OLS		(0.31)		(0.13)	(0.03)	(0.06)				(0.00)
34c	“	1.07	(-)	2.15	-0.10	0.40	2.80	0.76	(-)	132.49
TSLs		(0.33)		(0.13)	(0.04)	(0.06)				(0.00)
5a	HP-filter on real	1.18	0.84	2.16	0.53	(-)	2.92	0.98	0.019	11.1
GMM	GDP ^b	(0.54)	(0.06)	(0.20)	(0.64)					(0.00)
5b	“	0.48	0.99	1.54	7.89	(-)	1.29	0.99	(-)	0.40
OLS		(4.61)	(0.01)	(1.60)	(8.99)					(0.67)
5c	“	1.40	0.89	2.11	0.73	(-)	3.07	0.99	(-)	5.70
TSLs		(0.58)	(0.04)	(0.21)	(0.64)					(0.00)

Notes to Table 5:

The equations are estimated using the Generalised Method of Moments. When not specified otherwise, the instrument set includes lagged values (up to 6 lags) of inflation and the output gap. Industrial production is used to capture output developments on a monthly frequency, apart from the cases when the use of real GDP is explicitly mentioned.

a *p-value, null hypothesis that the coefficients on the output gap and the inflation term are jointly not statistically different from 0.5 and 1.5, respectively.*

b *When potential output is computed using the Hodrick-Prescott filter, the smoothing parameter is set equal to 14400 for monthly data and 1600 for quarterly data.*

4.3.7. Sensitivity of the results to selected Taylor rule variants

Table 6 contains a comparison of some variants of the Taylor rule. These variants not only include the deviation of inflation from its estimated objective (see eq. (22a)), but also, as additional explanatory variables, either (i) the money growth gap (b) indicator (see eq. (22b)) or (ii) the changes in real asset prices corrected for economic activity growth (see eq. (22c)). Both additional explanatory variables turn out to exhibit the expected sign and to be statistically different from zero. However, in the last specification, all coefficient estimates vary substantially with respect to those of the baseline equation (see eq. (1)).

Table 6:
Estimates of Taylor rules in the euro area – sample period 1985:01–2002:02

No. of eq.	Specification	α (1)	ρ (2)	β (3)	γ (4)	δ (5)	$\bar{r}$ (6)	$\bar{R}^2$	J-test (7)	Wald Test ^a
Variants of eq. (22)										
22a	Deviation of infl.	5.50	0.93	1.91	0.38	(-)	4.00	0.99	0.029	0.41
GMM	from its target	(0.48)	(0.04)	(0.45)	(0.24)					(0.66)
22b	Deviation of infl.	4.91	0.94	1.56	0.30	0.75	3.41	0.99	0.049	0.40
GMM	from its target & money growth gap (b)	(0.44)	(0.03)	(0.50)	(0.23)	(0.23)				(0.67)
22c	Deviation of	2.21	0.97	2.65	0.72	0.08	0.71	0.99	0.065	3.21
GMM	infl. from its	(1.20)	(0.02)	(0.56)	(0.45)	(0.04)				(0.04)
	target & DJ real									
	Euro Stoxx 50									
	corrected for ind.									
	prod. growth									

Notes to Table 6:

The equations are estimated using the Generalised Method of Moments. When not specified otherwise, the instrument set includes lagged values (up to 6 lags) of inflation and the output gap. Industrial production is used to capture output developments on a monthly frequency, apart from the cases when the use of real GDP is explicitly mentioned.

a *p-value, null hypothesis that the coefficients on the output gap and the inflation term are jointly not statistically different from 0.5 and 1.5, respectively*

Table 7 presents the results derived from a similar type of exercise using the specification of the Taylor rule which includes the money growth gap (b) indicator (see eq. (13a)). In this respect, we consider two variants: the first one omits the smoothing term, whereas the second one contains the additional explanatory variable represented by the real DJ Euro Stoxx 50 corrected for economic growth. Independently of the inclusion of the smoothing of the interest rate, the coefficient of the output gap is not statistically different from zero. The opposite result holds for the specification in eq. (36) where the output gap and asset prices enter significantly into the equation whereas the money growth gap indicator is not found to be of relevance any longer.³⁵

³⁵ A possible explanation for this result may be represented by the fact that asset prices might be, at least in certain periods, a relevant explanatory variable of money demand. Therefore, when

Table 7:
Estimates of Taylor rules in the euro area – sample period 1985:01–2002:02

No. of eq.	Specification	α (1)	ρ (2)	β (3)	γ (4)	δ (5)	λ	$\bar{r}$ (6)	$\bar{R}^2$	J-test (7)	Wald Test ^a
Variants of eq. (13)											
13a GMM	Money growth gap (b)	1.51 (0.69)	0.92 (0.03)	1.86 (0.30)	0.26 (0.18)	0.41 (0.17)	(-)	2.80	0.99	0.050	1.21 (0.30)
35 GMM	No lagged interest rate & money growth gap (b)	2.18 (0.53)	(-)	1.77 (0.21)	-0.02 (0.05)	0.40 (0.11)	(-)	3.342	0.74	0.068	53.00 (0.00)
36 GMM	Money growth gap (b) & real DJ Euro Stoxx 50 corrected for ind. prod. growth	-1.24 (0.97)	0.95 (0.02)	2.36 (0.40)	0.55 (0.25)	-0.07 (0.24)	0.06 (0.03)	0.80	0.99	0.072	2.77 (0.07)

Notes to Table 7:

The equations are estimated using the Generalised Method of Moments. When not specified otherwise, the instrument set includes lagged values (up to 6 lags) of inflation and the output gap. Industrial production is used to capture output developments on a monthly frequency, apart from the cases when the use of real GDP is explicitly mentioned.

^a *p-value, null hypothesis that the coefficients on the output gap and the inflation term are jointly not statistically different from 0.5 and 1.5, respectively.*

4.4. The equilibrium real interest rate

As already mentioned in the assessment of the results presented in Table 4, the implicit equilibrium real interest rate has experienced a downward trend over time. A possible explanation of the fact that the equilibrium real interest rate implied by the Taylor rule could have been higher in the 80s and early 90s than at present is the fact that the most recent period was one of disinflation and significant fiscal consolidation, together with increasing credibility of the convergence process.

introduced together with M3 in the set of the right-hand side variables in the policy reaction function, a problem of multicollinearity might arise thus impacting on the significance of the coefficients. This topic is, however, left for future research.

We carry out a further investigation of the behaviour of the implicit equilibrium real interest rate by considering the following two different approaches, both based on a time-varying inflation objective.

In the first approach, we derive the value of this variable recursively using the (time-varying) euro area inflation objective assuming that, during the convergence process, this inflation objective in each recursively selected sample period coincided with its latest observation in the same selected sample period.³⁶ Figure 1 below shows that some local peaks were present around the early 90s but, subsequently, the implicit equilibrium real interest rate exhibits a steep decline from 1996 onwards.

In our second approach, we derive the equilibrium real interest rate using a Kalman filter framework (see Annex D in GERDESMEIER and ROFFIA, 2003, for further detail). In particular, it is assumed that, in the baseline specification of the Taylor rule (see eq. (1)), the constant (out of which the equilibrium real interest rate is derived) follows an autoregressive process of order one (i.e. it is an AR(1) process) while the other coefficients are assumed to be constant.³⁷ In order to derive the equilibrium real interest rate, the time-varying inflation objective is used. In this case, the equilibrium real interest rate looks a bit more volatile. Nevertheless, from 1996 onwards, this procedure also shows a pronounced decline in the equilibrium real interest rate which reached a value of around 1 % at the end of the sample.

It turns out that the target interest rate derived from the Taylor rule specification estimated using the Kalman filter seems to track quite well the pattern of the short-term interest rate (see Figure 2).³⁸

36 This refers to the inflation objective described in Annex B in GERDESMEIER and ROFFIA (2003). In this exercise we use the baseline specification (see Table 1, eq. (1)).

37 In principle, there are good reasons to assume that the behaviour of the real interest rate follows a random walk. However, our AR(1) specification is more encompassing in that it allows for parameter values different from one. The resulting coefficient, however, is 0.99 with a standard error of 0.01, thus basically confirming the random walk hypothesis.

38 This result holds also when a backward-looking specification is adopted.

Figure 1:
Recursive and time-varying estimate of the equilibrium real interest rate in the euro area

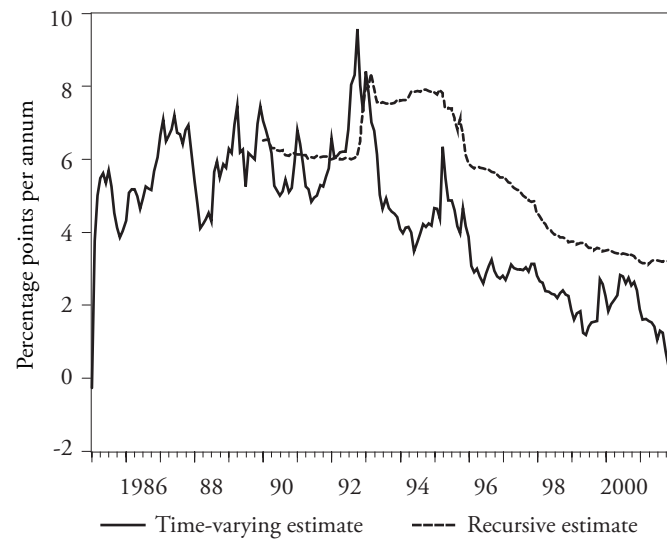
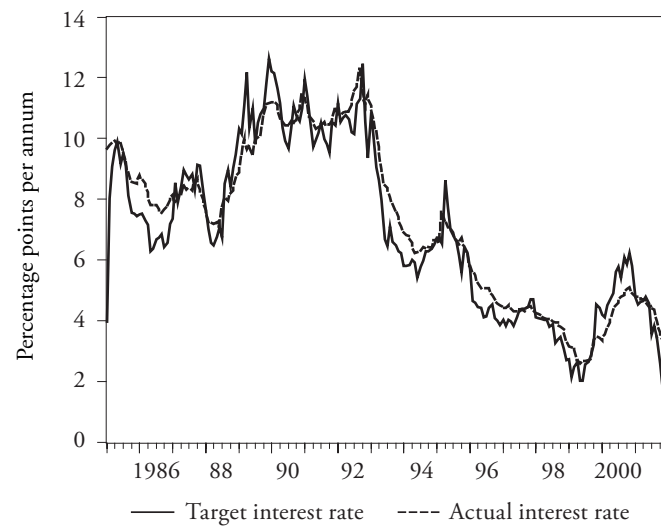


Figure 2:
Actual and target interest rates implied by the Taylor rule (baseline specification)



5. Conclusions

This study has investigated the impact of a number of variables on the decisions of a fictitious central bank in the euro area over the last two decades. The exercise has also considered a number of other issues, such as a robustness check of the basic results with respect to various sources of data and model uncertainty. The following conclusions can be drawn.

First, Taylor-like rules estimated over the last two decades appear to be able to capture on average, from an *ex-post* perspective, substantial elements of past monetary policy behaviour of a fictitious central bank in the euro area especially when a smoothing term (i.e. a lagged interest rate) is included. The estimated (long-run) coefficients for the main variables often do not differ (in statistical terms) from those originally suggested by Taylor (i.e. 1.5 and 0.5 for inflation and the output gap, respectively). In particular, considering the simple version of the Taylor rule with smoothing, the response coefficient to inflation would imply that an increase in the inflation rate of one percentage point is associated with 190–220 basis points higher short-term nominal interest rate. The range of the response of the interest rate to a change in the output gap of one percentage point would vary between 13 and 50 basis points. However, the size of this estimated response is slightly affected by the measure employed for real activity, being lower when using industrial production instead of GDP.

Second, the coefficient on the lagged interest rate appears to be very stable and significant across all the specifications, ranging between 0.8 and 0.9. This result could be well explained on both statistical and economic grounds; however, it may be worth further investigation.

Third, the deviation of M3 growth from its reference value (also interpretable as a money growth gap indicator) enters significantly equation and slightly reduces the coefficients of both the output gap and inflation. A possible interpretation could be that, over that sample period, excess money growth contained information for monetary policy makers which was not (fully) included either in the inflation term or the output gap. In relation to this, in the case of a Taylor rule specification including money among the right-hand side variables, the issue of “observational equivalence” should be noted. Given the fact that nominal money and nominal income (as well as real money and real income) are highly correlated, it might well be that the estimation procedure tends to mix the effects of these two variables. Still, given that monetary data become available earlier than nominal GDP data and are usually subject to smaller revisions, it may be rational for central banks to focus on the former in the real-time policy process.

Finally, the implied estimate of the equilibrium real interest rate is around or above 3 % when estimating since the early 80s, but it tends to decline when data for the most recent period (the 90s) are used.

This notwithstanding, the following caveats need to be kept in mind. First, these investigations are of an *ex-post* nature. Therefore, Taylor rules might be able to describe to some degree *ex-post* monetary policy of central banks which have been successful in stabilising inflation (and thereby output), independently of the actual strategies and policies followed by the same central banks.

Second, our results refer to a fictitious central bank given that the ECB was only officially responsible for the conduct of monetary policy in the euro area with the start of Stage Three of EMU. In this respect, prior to 1999 the outcome reflects the “average” monetary policy of the national central banks in the countries currently forming the EMU. Therefore, our results should not be overemphasised given the fact that the Deutsche Bundesbank, when deciding on the course of monetary policy, assigned a high weight to developments in monetary aggregates while the monetary policy of many European central banks was constrained by the ERM.

Third, the estimation of these rules does not take into account that the information on some variables is not available in real time whereas central banks are constrained to operate in real time. The data used are thus sometimes incomplete and often subject to substantial revisions. This might apply to the inflation forecasts as well as to measures for the output gap.

Fourth, there is substantial uncertainty around the parameters estimates which turn out to be rather sensitive to the specification of the rule (e.g. forward-looking versus backward-looking), the measure and the construction of the variables included in the rule and the sample period considered for the estimation.

Finally, the high degree of inertia or smoothing in the policy interest rate might reflect a deliberate smoothing objective of the central bank or a possible misspecification of the model (pointing, for instance, to omitted variables which are autocorrelated or to serially correlated shocks), thus leaving room for future research.

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SUMMARY

This study contains a set of estimates of reaction functions for the euro area based on a monthly data set starting in 1985. The main aim is to assess the performance of Taylor rules and to evaluate whether alternative specifications based, *inter alia*, on the inclusion of additional variables not contained in the original specification proposed by Taylor or the use of different measures of the output gap and the inflation term, can better track the interest rate setting in the euro area. An interesting result is that monetary developments (in the form of a money growth gap indicator derived as the deviation of M3 growth from its estimated reference value) enter significantly as an additional variable in a Taylor-like policy rule specification for the euro area.

ZUSAMMENFASSUNG

Die vorliegende Studie beinhaltet eine Reihe von Schätzungen hinsichtlich einer Zentralbankreaktionsfunktion für das Euro-Währungsgebiet. Ziel ist es, auf der Basis von Monatsdaten zu untersuchen, inwiefern eine Taylor-Regel das tatsächliche Zentralbankverhalten abzubilden vermag. Zudem wird analysiert, ob alternative Masse für die Outputlücke und die Inflation den Erklärungsgehalt einer solchen Regel verbessern. Dabei zeigt sich, dass monetäre Entwicklungen, wie beispielsweise die Abweichungen des M3-Wachstums vom (geschätzten) Referenzwert, signifikant und mit korrektem Vorzeichen in eine derartige geldpolitische Regel für das Euro-Währungsgebiet eingehen.

RÉSUMÉ

Cette étude présente une série d'estimations des fonctions de réaction pour la zone euro, sur la base de données mensuelles à partir de 1985. L'objectif principal de l'étude est d'évaluer la performance des règles de politique monétaire à-la-Taylor. En particulier, il s'agit de voir si des spécifications alternatives fondées, *inter alia*, sur l'inclusion de variables supplémentaires (exclues de la spécification originale envisagée par Taylor) ou sur l'emploi de mesures différentes de l'écart de production et de l'inflation, sont plus à même de décrire le processus de formation des taux d'intérêt dans la zone euro. L'étude montre que l'évolution de la masse monétaire (mesurée par un indicateur d'écart de croissance monétaire, c'est-à-dire la déviation du taux de croissance de l'agrégat large M3 par rapport à sa valeur de référence estimée) est une variable supplémentaire pertinente dans le contexte d'une règle à-la-Taylor pour la zone euro, ce qui représente un résultat intéressant.