Some New Results on Interest Rate Rules in EMU and in the US

Rafael Doménech[a], Mayte Ledo[b] and David Taguas[b]
[a]University of Valencia
[b]Research Department, BBVA

March 2001

Abstract

This paper offers two new results on interest rate rules. First, we show that the empirical evidence from 1970 onwards for the US is compatible with a Taylor rule when we consider the possibility of changes in the inflation target and in the real interest rate. Second, recursive estimates of a forward-looking version of the Taylor rule for EMU confirm an increasing weight for inflation in the area, possibly as a consequence of the EMS, and, furthermore, a convergence in the nineties to the German value observed for the whole period. This process has coincided with an important reduction in the deviation of inflation across EMU countries. The results also show that credibility problems have coincided with periods of higher real interest rate in the euro zone, which cannot be explained using the interest rule.[1]

Keywords: interest rates, monetary policy rules, convergence.
JEL Classification: E52, E58.

1. Introduction

The analysis of the behavior of the Federal Reserve and, more recently, of the European Central Bank (ECB) has received an increasing attention during the last few years.[2] This trend can be partially explained by the successful contribution of Taylor (1993), who provides a very simple characterization of the Federal Reserve "reaction function" in terms of the nominal federal funds rate, which depends on two clear objectives of monetary policy: the deviations of current inflation from an inflation target and the deviations of real output from its long-run trend. The fact that this rule seems to track very closely the

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[1] This paper has benefited from the valuable suggestions by two anonymous referees and J. Andrés. R. Doménech acknowledges the financial support of CICYT SEC99-0820 and Instituto de Economía Internacional (UV-EG). *Address for comments*: R. Doménech, Dpto. Análisis Económico, Universidad de Valencia, 46022-Valencia (SPAIN). *e-mail*: rafael.domenech@uv.es.

[2] Although this literature is constantly growing, Clarida, Gali and Getler (1999) and Taylor (1999) are good starting surveys to find a large list of references on this topic.

nominal federal funds rate from 1979 onwards has been considered by many economists as clear evidence that the Fed has implemented an activist stabilization monetary policy. Given this empirical evidence some authors (see Romer, 2000) have even suggested the convenience of changing the standard aggregate demand and supply framework used in macroeconomics to incorporate such an interest rule.

The original Taylor rule was carefully examined in recent studies at both theoretical and empirical levels. At the theoretical level, despite its simplicity, the Taylor rule seems to stabilize inflation and output in a way close to optimal policy rules in many macroeconomic models (see, e.g., Taylor, 1999, or Lansing and Trehan, 2001).[3] At the empirical level, it was extended in several directions. The first one allows for interest rate smoothing, since central banks seem to adjust interest rates gradually over time to their target levels (see, e.g., Goodfriend, 1991). The second extension was the estimation of forward looking versions of the Taylor rule (see, e.g., Clarida, Gali and Gertler, 1998 and 1999), in some cases enlarging the set of goal variables, for example, including the real exchange rate. As a result of these two extensions most estimates of central banks interest rules incorporate an adjusting mechanism to the interest rate target and expectations, at least, about future inflation and output gaps.

The Taylor rule has been used as a benchmark to evaluate stabilization policy of the Fed, the ECB and other central banks, as the Bundesbank or the central banks of Japan, England, France or Italy. In Fact, we can interpret Taylor-type interest rules as interesting exercises in order to examine the monetary policy of central banks. As Clarida, Gali and Gertler (1998 and 2000), Judd and Rudebusch (1998), Peersman and Smets (1999) or Gerlach and Schnabel (2000) have shown, the results of these exercises tend to find that central bankers were more permissive with inflation during the seventies, since in their reaction functions the response of interest rates to current or expected inflation was lower than during the eighties or nineties.

In this paper we initially compare the performance of the Taylor rule in the United States and in Europe. Since we are interested in estimating an interest rule for the ECB, we use weighted data for countries in EMU, exploring to what extend monetary policy in the past could be an appropriate guide for the future. Preliminary results add evidence in line with the most recent literature. But, a more detailed analysis shows some new features. In the US the short run interest rate and the Taylor rule had the same dynamics, not only in the eighties or nineties, but also in the seventies. Thus, a stabilization role for monetary policy for these years could be obtained simply by including in

[3] Svensson (2000) argues than in small open economy models the optimal reaction function will, in general, not be a Taylor rule since national central banks also use information about foreign inflation, interest rates and output.

the monetary rule changes in the inflation target and/or in the equilibrium real interest rates. Conversely to previous ones, these results suggest a change in the idea that monetary policy has not been activist enough in the seventies. In EMU, this "variable rule" does not seem to be a good explanation, but the results are fairly good for Germany. As monetary policies in the rest of EMU countries converged to the Bundesbank pattern given the compromises assumed with the EMS, the fight against inflation became a priority. Recursive estimates of a forward-looking version of the Taylor rule for EMU confirm an increasing weight for inflation in this area and, furthermore, a convergence from the mid eighties onwards to the German value observed for the whole period. When we estimate forward-looking rules for the US and EMU, the results for at least the last decade reveal that monetary policy reacts to inflation in a similar way in both areas.

The paper is structured as follows. In the second section we review the behavior of the original Taylor rule in the US and EMU, and we explore the fact that a change in the inflation target in the US helps us to recover an anti-inflationary bias in the monetary policy in the United States for the seventies. The third section presents the recursive estimates of a forward-looking interest rate rule. Most attention is devoted to analyzing the increasing inflation weight in EMU countries. We conclude in Section 4.

2. The Taylor rule

The original interest rule proposed by Taylor (1993) decomposed the target nominal interest rate (i_t^*), used as an instrument by the central bank, in three different terms: the current inflation plus the equilibrium real interest rate ($\pi_t + r_t^*$), and the response to deviations of current inflation from its target ($\pi_t - \pi_t^*$) and of output from its long-run trend level ($y_t - \overline{y}_t$). That is,[4]

$$i_t^* = (\pi_t + r_t^*) + (\beta - 1)(\pi_t - \pi_t^*) + \gamma(y_t - \overline{y}_t)$$

or

$$i_t^* = (r_t^* + \pi_t^*) + \beta(\pi_t - \pi_t^*) + \gamma(y_t - \overline{y}_t). \tag{1}$$

In order to make this rule operational, Taylor proposed $\beta = 1.5$, $\gamma = 0.5$ and $r_t^* = \pi_t^* = 0.02$. Additionally current inflation was defined as the difference of the log of the GDP deflator in t with respect to four quarters before, and the current output gap as the difference of real GDP with respect to a log linear trend estimated from 1984:1 to 1992:3.

In Figures 1 and 2 we have represented the Taylor rule for the United States and EMU area from 1970:1 to 1999:4 using the assumptions and definitions given above, ex-

[4] In the next section we introduce interest rate smoothing in this kind of rules.

cept for the output gap.[5] As we can see, a common characteristic between the United States and EMU countries is that the target interest rule defined in equation (1) was above the nominal interest rate during the seventies. In the United States this result changes from 1979:4 onwards, whereas in EMU countries the target was above the nominal interest rate until 1984:2. Another important difference was that the deviation of the nominal interest rate from the Taylor rule during the seventies was much larger in Europe than in the US. In other words, according to the Taylor rule, monetary policy in EMU countries was more permissive of inflation and over a longer period of time than in the United States.

In Table 1 we present additional results regarding the Taylor rule, with the estimation of the following equation:

$$i_t = a_0 + a_1 i_t^* + \varepsilon_t \tag{2}$$

where i_t is the current nominal interest rate and i_t^* is the target defined in equation (1).

In the case of the United States, the usual interpretation (Clarida, Gali and Gertler, 2000, or Judd and Rudebusch, 1998) of these results is that the rule explains reasonably well the Volcker and Greenspan period, but not the Burns and Miller mandates: compared with the results obtained from 1970:1 to 1999:4, the $\overline{R}^2$ increases notably in the Volcker and Greenspan years and, more importantly, the estimated coefficient for a_1 is close to unity, indicating that Taylor's assumptions about the values of β and γ seem to be well suited to the behavior of the interest rate in this period. However, when we estimate equation (2) for the seventies, the $\overline{R}^2$ also increases, a_1 is again close to unity, and we cannot reject the hypothesis of a_1 being the same in both subsamples.[6] The main differences between the seventies and the Volker and Greenspan period is in the estimated value of a_0, that is a function of r_t^* and π_t^*. Clearly, it is not possible to distinguish between variations in a_0 given by increases in r_t^* or by decreases in π_t^* without additional assumptions, and probably what happened at the end of the seventies was a mixture of both types of changes. If different values of π_t^* are the main source of the changes in a_0, a reasonable hypothesis to test is that, although the weights of inflation and the output gap in the rule were very similar during the whole period, monetary policy pur-

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[5] For the United States we use the Congressional Budget Office estimates of output gap. In the case of Europe, we have estimated the output gap as the deviation of the log of GDP from a quadratic function of time. The data set and an Appendix describing the source and definitions of the variables, as well as the aggregation procedure to obtain EMU variables, are available at http://iei.uv.es/~rdomenec/rules/rules.html.

[6] The estimated equation from 1970:1 to 1979:4 includes a time dummy which is equal to 1.0 in the first and second quarter of 1975.

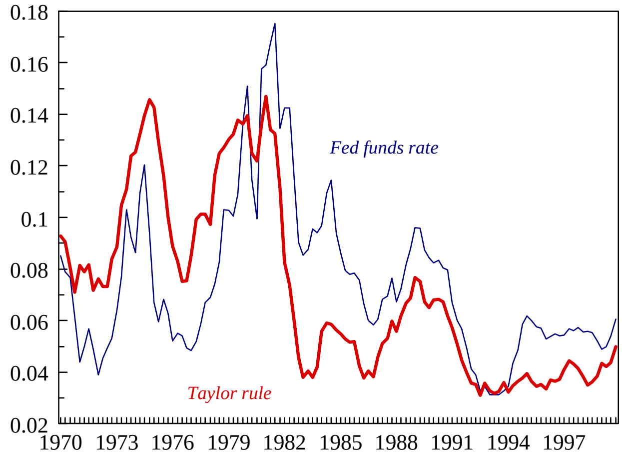

Figure 1: *Taylor rule for the United States.*

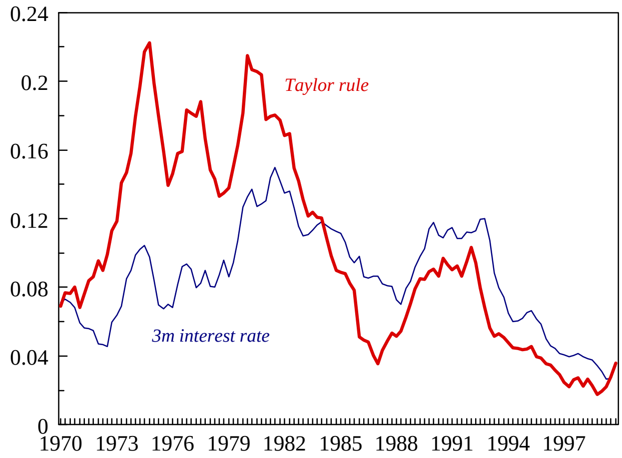

Figure 2: *Taylor rule for EMU countries.*

sued different inflation objectives in both subsamples, it being more aggressive in the post-Volcker years.[7]

In Table 2 we offer some statistics of the main variables involved in the original Taylor rule for two different subsamples, in order to provide some estimates of the equilibrium real funds rate and the inflation target. Our assumption about π_t^* is that in the seventies probably it was not too far from the average inflation in this period, whereas the inflation target in the Volcker and Greenspan period was equal to 0.02. Defining the cyclical or short-run component of the interest rate target as

$$i_t^c = 1.5(\pi_t - \pi_t^*) + 0.5(y_t - \overline{y}_t) \tag{3}$$

we can obtain two estimates of r_t^*:

$$r_t^* = \overline{i_t} - \pi_t^* - \overline{i_t^c} \tag{4}$$

where the bar over the variables denotes the averages across each subsample. Given these assumptions, a possible alternative interpretation of the main differences in monetary policy between the seventies and the Volcker and Greenspan years is that, although the Fed implemented activist stabilization policies in both periods, the inflation objective was more ambitious from 1980 onwards, in a context of higher real interest rates (probably even higher in the Volcker years).

In Figure 3 we have represented an alternative "variable rule" obtained with these two different inflation targets ($\pi_{70-79}^* = 0.065$, $\pi_{80-99}^* = 0.02$) and the estimated values of the equilibrium real funds rates ($r_{70-79}^* = 0.011$, $r_{80-99}^* = 0.036$). The difference with the original Taylor rule is obvious, since the rule with variable π_t^* and r_t^* tracks the Fed funds rate much better. When we estimate equation (2) using this variable rule we can accept the hypothesis $a_0 = 0.0$ and $a_1 = 1.0$ with a significance level equal to 0.10 (the $\overline{R}^2$ of the restricted model is equal to 0.713 for the whole period). The highest and most persistent deviation of the interest rate from the rule occurred from 1982 to 1985. The explanation of this deviation is an open question since there are alternative explanations. One possibility is that during these years the Fed persisted in a policy of higher interest rates, well above the rule, until policymakers considered that inflation was under control, close to the inflation target, as it occurred at the end of 1985. A second explanation is that the equilibrium real interest rate was higher in this period due to the large federal budget deficits (e.g., the ratio of the budget deficit over the GDP was approximately

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[7] Orphanides (2000) also finds that activist stabilization policies can explain reasonably well the empirical evidence on interest rates during the seventies, but offers an alternative explanation based on real time data for the US economy.

equal to 6.0 per cent, the largest figure during the last 40 years). Thirdly, estimates of the output gap in these years vary significantly when we use alternative procedures. Thus, whereas the CBO figure was equal to -0.081, the output gap estimated by the Hodrick-Prescott filter was -0.047. Finally, it is possible that β was higher than 1.5, the value assumed by Taylor, during the Volcker mandate. We analyze the latter possibility in the next section.

The evidence for the EMU area is in some respects more unfavorable with the assumptions of the original Taylor rule. As we can see in Figure 2, the original Taylor rule seems to track the nominal interest rate only from mid eighties onwards. Moreover, the rule is beyond doubt above the observed interest rates in the seventies and early eighties, whereas in the remaining years it is clearly below. Additionally, conversely to US experience, we do not find any indication that this result could be driven by a change in the constant term $r_t^* + \pi_t^*$ that appears in equation (1). As shown in Table 2, although the constant term (a_0) almost doubles in the eighties and nineties with respect to the seventies, the coefficient of a_1 is still well below unity.[8]

The comparison of Figure 4 for EMU countries with Figure 3 for the United States also clarifies the performance on the interest rule. In this figure we are allowing for different equilibrium real interest rates across subperiods, and different inflation targets. The most favourable scenario is one in which the inflation target for the seventies is the average rate of inflation, then it decreases steadily to 2.0 per cent from 1980:1 to 1982:4, remaining at these levels for the rest of the sample, the real equilibrium interest rate is $r_t^* = 0.011$ during the seventies.[9] As we can see, this variable rule performs rather well during the nineties, but even allowing for a less ambitious inflation target in the seventies and early eighties, the interest rates implied by the rule were higher than the observed interest rates in most of the years during this period. A possible explanation for these differences is that, simultaneously, the inflation target has been different in the EMU countries, and that monetary policy was in general less active and more accommodative until the mid eighties than in the United States. In other words, if β was lower than the value assumed in the original Taylor rule in the seventies and early eighties, this can explain why the target interest rate implied by the rule is well above the observed interest rate and, conversely, we can also explain the result obtained in Table 1, where the estimated value of a_1 is below 1.0.

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[8] The hyothesis $a_1 = 1.0$ from 1980:1 to 1999:4 is clearly rejected at the 99 per cent significance level.

[9] It is important to note that credibility problems in many European countries could have increased the equilibrium real interest rate in the euro area. The period 1980:1-1982:4 roughly comprises the starting dates chosen by Clarida, Galí and Getler (1999) in the estimation of their forward interest rules for Germany (March, 1979), France (May, 1983) and Italy (June, 1981).

It is important to note that what we consider to be the monetary policy in the EMU area in most of the years of our sample is only a weighted average of eleven, and not always coincident, monetary policies. Therefore, the failure of the Taylor rule to explain the behavior of interest rates should be interpreted taking into account that EMU countries had different inflation targets (π_t^*) and conducted their monetary policy with diverse sensitivities to inflation (i.e., different β). Moreover, most of these countries were engaged in the ERM, at least in part of the sample years we consider. In these circumstances, for some countries interest rates could not reflect appropriately domestic macroeconomic conditions, as expected in the rule (see Clarida, Gali and Gertler, 1998, for more details of the UK, France and Italy experience). This issue is related to the Bundesbank's dominance of the current monetary policy of the ECB. Assuming that the ECB has inherited the reputation and the targets of the Bundesbank's monetary policy there are two interesting hypotheses to test:

1. To what extent the Taylor rule can explain the behavior of German interest rates
2. To what extent the superior performance of the interest rule during the nineties is a consequence of the convergence process of the monetary policy of different EMU countries to that of the Bundesbank.

We try to answer the second question in the next section, for the moment we shall focus on the performance of the interest rule to explain the behavior of short-run interest rates in Germany. In this case the interest rule seems to track reasonably well interest rates for the whole period. Surprisingly, the estimated value of a_1 in equation (2) is higher in the seventies than during the remaining years (the rule is more volatile than the observed interest rates), although this result can be partially explained by the economic expansion following the German reunification in 1991 and the particular performance of the consumer price index in 1986.[10] These results show that the “variable rule” seems to fit very well the behavior of German interest rates, but not the interest rate for all EMU countries. The second hypothesis, the convergence of monetary policy to the Bundesbank pattern is analyzed in the following section.

[10] Again the consideration of these two subsamples (with 1980 as the splitting year) can be justified by economic reasons. For example, Clarida, Gali and Getler (1998) estimate their forward-looking interest rule after March 1979, when Germany entered the EMS.

Table 1

Interest rates and Taylor rules

$i_t = a_0 + a_1 i_t^* + \varepsilon_t$

	USA	EMU
	1970:1-99:4	1970:1-99:4
a_0	0.036	0.053
	(7.18)	(11.8)
a_1	0.539	0.325
	(8.50)	(8.40)
$\overline{R}^2$	0.374	0.377
	1970:1-79:4	1970:1-82:4
a_0	-0.019	0.022
	(-2.12)	(2.09)
a_1	0.908	0.463
	(10.6)	(6.88)
$\overline{R}^2$	0.741	0.477
	1980:1-99:4	1983:1-99:4
a_0	0.017	0.027
	(4.45)	(7.31)
a_1	1.026	0.863
	(15.3)	(16.1)
$\overline{R}^2$	0.747	0.792

Table 2

Averages for the United States

	70:1-79:4	95:1-99:4
i_t	0.073	0.055
π_t	0.064	0.017
$y_t - \overline{y}_t$	-0.005	0.007
π_t^*	0.065	0.020
i_t	-0.003	-0.001
r_t^*	0.011	0.036
$r_t^* + \pi_t^*$	0.076	0.056

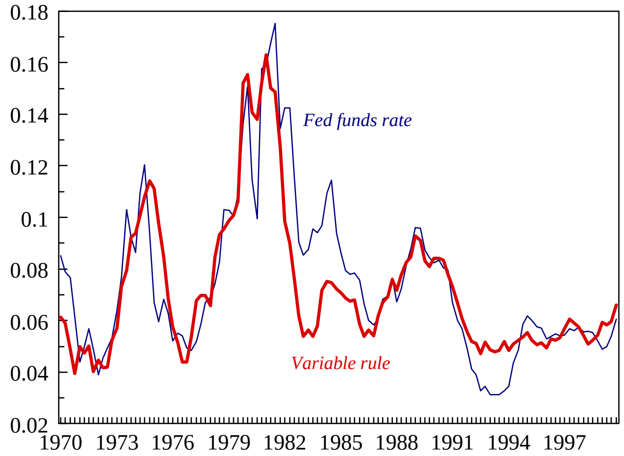

Figure 3: *An alternative estimate of the Taylor rule for the United States with variable inflation and equilibrium real funds rate.*

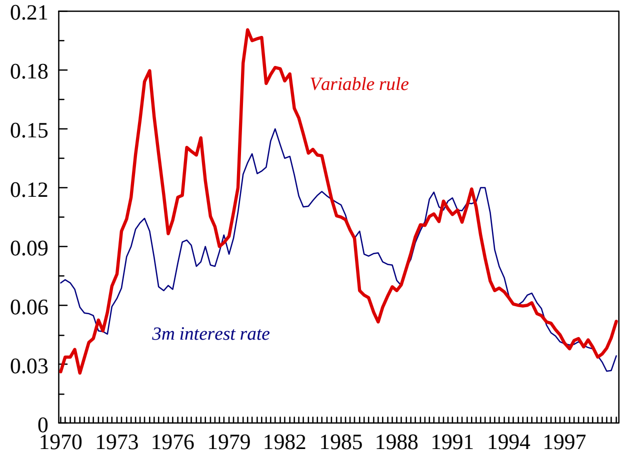

Figure 4: *An alternative estimate of the Taylor rule for EMU countries with variable inflation targets and equilibrium real funds rate.*

3. Recursive estimates of forward-looking interest rules in the US and EMU

Given the evidence presented in the preceding section, the recursive estimation of the interest rule can provide additional information about the changes along the sample years of inflation and output gap weights in the rule (i.e., γ and β), and also about the term composed by the equilibrium real interest rate and the target inflation (r_t^* and π_t^* respectively).

Our starting point is the forward-looking interest rule proposed by Clarida, Galí and Gertler (1998 and 2000), which assumes that the instrument of monetary policy is the interbank lending rate. In contrast to the Taylor rule, the target rate i_t^* is a function of the gaps between expected inflation and output and their target levels:

$$i_t^* = (r_t^* + \pi_t^*) + \beta_t(E[\pi_{t+i}/I_t] - \pi_t^*) + \gamma_t E[(y_{t+j} - \overline{y}_{t+j})/I_t] \tag{5}$$

where E is the expectation operator and I_t comprises information available when the central bank decides its target rate. We can consider that the original Taylor rule is just a particular case of the rule implied by equation (5), in which $i = j = 0$, $\beta_t = 1.5$, $\gamma = 0.5$ and I_t also includes the information about current prices and the output gap. However, the forward-looking rule has the advantage of considering other situations in which, for example, the central bank is more concerned with future inflation. Another important feature of equation (5) is that we allow for changes in r_t^*, π_t^*, β_t and γ_t. For some given values of r_t^* and π_t^*, we can characterize monetary policy as stabilizing if $\beta_t > 1.0$ or as accommodative if $\beta \leq 1.0$, since in this case an increase in inflation is accompanied by a decrease of the ex-post real interest rate. The same characterization of monetary policy applies for values of γ_t greater (stabilizing) or lower (accommodative) than zero. Nevertheless, it should be acknowledged a potential identification problem in the estimation of these parameters which it is often not considered in the literature. For example, a positive value of γ can reveal an activist monetary policy but it can be also the result of other forces which cause the short run interest rate to vary prociclically. In other words, equation (5) do not fully characterize the exact policy reaction function of the central bank and it objective function, and other pieces of information (e.g., FOMC minutes) can be useful to explain the conduct of monetary policy in different economic scenarios.

Since the target interest rate is not observable, we have to use an operational version of equation (5) in order to estimate its different parameters. The easiest way of solving this problem is just to consider the following equation:

$$i_t = (r_t^* + (1 - \beta)\pi_t^*) + \beta_t E[\pi_{t+i}/I_t] + \gamma_t E[(y_{t+j} - \overline{y}_{t+j})/I_t] + u_t \tag{6}$$

where u_t is a random variable orthogonal to any variable in the information set. However, the empirical evidence for the United States and for some European countries suggests that central banks tends to smooth the changes in interest rates (see, among others, Rudebusch (1995), Judd and Rudebusch (1998) or Clarida, Gali and Gertler, 1998 and 2000). Thus, it is convenient to consider an alternative specification to (6) allowing for a partial adjustment from the actual level of the interest rate to its target:

$$i_t = \rho(L)i_{t-1} + (1-\rho)\left(\alpha_t + \beta_t E[\pi_{t+i}/I_t] + \gamma_t E[(y_{t+j} - \overline{y}_{t+j})/I_t]\right) + u_t \qquad (7)$$

where $\alpha_t = r_t^* + (1-\beta)\pi_t^*$, $\rho(L) = \rho_1 + \rho_2 L + ... + \rho_n L^{n-1}$ and $\rho \equiv \sum_{i=1}^n \rho_i$.

As suggested by Clarida, Galí and Gertler (1998 and 2000), the Generalized Method of Moments produces efficient estimators of ρ, α_t, β_t and γ_t in the class of instrumental variable estimators defined by the orthogonality conditions

$$E\left\{\mathbf{z}_t\left[i_t - \rho(L)i_{t-1} - (1-\rho)\left(\alpha_t + \beta_t\pi_{t+i} + \gamma_t(y_{t+j} - \overline{y}_{t+j})\right)\right]\right\} = 0$$

where $\mathbf{z}_t$ is a vector of instruments included in the information set I_t.

As the number of instruments usually exceeds the number of parameters to be estimated, the GMM estimation computes an optimal weighting matrix W of the instruments such that $u'\mathbf{z}W\mathbf{z}'u$ is asymptotically distributed as χ^2 with degrees of freedom equal to the number of overidentifying restrictions. We use this test to evaluate the validity of our instrument set.

In contrast to Clarida, Gali and Gertler, our approach consists in the recursive estimation of equation (7) using the GMM estimator. As the sample period runs from 1970:1 to 1999:4, we consider alternatively a moving window of 40 quarters and recursive estimates adding one observation each time from 1979:3 onwards. This strategy gives us additional information of the changes in ρ, α, β and γ. The choice of a starting sample running from 1970:1 to 1979:2 is motivated by

- the evidence presented in Section 2 for the United States,
- the different characterization of monetary policy between the seventies and the eighties and nineties offered, among others, by Judd and Rudebusch (1998) or Clarida, Gali and Gertler (1998),
- the fact that this period contains enough variability in the interest rates, in inflation and in the output gap

3.1 Results for the United States

Results for the GMM estimates of equation (7) for the US for different samples are shown in Table 3. The best results in terms of the standard errors of the coefficients and residuals are obtained with $i = j = 1$, so the Federal Reserve seems to target inflation and output gap a quarter ahead. The instruments used in this estimation are four lags of the explanatory variables, the nominal interest rates in the US and EMU, the exchange rate dollar/euro (er_t) and the log of an oil price index (p_t^{oil}).

Table 3

Interest rates reaction functions

USA

	70:1-99:4	70:1-79:2	79:3-99:4
α	-0.030	-0.026	0.017
	(2.75)	(2.81)	(2.91)
β (π^e_{t+1})	1.536	1.454	1.740
	(9.52)	(9.38)	(7.74)
γ (y^c_{t+1})	0.794	0.898	0.318
	(5.20)	(5.01)	(2.34)
ρ (i_{t-1})	0.679	0.699	0.698
	(14.3)	(15.2)	(13.9)
$d_{79:4-99:4}$	0.083		
	(9.10)		
$d_{87:1-99:4}$	-0.035		
	(4.96)		
$\overline{R}^2$	0.836	0.797	0.837

For the whole sample 1970:1-1999:4, we include in the estimation two dummy variables ($d_{79:4-99:4}$ and $d_{87:1-99:4}$), which are equal to one from 1979:4 and 1987:1 onwards, respectively, and zero otherwise. All the coefficients are significant and remain relatively stable among the different samples. The slight fall in the weight of the output gap occurred in the period 1979:3-1999:4 is the sole change, but its value is not far from 1.5 proposed by Taylor.

To analyze further the stability of the coefficients we have run recursive estimates of equation (7) starting with a sample of forty quarterly data for the period 1970:1-1979:2. We add a new observation each time. Figures 5 and 7 show the stability of β and γ coefficients for the US economy. In particular, the weight of inflation is above 1, and even though it moderately increases from its initial value, it shows that monetary policy has played an activist role not only in the eighties or nineties but even in the seventies. This result contrasts with the ones by Clarida, Gali and Gertler (2000), who estimate β equal to 0.86. A possible explanation of this difference is that these authors impose β

to be the same during the sixties and seventies. When we compare columns [2] and [3] in Table 2, our results show that the main variation which occurred at the end of the seventies was in the estimated value of α, reflecting the changes in the inflation target and in the equilibrium real interest rate.

3.2 Results for EMU

In Table 4 we present the GMM estimates of equation (7) for EMU, when the target horizon is $i = 2$ and $j = 1$, which offers the best results in terms of the standard errors of the coefficients and residuals. As before, we consider as instruments four lags of the first difference of the (log) consumer price index (π_t^c), the output gap (y_t^c), the nominal interest rates (in EMU and in the US), the exchange rate dollar/euro (er_t) and the log of an index price of oil (p_t^{oil}).

In column (1) we present the results for the whole sample 1970:1-1999:4, when we include in the estimation of equation a dummy variable ($d_{83:1-99:4}$) which is equal to 1 from 1983:1 onwards and 0 otherwise. The interest rule provides a better explanation of the interest rate behavior than it does for the Unites States, possibly because interest rate smoothing is also higher in EMU. The output gap coefficient γ is statistically significant. Again, the estimated value of β is significantly greater than 1.0, but it seems to be very unstable. In column (2) we have estimated the same equation for the period 1970:1-1979:4. As we can see, the value of β is significantly below unity. In column (3) we estimate the interest rule for the period 1983:1-1999:4, when we find evidence of a change in the constant term α_t.[11] Again the value of β is significantly greater than 1.0, and close to the value estimated for the whole period, whereas γ is lower than its value for the rest of the years in the sample. Finally, in column (4) we include a dummy variable ($d_{92:3}$) which is equal to 1 in 1992:3, coinciding with the beginning of the ERM crisis, and 0 otherwise. As we can see, its estimated coefficient is positive and significant suggesting that the lack of credibility of many European countries forced their central banks to raise interest rates more than 1.1 per cent, reaching levels that cannot be explained by either the inflation rate or the output gap, in other to sustain the exchange rate parities. In other words, credibility problems originated increases in the equilibrium real interest rate across Europe. The consequences of the ERM turmoil are also well observed in Figure 4, where interest rates are above the levels implied by the variable rule during this period. When the central banks of these countries recovered their credibility reducing the inflation differential against Germany the real interest rate decreased. In fact, the real interest rate reached its minimum level with the launch of the euro once credibility

[11] In this case we include the additional term $\lambda\Delta i_{t-1}$ in equation (7) to get rid of any serial correlation in the residuals.

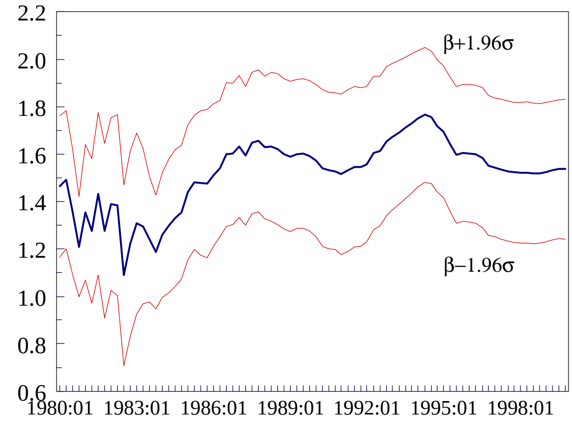

Figure 5: *Recursive estimation of β for the USA, 1970:1-1999:4.*

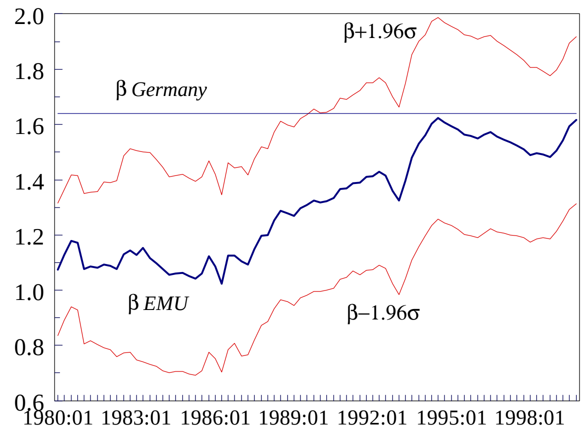

Figure 6: *Recursive estimation of β for EMU, 1970:1-1999:4.*

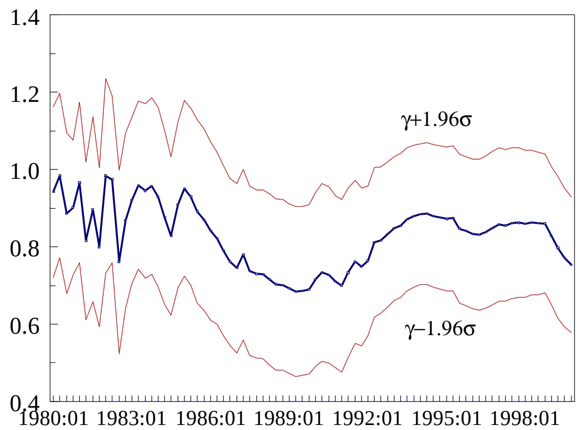

Figure 7: *Recursive estimation of γ for the USA, 1970:1-1999:4.*

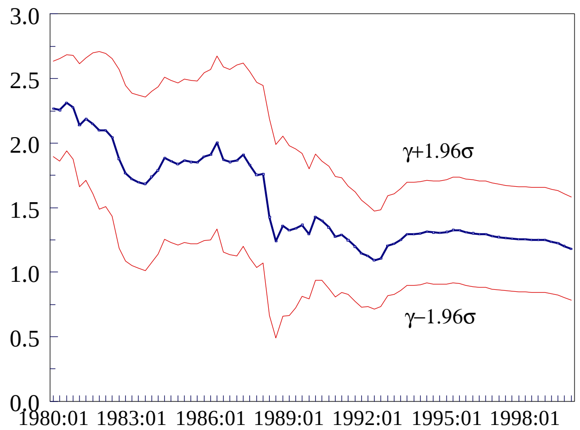

Figure 8: *Recursive estimation of γ for EMU, 1970:1-1999:4.*

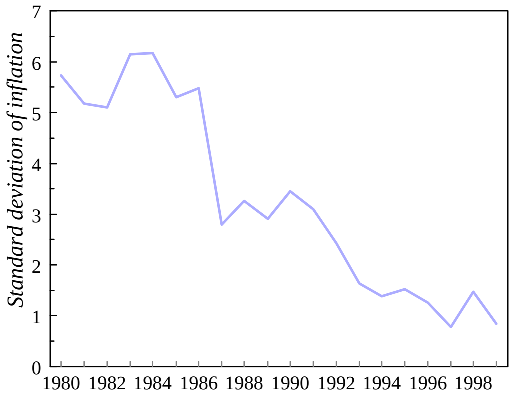

Figure 9: *Standard deviation of inflation (GDP deflactor) in EMU countries, 1980-1999.*

problems disappeared after the accomplishment of Maastricht criteria.

Imposing $\rho = 0.878$ (i.e., the estimated value of ρ for the whole sample), a hypothesis that is not rejected in the different subperiods, we have done a recursive estimation of equation (7) using the same starting sample as that for the USA (i.e.: 1970:1-1979:2), and adding a new observation each time. In Figures 6 and 8 we present the estimated values of β and γ. The changes in β confirm the evidence suggested by Table 4: β was close to 1.0 until the mid eighties when it started to grow until the mid nineties. Not surprisingly, this process occurred until the value of β for the whole EMU converged to its estimated value for Germany ($\beta = 1.639$). These results contrast with the relative constancy of β for the United States. It is also interesting to note that this convergence process to the estimated β for Germany has coincided with the convergence in inflation rates among EMU countries, as we can observe in Figure 9. Thus, the standard deviation of inflation remains relatively constant from 1980 to 1986 as in the case of β. When β started to increase from a value close to 1.0 to 1.6 between 1986 and 1994 (a process only detained during the EMS turmoil at the end of 1992 and the beginning of 1993), the standard deviation of inflation fell from 5.0 to 1.0. During these years, countries such as Spain or Portugal engaged in the exchange rate mechanism of the EMS, abandoning looser past monetary policies. Finally, from 1994 onwards both the standard deviation of the inflation rate and the response of nominal interest rates to the deviations of inflation from its target remained relatively constant, with only minor changes. Therefore, changes in β can be explained by changes in the monetary policy of the countries finally participating in EMU towards a more tight desinflation policy from the mid eighties on-

Table 4
Interest rates reaction functions
EMU

	70:1-99:4	70:1-82:4	83:1-99:4	83:1-99:4
α	-0.060	0.005	0.022	0.023
	(3.59)	(0.69)	(4.20)	(4.69)
$\beta \quad (\pi^e_{t+2})$	1.604	0.806	1.625	1.594
	(9.43)	(9.87)	(12.6)	(13.5)
$\gamma \quad (y^c_{t+1})$	1.303	1.308	0.800	0.754
	(4.25)	(4.02)	(5.04)	(5.13)
$\rho \quad (i_{t-1})$	0.878	0.772	0.883	0.875
	(45.0)	(15.9)	(39.1)	(38.1)
$d_{83:1-99:4}$	0.084			
	(6.79)			
$\lambda \quad (\Delta i_{t-1})$			0.394	0.395
			(7.03)	(6.62)
$d_{92:3}$				0.011
				(3.64)
$\overline{R}^2$	0.967	0.903	0.981	0.982

wards.

The weight of the output gap decreases from a value well above 1 in the first recursive estimation to one which doubles the 0.5 proposed by Taylor. The fact that this coefficient is greater than in the US reveals that monetary policy has focused more on growth in EMU countries. A possible explanation would be that these countries did not have a lot of leeway in fiscal policy at that time. Moreover, the output gap influences future inflation and this relationship could be higher if there are more real rigidities as could have happened in the European countries. For example, regarding the uncertainty in the output gap estimation, Gerlach and Smets (1999) conclude that output gap matters for the monetary policy in EMU, even if the central bank cares solely about inflation.

4. Conclusions

The Taylor rule has become a useful tool for explaining the behavior of central banks. Its simplicity allows to explain the reaction function of monetary policy simply by including as explanatory variables the deviations of inflation from its target and the deviations of real output from its trend. Forward-looking behavior or the room for interest rate smoothing improves the performance of these rules.

Conventional wisdom reveals that central banks, in particular the Federal Reserve in the US, were more permissive with inflation during the seventies than in the last two decades. But some new papers put this result into question. In particular, Orphanides (2000) focuses on the use of data without the benefit of hindsight. In this paper we look for a new explanation: even when we use the revised data it is difficult to sustain a less activist monetary policy in the US in the seventies. In fact, it is impossible to reject a similar behavior in short-run interest rates and in the Taylor rule. The problem is in the level of these two variables. These suggest that simply by including changes in the inflation target it is possible to recover a stabilization role for monetary policy.

In EMU, the limited weight for inflation in the seventies was the result of different behaviors in monetary policies in the eleven countries. In Germany, there has traditionally been a strong commitment to fighting against inflation. In other countries, the EMS and the route towards nominal convergence, as imposed by the Maastricht Treaty, contributed to increasing the weight of inflation in monetary policy. This is what recursive estimates of a forward-looking version of the Taylor rule show. Moreover, in the nineties, the weight of inflation in EMU countries finally converged to the value observed in the German economy. A possible explanation of this results is the following. Until mid eighties, the central banks of European countries show different attitudes towards inflation. This picture started to change from 1985 onwards, when some countries joined the EMS and previous members assumed their commitment to avoid realignments of the exchanges rates. This process explains the significance of German nominal interest rates in the interest rules estimated for individual countries in preceding studies and, in our case, it accounts for the gradual increase of the inflation coefficient in a weighted interest rule, which tries to summarize the monetary policy of participating countries in EMU.

Forward-looking versions of the Taylor rule seem useful to explain the behavior of central banks in the US and EMU. In the case of EMU, the interest rule does not present any evidence of instability from the end of the EMS turmoil in 1992 and 1993 onwards and, therefore, it is a good candidate to explain the ECB monetary policy. The main results show that the current weight of inflation is similar in both areas and close to the value proposed by Taylor (1.5) and the weight of output gaps is slightly higher in EMU than in the US but, anyway, not far from the original 0.5 proposed.

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