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Asset Prices in Taylor Rules: Specification, Estimation, and Policy Implications for the ECB

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Abstract:

This paper estimates standard and extended Taylor rules for core countries in the euro area, namely France, Germany and Italy, as well as for the ECB. Forward, backward and forecast-based rules are estimated for a variety of samples since the late 1970s. We are particularly interested in the impact of adding asset prices to the standard Taylor rule specification. Since forward-looking Taylor rules are usually estimated via GMM we perform extensive tests for over-identifying restrictions and instrument relevance, a practice generally eschewed in previous work. We find that asset prices can be highly relevant as instruments rather than as separate arguments in policy rules. Backward-looking Taylor rules, however, cannot be rejected outright. Forecast-based rules perform best using the root mean squared error metric but produce coefficients implying that central banks may be too aggressive at fighting inflation. Encompassing tests are therefore required to select the "best" policy rule and these suggest that policy rules need to have a mix of forward and forecast-based elements. Furthermore too aggressive reactions to stock prices in particular would have led to an implausible monetary policy. Hence, asset prices appear at best to serve as indicators of the direction of interest rates and not as a variable that the ECB directly reacts to.

Keywords: reaction function, asset prices

JEL-Classification: E 4, E 5

Non Technical Summary

We estimate for three euro area countries (Germany, France, Italy) Taylor rules for samples that yield plausible estimates of the weights for the inflation and output gap objectives, that is, ones that at least fulfill the so-called "Taylor principle" according to which a larger than unit nominal interest rate response is required for any unit increase, especially, in inflation. Hence, for example, a tightening of monetary policy requires a rise in the real interest rate. We are also interested in whether forward-looking reaction functions admit a significant reaction to the output gap. Next, we ask what are the empirical implications of extending the Taylor rule, either by adding some asset price variable or by using asset prices as an additional instrument. Our aim here is to examine how well such rules perform under these alternatives. For example, while central banks routinely admit to considering the role of asset prices in their deliberations (e.g., see ECB 2001), it is unclear whether this means that they actually respond to such developments or whether instead movements in such prices more appropriately serve the function of covariates that can enhance our understanding of interest rate behavior in the context of a standard Taylor rule.

Briefly, we conclude the following. Evidence consistent with the "Taylor principle", that is, a larger than a unit reaction of nominal interest rates to a one percent rise in inflation, is most apparent when forward-looking or forecast-based reaction functions are estimated. Furthermore, adding asset prices to the reaction function usually produces highly volatile interest rate rules, thereby confirming empirically the simulation evidence of, for example, Bernanke and Gertler (1999). If, instead, we introduce assets prices as additional instruments in the GMM estimation phase, estimates become not only more plausible but result in policy rules that achieve a better fit. In addition, asset prices as instruments were found to be relevant in statistical terms. We interpret these results to mean that, whereas the central banks of France, Germany, and Italy did not directly respond to asset price developments, these did influence expectations of inflation and the output gap and, hence, indirectly reflected their concern over potential misalignments in them. Finally, we find that the ECB's monetary policy is well within the range of interest rate paths that would be obtained if the central banks in our sample

were still able to set levels for the interest rate instrument. In other words, the ECB does not appear to have skewed its policies toward any of the major members of the euro area. Nevertheless, by 2002, according to our estimations ECB monetary policy looks to be too tight compared to NCB reaction functions, whereas other studies came to the opposite conclusion. Moreover, it appears that the ECB did not respond to asset price developments, as these would have produced implausible behavior in interest rates. Indeed, it would be difficult for the ECB to know which asset price to respond to since, prior to 1999, housing prices appeared to make a difference in monetary policy performance in some euro area countries while, in others, either a real exchange rate or stock prices were the more relevant asset price indicators.

Nicht technische Zusammenfassung

Für drei Euro-Länder (Deutschland, Frankreich, Italien) schätzen wir Taylor-Regeln, die plausible Schätzungen für die Gewichtung von Inflations- und Produktionslücke erbringen, das heißt Schätzungen, die zumindest das so genannte „Taylor-Prinzip" erfüllen, wonach die Reaktion des Nominalzinses auf jede Erhöhung der Inflationsrate größer als eins sein sollte. Außerdem interessiert es uns, ob Schätzungen für vorausschauende Reaktionsfunktionen eine signifikante Reaktion auf die Produktionslücke zulassen. Als nächstes stellen wir die Frage, welche empirischen Folgen es hat, wenn man die Taylor-Regel entweder durch Aufnahme einer Vermögenspreisvariable oder die Verwendung von Vermögenspreisen als ein zusätzliches Instrument erweitert. Unser Ziel hier ist es, herauszufinden, wie gut solche Regeln bei Verwendung dieser Alternativen abschneiden. Zwar geben Zentralbanken in der Regel zu, dass sie die Vermögenspreise in ihre Überlegungen einbeziehen (siehe z. B. EZB 2001), doch ist unklar, ob dies bedeutet, dass die Zentralbanken tatsächlich auf Entwicklungen der Vermögenspreise reagieren oder ob stattdessen Veränderungen dieser Preise eher als Kovariate dienen, die uns zu einem besseren Verständnis des Verhaltens der Zinssätze im Kontext einer gewöhnlichen Taylor-Regel verhelfen können.

Wir kommen zu folgender Schlussfolgerung. Am augenfälligsten ist der dem „Taylor-Prinzip" entsprechende Befund, d.h. eine Reaktion der Nominalzinssätze auf einen Inflationsanstieg über eins, wenn vorausschauende Reaktionsfunktionen geschätzt werden. Außerdem führt die Einbeziehung von Vermögenspreisen in die Reaktionsfunktion gewöhnlich zu äußerst volatilen Zinsregeln; dies bestätigt den Simulationsbefund z. B. von Bernanke und Gertler (1999). Beziehen wir stattdessen Vermögenspreise als zusätzliche Instrumente in die GMM-Schätzung ein, so werden die Schätzungen nicht nur plausibler, sondern führen auch zu zinspolitischen Regeln, die besser mit der tatsächlichen Entwicklung übereinstimmen. Darüber hinaus hat sich herausgestellt, dass Vermögenspreise als Instrumente auch in statistischer Hinsicht sinnvoll sind. Wir interpretieren diese Ergebnisse dahingehend, dass, obwohl die Zentralbanken Frankreichs, Deutschlands und Italiens nicht direkt auf die Vermögenspreisentwicklung reagierten, deren Entwicklung doch die

Inflationserwartungen und Produktionslücke beeinflusste und indirekt Sorgen der Zentralbanken um dadurch ausgelöste Verzerrungen in diesen Größen widerspiegelt. Schließlich stellen wir fest, dass sich die Geldpolitik der EZB durchaus innerhalb des Zinskorridors bewegt, der sich ergeben würde, wenn die in unserer Stichprobe enthaltenen Zentralbanken noch selbst die Zinsen (entsprechend ihrer früheren Regeln) festsetzen könnten. In anderen Worten, die EZB scheint bei ihrer Geldpolitik nicht einseitig eines der größeren Mitgliedsländer des Euro-Währungsgebiets bevorzugt zu haben. Allerdings erscheint unseren Schätzungen zufolge die Geldpolitik der EZB im Jahre 2002 als zu restriktiv, gemessen an den früheren nationalen Reaktionsfunktionen, während andere Unersuchungen zum entgegengesetzten Schluss kamen. Außerdem zeigt sich, dass die EZB nicht auf Vermögenspreisentwicklungen reagierte, da dies ein unplausibles Verhalten der Zinssätze erzeugt hätte. Für die EZB wäre es in der Tat schwierig gewesen zu entscheiden, auf welche Vermögenspreise sie reagieren soll; vor 1999 scheinen in einigen Euro-Ländern die Immobilienpreise einen wichtigen Einfluss auf die Geldpolitik gehabt zu haben, während in anderen Länder dem realen Wechselkurs beziehungsweise den Aktienkursen eine größere Relevanz als Indikator der Vermögenspreise beigemessen wurde.

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1. Introduction

The creation of the European Central Bank (ECB) resulted in a historic transfer of responsibility in monetary policy from many central banks to a single supra-national authority. By virtue of its structure, the ECB is a creature of its predecessors' experiences and so it is of independent interest to ask what its policies look like relative to ones implemented by the central banks that, prior to 1999, had full responsibility over the conduct of monetary policy. Despite the existence of an exchange rate mechanism, the pre-existing central banks shared different economic histories and differences in emphasis over the principal objectives of monetary policy. Some of these differences were institutional while others were more policy oriented. Thus, for example, the Banque de France became autonomous following the ratification of the Maastricht Treaty while the Bundesbank has acted independently of direct government influence. To be sure, the Maastricht treaty imposed a form of "convergence" in a variety of policy instruments and indicators. Nevertheless, economic shocks affected prospective euro area members in a variety of ways (e.g., as with German reunification) and, until the end of 1998, might have elicited different monetary policy responses. This paper considers whether this is indeed the case for select countries in the euro area.

Paralleling these developments, the last two decades in Europe and elsewhere has led to a greater emphasis on inflation control. Whereas inflation performance used to be interpreted through the behavior of consumer prices alone, more questions are being asked about whether and how the behavior of asset prices more generally may have played a role in the conduct of monetary policy.

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This led us to consider the following issues. First, could central banks have additional objectives such as a real exchange rate target, or objectives motivated by the need to maintain financial stability? Second, although it is widely understood that central banks need to be forward-looking in conducting monetary policy, economists have had mixed success in generating proxies for forward-looking behavior. Current best practice typically involves estimating reaction functions using GMM with little or nor attention paid to how instruments are chosen nor whether they belong in the estimated relationships. Third, there have relatively few attempts to systematically estimate reaction functions for member countries within the euro area. While theoretically more plausible, according to central bankers, forward-looking rules do not appear to describe monetary policy especially well, as estimates reveal little or no concern for output performance. Moreover, if we accept a learning-by-doing perspective, it is by no means clear that backward-looking rules, which can fit the data relatively better, are implausible. Finally, forward-looking rules rely on proxies for expectations of key variables. However, central banks and financial markets typically rely on forecasts. Such forecasts are likely, at least indirectly, to incorporate asset price developments. Indeed, good conduct in monetary policy has been described as requiring a forecast-based response (e.g., see Svensson 2003). Consequently, we also provide an assessment of the relative performance of different types of reaction functions.

The plan of the paper is as follows. First, we estimate for three euro area countries Taylor rules for samples that yield plausible estimates of the weights for the inflation and output gap objectives, that is, ones that at least fulfill the so-called "Taylor principle" according to which a larger than unit nominal interest rate response is required for any unit increase, especially, in inflation.[1] Hence, for example, a tightening of monetary policy requires a rise in the real interest rate. We are also interested in whether forward-looking reaction functions admit a significant reaction to the output gap. Next, we ask what are the empirical implications of extending the Taylor rule, either by adding some asset price variable or by using asset prices as an additional instrument. Our aim here is to examine how well such rules perform under these alternatives. For example, while central banks routinely admit to considering the role of

asset prices in their deliberations (e.g., see ECB 2001), it is unclear whether this means that they actually respond to such developments or whether instead movements in such prices more appropriately serve the function of covariates that can enhance our understanding of interest rate behavior in the context of a standard Taylor rule.

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The following section provides a brief survey about the varieties of Taylor rule. Next, we describe the estimation and testing strategy of the paper, and how our

[1] Policy rules for smaller euro area members including Austria, Belgium, Finland, and the Netherlands were also examined but, as these did not materially affect the conclusions reported below, they are not separately discussed.

estimates might be used to evaluate the stance of monetary policy over time in the countries considered. A separate section describes the data and presents the empirical evidence. The paper concludes with a summary and suggestions for future research.

2. Standard Versus Extended Taylor Rules: Key Considerations

We follow much of the literature by assuming that the central bank minimizes a loss function of the form:

$$E_0 \sum_{t=0}^{\infty} \delta^t [\omega_\pi (\pi_t - \pi_t^*)^2 + \omega_{\tilde{y}} \tilde{y}_t^2 + \omega_i (i_t - i_{t-1})^2] \quad (1)$$

where π_t is inflation, π_t^* is the inflation target (implicit or explicit, depending on the institutional arrangement in place), $\tilde{y}_t$ denotes the output gap, δ is a subjective discount factor, while i_t is the policy instrument, namely a short-term interest rate (i.e., an overnight or repo rate). The ω represent the weights on inflation (ω_π), the output gap ($\omega_{\tilde{y}}$), and the degree of interest rate smoothing (ω_i). According to (1), the central bank minimizes the squared deviations from some target for those variables in its objective function. Further, if we let δ=1, we obtain the familiar trade-off between inflation and output variability.

While tradition, and a considerable amount of empirical evidence, points to inflation, output, and a desire to minimize interest rate volatility as chief among the concerns of most central banks (e.g., Favero and Rovelli (2003) but see Rudebusch (2002) and Lansing (2002)), recent events have prompted some to consider the possibility that the monetary authority has, or ought to, respond to other variables, notably asset prices. Theoretically, there is a considerable difference between assuming that the central bank includes asset prices in its objective function versus assuming that it treats asset prices as indicators of future inflation and/or the output gap (e.g. see the debate between Bernanke and Gertler (1999), and Cecchetti et al. (2000)). In the present paper, we pursue the latter approach since this is consistent with the widely held view that, while central banks may or may not respond to asset prices, they ought not explicitly target them.

Nevertheless, we are left with the problem of asking which asset prices central banks might be concerned about. In the case of an open economy one might well envisage the possibility that policy makers are concerned with real exchange rate movements (e.g., Leitemo (1999), Leitemo and Røisland (1999), and Medina and Valdés (1999)). Lately, attention has turned to the behavior of stock prices and housing prices, or some other financial indicator (see below), as central banks are increasingly seen as responsible for stemming the cycle of booms and busts in asset prices, reflected in an apparent widening of central bank mandates to include a concern over the maintenance of financial stability.

Even if it is deemed desirable to incorporate a role for asset prices the investigator faces a number of difficulties. In particular, there is no widespread agreement on how best to define an equilibrium real exchange rate (a form of relative purchasing power parity is the likely candidate), and even less on how to define equilibrium stock or housing prices, though these problems seem no less intractable than defining the "trend" in output used in deriving an output gap measure. In the case of stock and possibly housing prices, the former the subject of a great deal of interest among academics and policy makers, matters are complicated still further either because there is an element of "irrational exuberance" that might contain a "bubble" component that is difficult to measure empirically, or because there is no widespread agreement on how to define equilibrium conditions in these settings.

Table 1 presents selected estimates of Taylor rules and these tend to be consistent with the "Taylor principle". Some are based on estimates of forward-looking reactions functions; others are of backward-looking variety. Ordinarily, they leave out a role for asset prices with the notable exception of Bernanke and Gertler (1999) who examine how sotck prices affect interest rate determination in the U.S. and Japan. Cecchetti (2003) also reports that the Fed reacted to stock market developments relying again on Taylor rule estimation. There is considerable variation in the estimated weights on the inflation and output gap objectives, the role of asset prices is not extensively investigated, nor is the robustness of results or the relative suitability of forward versus backward-looking or forecast-based models extensively analyzed. Finally, other than for Germany (e.g., Faust, Rogers and Wright 2001), there is little discussion of what ECB policy looks like for the euro area in relation to monetary policy in the member

countries prior to the start of EMU. It is to these issues that we now turn our attention to.

Table 1: Taylor Rule Coefficients: Selected Estimates

Author	Type[5]	Inflation	Output Gap	Other	Sample
Bernanke and Gertler (1999)	FL	1.12-2.21	0.20-0.33	0.19-0.29	Japan 68-89
		1.60-1.71	0.14-0.20	-.082	US 68-89
Cecchetti and Krause (2001)[1]	BL	.999(.999)	.001(.001)	NA	Austria 82-89 (90-97)
		.999(.999)	.001(.001)	NA	Belgium
		.470(.981)	.530(.019)	NA	France
		.958(.998)	.042(.002)	NA	Germany
		.253(.880)	.747(.120)	NA	Italy
		.980(.999)	.020(.001)	NA	UK
Cecchetti (2003)	FL	0.34-0.67	0.41-0.50	-0.65 s^2	US 1990-2003
				-0.23 bank[3]	
Clarida, Gali and Gertler (1998)	FL	1.10-1.37	0.25-0.35	NA	Germany
		1.81-2.04	0.03-0.10	NA	Japan
		1.05-2.20	0.14-0.52	NA	US
Gerlach and Schnabel (2000)	BL	1.51-1.58	0.45-0.49	NA	1990-98 Euro-11
	FL	0.98-1.62	0.22-0.32	-0.03- (-0.56)[4]	
Faust, Rogers and Wright (2001)	FL	1.31	0.18	NA	Germany
Fuhrer and Moore (1992)	*	a. 1	a.0	NA	Moderate IT
		b. .05	b.0	NA	Weak IT
		c. 10	c.0	NA	Strong IT
Hetzel (2000)	BL	1.56	0.62	NA	Greenspan 87-99
		1.16	0.14	NA	Volcker 79-87
Hu (2002)	FL	1.05	0.033	0.026	US 1980-2001

Note: [1] Coefficients are such that they are constrained to sum to 1; [2] measure of equity premium risk; [3] measure of stress in the banking system; [4] money growth, lagged inflation, fed funds rate, or real euro/$ exchange rate; * simulations; [5] type of reaction function: FL= forward-looking, BL= backward-looking.

3. Estimation and Testing Strategy

An important motivation for estimating a large variety of reaction functions is to determine how wide was the variation in policy rules behavior select euro area countries in the lead up to the start of EMU. This necessitates not only considering the extent to which member states central banks might have been forward looking, but also in investigating the role of asset prices in each country's policy rule.

3.1 Standard reaction function estimates and econometric considerations

We begin with a standard version of the reduced form version of Taylor's rule, written in regression form as:

$$i_t = \bar{i} + \gamma_{i,\tilde{\pi}}\,\tilde{\pi}_t + \gamma_{i,\tilde{y}}\,\tilde{y}_t + \rho_i\, i_{t-1} + \upsilon_t \qquad (2)$$

where i_t is the (nominal) interest rate instrument of monetary policy, $\bar{i}$ [= (1-ρ)α] is the sum of the steady-state real interest rate and the annual inflation target, $\tilde{\pi}$ and $\tilde{y}$ are, respectively, the inflation and output gaps, ρ is the interest rate persistence or smoothing term, and υ_t is a residual term. If the reaction function is forward looking, the inflation gap is simply the difference between expected and targeted inflation rates (i.e., $[E_t(\pi_{t+n}) - \pi^*]$). In a similar fashion, the output gap is the percentage deviation of real GDP from its potential level. The coefficients $\gamma_{\tilde{\pi}}$ [=(1-ρ)β] and $\gamma_{\tilde{y}}$ [=(1-ρ)θ] reflect the weights policy makers place on inflation versus the output gap, while the central bankers' preferences for inflation versus output are captured via estimates of β and θ though these must be "identified" since the economy responds to the same variables. The coefficients in the reaction function are obtained from an expression that summarizes the interest rate targeting policy of the central bank, namely:

$$i^*_t = \alpha + \beta_n\, E_t(\pi_{t+n}) + \theta_n E_t(\tilde{y}_{t+n}) \qquad (3)$$

where i^*_t is the interest rate target, $E_t(\pi_{t+n})$ and $E_t(\tilde{y}_t)$ are the conditional expectations of inflation, *n*-periods ahead (*n≥0*), and of the output gap.[2]

Since $E_t(\pi_{t+n})$ and $E_t(\tilde{y}_{t+n})$ are unobservable, instruments serve as proxies (see below). Alternatively, a forward-looking central bank, and one that is able to clearly communicate its future outlook, might be interpreted as acting on the basis of forecasts of inflation and output growth. In this case, central bank forecasts or private sector forecasts such as the ones from Consensus Forecasts, the OECD, *The Economist*, can serve as proxies. Hence, a version of (2) using forecasted values would be written as:

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[2] In (2) the inflation target has been normalized to zero. Equation (1) is then derived from the relation $i_t = \rho\, i_{t-1} + (1-\rho) i^*_t + \upsilon_t$.

$$i_t = \bar{i} + \gamma_{i,\tilde{\pi}}{}^{*}\tilde{\pi}_t{}^{f} + \gamma_{i,\tilde{y}}{}^{*}\tilde{y}_t{}^{f} + \rho_i i_{t-1} + \upsilon_t \qquad (2a)$$

where most of the variables have been previously defined, and $\tilde{\pi}_{t+i,t}{}^{f}$ and $\tilde{y}_{t+i,t}{}^{f}$ are, respectively, forecasts of inflation (or the inflation gap) and the output gap $t+i$ periods ahead, conditional on information available at time t.

There is some evidence about the desirability of incorporating a mix of forward backward-looking, or even forecast-based elements. This is partly because Gali and Gertler (1999) report that a purely forward-looking Phillips curve does not fit the data well, and Fuhrer's (1997) finding that there is sufficient inflation persistence to a warrant incorporating a significant backward-looking component in models of inflation. A natural way of considering a mix of forward and backward-looking elements, not heretofore considered, is to ask whether one type of reaction function estimate can "encompass" another. In this fashion, backward, forward and forecast-based Taylor rules are tested against each other to determine whether, statistically speaking, it might be preferable to estimate such rules are linear combinations of each other.

Next, the question arises how to proxy π^*, the inflation target necessary to evaluate the inflation gap (π_{t+n} - π^*). Usually, π^* is assumed to be a constant (say 2%). Alternatively, estimates for each of the euro area countries under investigation can be generated. In this paper we also consider two proxies. First, we tried an HP filter to estimate the inflation objective.[3] Next, we also assumed that the inflation target is the mid-point of the spread between the average annual inflation rate in the euro area countries and the average annual inflation rate in the three lowest inflation rate countries in the euro area plus 1.5%, as specified in the Maastricht Treaty (article 121, ex article 109j).[4] Since 1988, when the Delors Report was published, if not earlier, European policy makers discussed the need for European economies' inflation rates to converge to

[3] Stock and Watson (2003) recommend a one-sided HP filter. In the present paper we also use the regular HP filter with a standard smoothing parameter (1600) as well as a much larger smoothing parameter (4800).

[4] For the relevant calculations, the euro area is assumed to consist of the original 11 member countries, namely: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Portugal, Spain, and Sweden.

some acceptable level prior to the start of monetary union.[5] This assumes that central banks in the euro area may have regarded the Maastricht requirement as an effective inflation objective.[6] In practical terms we will assume that inflation in country *j* converges by the end of 1998 linearly toward the mid-point of the long-run average German inflation rate, plus 1.5%, that is when the EU announced the initial membership in the euro area.[7] Since our conclusions were unaffected by the type of inflation gap proxy used, we report results which assume a constant inflation objective. This also has the slight advantage of allowing for a comparison with the bulk of the literature on Taylor rules.

Similarly, estimation of the output gap has been problematic, especially since subsequent research has shown that the interpretation of monetary policy actions in an historical context is very much dependent on whether policy makers at the time based their decisions on a mis-measurement of the output gap (e.g., see Orphanides (2001) for the US). As in the case of the inflation gap, we utilize an HP filter as there are relatively few alternative proxies for the output gap in a cross-section of countries.[8] We also generate, but do not report here, estimates of the output gap based on a Blachard-Quah type decomposition with no impact on our conclusions.

Following much of the empirical literature we estimate (2), and its variants, via a single equation approach, using GMM. Under this procedure, we replace the unobservable series using lags of actual values of the time series as instruments. In addition, further adjustments may be made to correct for serial correlation and heteroskedasticity. The chief advantage of GMM is its robustness against a variety of assumptions about the distribution of the disturbances. Nevertheless, there are a number

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[5] As is now well-known, progress toward EMU occurred in three stages: Stage I: July 1990-December 1993, capital market liberalization, ratification of Maastricht (November 1993); Stage II: January 1994-December 1998, ERM I and EMI; Stage III: EMU, January 1999.

[6] While this is a reasonable working hypothesis, there remains the problem of translating it into practical terms for the actual horizon by which time monetary union was in place was far from known with certainty. Although subsequent "convergence reports" assessed, among other things, inflation performance in terms of the Maastricht criteria, there were no annual objectives as such, beyond an expectation of progress toward convergence.

[7] Other definitions are possible of course though we show in an appendix (not included but available on request) that this assumption appears to be a fairly reasonable one by calculating, on an annual basis, the inflation rate dictated by the Maastricht Treaty, plus 1.5%, and comparing these figures with German inflation over the same period.

of drawbacks with the GMM approach, such as the lack of theoretical motivation for the choice of instruments, some of which can be weak thereby affecting the power of tests, among other problems that are becoming increasingly apparent (e.g., see Mavroeidis (2001), Florens, Jondeau, and Le Bihan (2001), and Baum, Schaffer and Stillman (2002)).

More importantly perhaps, with the exception of Boivin and Giannoni (2002), there has been no systematic effort to examine the goodness of fit of various reaction functions and even less concern has been evinced about the relevance of the instruments used.[9] For example, the *J*-test for goodness of fit is reported without comment. Nevertheless, focusing on such a test alone also poses problems because one risks choosing a model with coefficients in the rule that are theoretically implausible. In addition, while instrumental variable estimation is a powerful tool, it is important to ascertain how well the instruments are correlated with the endogenous variables appearing here in the policy rule (e.g., the output gap). Shea (1997) points out that regressing the endogenous variables against the chosen instruments can be misleading when there are several endogenous variables in the estimated specification. Godfrey (1999) develops a simple measure for computing instrument relevance. With this in mind, we use asset prices, among other variables to be discussed below, as instruments in the GMM phase of estimation and test both their impact on the fit of estimated policy rules as well as their relevance as instruments.

Our strategy is to obtain estimates of the main parameters of interest, namely, $\gamma_{\tilde{\pi}}$, $\gamma_{\tilde{y}}$, θ, and β for select euro area members prior to the start of operations of the ECB in 1999. Then, relying on historical estimates, we ask to what extent the behavior of the euro repo rate since 1999 reflects pre-ECB monetary policy as well as the potential role of asset prices under the monetary union. An obvious question that arises in this context is whether it is at all possible to think of euro area members as having an autonomous

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[8] Much of the literature uses a two sided HP filter for convenience, or an alternative measure of the economy's capacity, but comparable time series are not available for the vast majority of euro area countries.

[9] The authors report a variety of *J*-statistics to determine the horizon used by the policy makers (also see below). They do not, however, report whether plausible reaction function estimates were obtained for all the combinations reported. As we shall see, estimates at different horizons do not always produce plausible coefficients.

monetary policy over the sample in question.[10] Clearly, institutional devices such as the EMS, and the Maastricht Treaty, constrained the ability of the prospective members' central banks to engage in an independent interest rate setting policy. However, during the period under study concerns were expressed over the interpretation of convergence requirements for fiscal policy[11] and short-term interest rates, although the Maastricht Treaty imposed a convergence requirement on long-term interest rates.

Moreover, not only was the EMS subject to numerous realignments but it is widely agreed that German monetary and economic reunification provided a large asymmetric shock to the euro area for a time even calling into question whether EMU would go ahead on time as planned. Clarida, Gali and Gertler (2001, 2000; also see Clarida 2001) argue that their specification can be applied essentially in the same manner for fixed as for floating rate regime countries.[12]

Returning to estimation issues, it would seem desirable to make some allowances for interdependencies in interest rate setting behavior among the central banks in the euro area. One simple solution is to replace the domestic interest rate with the lagged German short-term rate. The Bundesbank was the dominant central bank in the euro areas over the sample prior to the start of EMU. We also consider this possibility.

Once the reaction functions are estimated we can back-out the implied target interest rates over time (i.e., i_t^*) to determine how well reaction function (1) "fits" with actual interest rate developments in the individual countries considered. As a result, we can also ask, via encompassing tests, which measure provides the best "fit" overall (also see Collins and Siklos (2004)). Next, we generate the implied target interest rate if individual countries in the euro area used a harmonized measure of inflation and output after 1999, as well as evaluating the path of interest rates after 1999 using coefficient estimates from each country prior to the start of EMU. This test effectively asks whether it is possible to detect an interest rate "bias" in the early years of operation of the ECB by comparing the interest rate path predicted based on each country's reaction function against the actual interest rates set by the ECB, or whether there is some sensible linear

[10] This is an aspect of the problem that appears to have been largely downplayed in the literature.
[11] Namely, the 3% of GDP deficit rule, and the 60% of GDP public debt rule. These concerns would lead to the formulation of the Stability Pact.
[12] Neiss and Nelson (2001) argue that exchange rate effects are effectively incorporated into models such as (2) and (3) provided we interpret the shocks in such a model "broadly".

combination of reaction function estimates of i^* is able to replicate the ECB's interest rate policy. Finally, we also consider the potential role for some euro area wide indicators of asset prices.

3.2 Extended Taylor rules

We now consider whether select euro area central banks can be said to have reacted to variables other than inflation, the output gap, or lagged interest rates, during the period in question. A criticism of this strategy is that, to the extent that asset prices are forward looking indicators of inflation, these may effectively act as a proxy for $\tilde{\pi}_t$ and $\tilde{y}_t$. However, as shown convincingly by Stock and Watson (2003), it is not the case that asset prices can reliably forecast future inflation or output. An extended Taylor rule might be written as follows:

$$i_t = \bar{i} + \gamma_\pi \tilde{\pi}_t + \gamma_{\tilde{y}} \tilde{y}_t + \rho i_{t-1} + \gamma_{\tilde{x}} \tilde{x}_t + \upsilon'_t \qquad (4)$$

where $\tilde{x}_t$ represents deviations in asset price movements from some equilibrium or "fundamental" value.

In the empirical work that follows, we have in mind three classes of asset prices, namely the real exchange rate (ε), stock prices (s), housing prices (h), as well as some aggregate measure of asset price (a).[13] When the variables enter individually, equilibrium asset prices are again proxied via an HP filter. Stock prices present somewhat of a complication owing to theoretical considerations that are used to explain asset price movements. It is also well known that while housing is an important component of wealth, markets across countries are rather idiosyncratic in nature (e.g., Iacoviello (2000)) with potentially dissimilar effects on individual economies (e.g., see Iacoviello and Minetti (2000), and Goodhart and Hofmann (2001)). Stock prices have played an increasingly important role in central bank deliberations, because a rising share of households own such assets, as well as due to concerns over the implications of more volatile stock prices.

[13] We also consider the case where a measure of consumption expenditures serves as a potential instrument for output.

Some have noted (e.g., Borio and Lowe (2002)) that it is not individual asset prices as such but some combination of asset prices that central banks ought to consider reacting to. These combinations come in the form either of a financial conditions index (e.g., Goodhart and Hofmann (2001), Smets (1997)) or an index that attempts to capture the changing relative importance of asset prices over time. We then repeat the exercises conducted using the baseline model, make some comparisons, and draw conclusions.

3.3 Discussion

Irrespective of the method or assumed determinants of the estimated reaction function, we proceed by estimating such functions for three European countries, namely France, Germany, and Italy.[14] This implies, for example, that in (2) estimates of β, θ, and ρ are all positive. Moreover, plausible estimates consistent with the Taylor principle would require a value for β that exceeds one. Under some circumstances, such as uncertainty about whether the rise in inflation is transitory or not, whether the reaction function is forward or backward-looking, the price index used, and even the type of monetary regime in place, an estimate of $\beta<1$ may be retained (see below). Otherwise, all instances where the signs of these coefficients violate the theoretical predictions are discarded.[15] In the case of extended Taylor rules, we similarly expect that the coefficients on housing prices, stock prices, aggregate asset prices or the financial conditions index, to be positive corresponding to $\beta_{\tilde{H}}, \beta_{\tilde{s}}, \beta_{\tilde{F}}$, while the coefficient on the real exchange rate, namely $\beta_{\tilde{e}}$, should be negative.[16] The same strategy is applied to estimates of backward-looking Taylor rules as well as rules based on external forecasts.

The estimation strategy then proceeds as follows. First, we generate a set of forward, backward and forecast-based Taylor rules that are plausible, that is, ones that result in the theoretically expected signs.[17] At all times we are careful to examine the

[14] This is done partly to minimize the well-known small sample problems that arise when the GMM technique is applied.

[15] Since we will be considering a very large number of cases this seems like a sensible strategy to minimize inclusion of borderline cases and prevent relying on reaction functions solely based on some arbitrarily chosen statistical significance level.

[16] Due to the manner in which the IMF defines the real exchange rate, a rise signifies a fall in competitiveness and vice-versa for a fall in the real exchange rate.

[17] We also consider the sensitivity of our estimates to the choice of a smaller sample, namely consisting of the 1990s only where there is more of a consensus that the central banks in our study were indeed forward-looking and can be described as setting interest rates in the kind of setting envisioned by

goodness of fit of our reaction functions by conducting tests for over-identifying restrictions. An alternative way to examine goodness of fit is to ask how well the estimated Taylor rules forecast in sample. Consequently, we also report the root mean squared error (RMSE) for each specification. Simultaneously, we test the validity of the instruments in our forward-looking specifications. Finally, we attempt to reduce the number of plausible estimates to a minimum by applying encompassing tests prior to reporting a comparison of actual ECB interest rate policy relative to a counterfactual based on the historical performance of Taylor rules in the pre-ECB era.

Taylor. These produce coefficient estimates and specifications that are broadly comparable with the ones shown below.

4. Data and Empirical Evidence

All data were either quarterly at the source or converted to the quarterly frequency by taking monthly averages where necessary. In the case of real GDP, seasonally unadjusted data were used and adjustment was made using X-11. To generate the output gap we use the HP filter with smoothing parameters 1600 or 4800. We also experimented with a one-sided HP filter due to the well-known endpoint problem with such filters with no discernible impact on our conclusions.[18] Next, we transform all variables, except the nominal interest rate, into 100 time the fourth order log difference, that is, $(\log X_t - \log X_{t-4})$, where X is the variable of interest. Aggregate asset prices are from the BIS. Readers should refer to Borio and Lowe (2002) for details. The financial conditions index (FCI) is constructed from the weights estimated by Goodhart and Hofmann (2001) using a reduced form model of the economy. The index then is a linear combination of changes in interest rates, real exchange rates, house prices, and stock prices, the latter three variables as deviations from their equilibrium (also evaluated via HP filtering).

Table 2 presents full sample estimates of forward-looking reaction functions. All the reaction functions have in common the fact that the weight on the inflation gap is often, though not always, greater than one (see below), while the weight on the output gap is positive and often statistically significant. In addition, the *J*-test statistic suggests that the specifications are admissible. Moreover, and in keeping with much of the rest of the literature, all reaction functions are based on a one-year ahead (i.e., four quarters ahead) horizon.[19] Table 2 also shows instances where plausible extended Taylor rule estimates were obtained.

Examination of forward-looking reaction function estimates in Table 2 yields six broad conclusions. First, point estimates of the inflation gap are quite sensitive to the

[18] Rennison (2003) reports that the HP filter (though he seems to prefer a version augmented with the residuals from a reduced form Phillips curve), combined with estimates from a Blanchard-Quah structural vector autoregression, is the best output gap estimators. He generated data from an artificial economy and uses a Monte Carlo experiment to determine which from among several estimators of the output gap are able to mimic the "true" output gap. Turning points and amplitudes of the resulting output gap data published by the Bank of Canada are very similar to the residuals from HP filtered data. See Siklos, Werner, and Bohl (2004).

[19] Siklos, Werner and Bohl (2004) estimate reaction functions for a group of inflation and non-inflation targeting countries, and find that inflation targeting countries are more forward-looking.

specification of the instruments and to whether a standard or an extended Taylor rule is estimated. Indeed, if we take the case of Germany, goodness of fit is improves considerably if housing prices are used as an additional argument. Second, plausible reaction function estimates, wherein the central bank evinces a concern for the output gap, are found with weights broadly comparable with others reported in the literature (see Table 1). Third, the set of plausible reaction function estimates consistent with the Taylor principle can just as easily be found where asset prices serve as an additional instrument as when such variables appear as separate argument in the Taylor rule. Nevertheless, when we test for instrument relevance we are able to conclude that standard Taylor rules with asset prices as additional instruments produce adequate specifications. For example, housing prices are highly correlated with the output gap for Germany and France and with inflation for Italy. However, asset prices are largely orthogonal to innovations in the policy rule, with the exception of Italy, where either stock returns, housing prices, or the aggregate asset price index appear to belong as additional arguments in the Taylor rule.

Adding some asset price to a standard Taylor rule tends to reduce the weight on the inflation variable although, other than for France, the Taylor principle is not violated. However, if we test whether the *sum* of the coefficients on the inflation and asset price gaps is greater than one the relevant null hypothesis cannot be rejected,

Table 2: Coefficients in Forward-Looking Standard and Extended Taylor Rules: Full sample Estimates

Country- Case #.Type of Rule, filter [asset price]	β	θ	*x*	ρ	α	J	RMSE	R^2_p $\tilde{\pi}$	$\tilde{y}$	$\tilde{x}$
France										
1. Standard hp4800	2.00 (0.92)*	9.60 (9.02)	NA	0.95 (0.04)*	-0.60 (5.06)	.16	7.05	.10	.03	
2. Extended hp4800 [$\tilde{a}$]	0.63 (0.28)*	0.88 (1.80)	0.50 (0.21)*	0.92 (0.02)*	3.75 (0.02)*	.12	2.90	.14	.09	
3. Standard ($\tilde{h}, \tilde{c}$)	2.96 (0.59)*	2.67 (0.10)*	NA	0.91 (0.03)*	-0.83 (1.58)	.16	9.65	.13	.79	
4. Extended hp4800 [$\tilde{a}$] / ($\tilde{h}, \tilde{c}$)	0.60 (1.16)*	3.60 (11.99)	0.20 (10.96)	0.95 (0.02)*	1.00 (3.10))	.14	2.86	.04	.02	.003
Germany										
5. Standard hp4800	1.33 (1.13)*	0.83 (1.85)	NA	0.94 (0.08)*	-0.17 (3.04)	.13	3.48	.04	.03	
6. Extended hp4800 [$\tilde{h}$]	0.27 (0.05)*	0.04 (0.05)	0.57 (0.02)*	0.49 (0.13)*	4.59 (0.16)*	.21	3.17	.79	.85	.21
7. Extended $\tilde{\varepsilon}$	1.18 (0.44)*	1.98 (0.58)*	-0.20 (0.06)*	0.95 (0.02)*	-1.20 (1.67)	.21	6.47	.14	.01	.10
8. Extended hp4800 $\tilde{\varepsilon}$	1.33 (0.44)*	0.83 (0.34)*	-0.17 (0.05)*	0.94 (0.02)*	-0.17 (1.47)	.20	5.31	.10	.01	.07
Italy										
9. Standard	1.79 (0.26)*	1.40 (0.80)*	NA	0.58 (0.08)*	2.21 (1.34)*	.13	3.11	.68	.47	
10. Extended [$\tilde{s}$]	1.70 (0.11)*	0.47 (0.43)	0.03 (0.02)	0.70 (0.06)*	2.50 (0.72)*	.16	23.57	.99	.01	.55
11. Extended hp4800 [$\tilde{a}$]	1.75 (0.13)*	0.81 (0.37)*	0.07(0.03)*	0.64 (0.05)*	2.41 (0.77)*	.16	2.78	.99	.03	.65
12. Extended hp4800 [$\tilde{h}$]	1.30 (0.13)*	0.39 (0.44)	0.38(0.08)*	0.77 (0.05)*	4.09 (0.97)*	.16	2.22	.66	.02	.67

Notes: Standard refers to the Taylor rule as in (1). Extended refers to the extended Taylor rule as in (4). $\tilde{\pi}$ is the inflation gap where all estimates shown assume a constant value (normalized to zero). The results are shown only for those cases where plausible estimates for the coefficients in the various Taylor rules were obtained. The "filter" refers to the smoothing parameter λ used in the H-P filtering of the series in question (16 signifies that λ=1600; 48 means that λ=4800 in which case a "hp4800" is added). The extended rules add the relevant financial asset in the rule itself, otherwise financial assets may enter as additional instruments used in testing the over-identifying restrictions. These asset prices are shown in the brackets and are also defined in the text but see also below. J is the p-value for the test of over identifying restrictions. R^2_p is the partial R-squared measure developed in Godfrey (1999). It is calculated as $(se^{OLS}/se^{GMM}) * (RSD^{GMM}/RSD^{OLS})$ where *se* is the standard error estimates for the coefficients on the endogenous variables, and RSD is the residual standard deviations for the regressions estimated either via OLS or GMM. Data used are quarterly. The financial assets represented are $\tilde{a}$ (aggregate asset price index), $\tilde{h}$ (housing prices), $\tilde{s}$ (stock prices). Additional instruments include $\tilde{c}$ (consumption spending), $\tilde{\varepsilon}$ (real exchange rate), lagged US interest rates (i_{US}), lagged interest rates (i), the rate of change in oil prices (*oil*), the lagged output gap ($\tilde{y}$), and a constant (*const*). Four lags for all instruments were used. Samples are given in Table 2. Estimates use GMM with 4 lags for each instrument, a Bartlett kernel, Newey-West bandwidth, and HAC weighting matrix. RMSE = root mean squared errors.

based on a Wald test.[20] A good example is the extended Taylor rule for Germany augmented with housing prices (case 6), or France with the BIS's measure of aggregate asset prices added (case 2). Hence, the reaction to a more general set of "prices" also produces results consistent with the Taylor principle. Fifth, we find that while interest rate smoothing is an important feature in all reaction function estimates, as proxied by the lagged interest rate variable, there appear to be substantial cross-country differences. In addition, estimates of ρ can be sensitive to the specification in question. For example, in the case of Germany, the degree of interest rate smoothing drops substantially if housing prices represent a separate argument in the reaction function. In the case of Italy, there appears to be somewhat more interest rate persistence when either housing or stocks enter an extended Taylor rule. Finally, it is notable that if we evaluate the root mean squared errors (RMSE) based on the differences between actual and the implied interest rate target based on the various estimated rules, the best outcome is when an asset price is added to the Taylor rule.

In general then, a statistical approach to estimating forward-looking reaction functions would result in choosing a standard Taylor rule possibly with housing prices as an additional instrument to the usual list of lags in inflation, the output gap, and the nominal interest rate. While other estimates seem equally valid, the preferred ones have the advantage of retaining Taylor's original rule while using the same type of asset price for a cross-section of countries.

Next, we briefly describe some extensions to the results shown in Table 2 considered but not shown here. For example, we considered the possibility that central banks react differently to positive versus negative changes in inflation.[21] We find that the null of $\beta^+ + \beta^- = 0$, that is, that the reaction to the sum of positive and negative inflation changes cannot be rejected for France and Germany while, in the case of Italy, the results are mixed. The bottom line is that there is no evidence that central banks

[20] In the case where the real exchange rate gap appears in the extended Taylor rule, the absolute value of the coefficient is used owing to the manner in which the real exchange rate series is defined, as explained above.

[21] We also considered a separate possibility, namely that reactions to the output gap might also be asymmetric. However, owing to the uncertainty surrounding the measurement of this variable we opted to focus on inflation which is both more easily measured and the subject of debate among those who view some central banks as displaying a bias toward tight monetary policies, especially during the 1990s.

examined here are more likely to tighten than other central banks in our sample.[22] Replacing the lagged domestic interest rate with the lagged German rate leaves most of the reaction function estimates unchanged. Finally, we also re-estimated all the reaction functions by replacing the HP filtered output gap measure with a measure derived from applying a Blanchard-Quah decomposition.[23] The resulting reaction functions are broadly similar to the ones shown in Table 2 although the range of coefficients on the output gap is somewhat greater when an SVAR is used to generate the output gap. In addition, the p-values for the test of over-identifying restrictions are also generally higher than in the case where the HP filter is employed.

Next, we turn our attention to estimates of backward-looking Taylor rules. These are shown in Table 3. Again, we retain only those Taylor rules which appear plausible (i.e., have the correct signs). It is quite apparent, however, that such an approach results in central banks potentially "under"-reacting to inflation and "over"-reacting to the output gap. Only estimates from Italy produce coefficients on inflation that are roughly consistent with the "Taylor principle". Also notable is that the coefficients on the output gap are considerably larger than was found for the forward-looking models. When the lagged German interest rate is used in place of the domestic interest rate (not shown), reactions functions for France are now consistent with the Taylor principle.

[22] Since the sample extends back into the 1980s the result is not unduly influenced by the disinflation since the 1990s nor by the Maastricht convergence requirements. Indeed, when the "threshold" for positive versus negative gaps is defined by the inflation rate consistent with the Maastricht Treaty, we find significantly higher interest rate responses to positive inflation gaps for Italy and France. For Germany the results are mixed although the size of the bias is quantitatively small.

[23] The relevant output gaps were obtained by estimating a VAR of order 8 consisting of the log of real GDP and inflation, with an exogenous deterministic trend. The estimated output gap is then the sum of demand shocks, that is, the level of output due to the accumulated temporary shocks. The restriction imposed is that inflation cannot affect output in the long-run.

Table 3: Estimates of Coefficients in Backward-Looking Taylor Rules

Country-case [sample], filter, asset price variable	β	θ	*x*	ρ	α	RMSE
France						
1 [75-98], hp1600	0.50 (0.25)*	2.70 (1.57)*		.89 (0.05)*	5.50 (1.82)*	3.13
2 [75-98], hp1600 $\tilde{h}$	0.38 (0.21)*	1.38 (1.14)	0.69 (0.36)*	.87 (0.05)*	6.07 (1.43)*	2.52
3 [75-98], hp4800 $\tilde{h}$	0.36 (0.19)*	0.71 (1.14)	0.57 (0.36)*	.86 (0.05)*	6.07 (1.43)*	2.69
Germany						
4 [78-98], hp4800 $\tilde{\varepsilon}$	0.27 (0.45)	1.90 (0.70)*	0.05 (0.03)	.89 (0.04)*	3.73 (1.19)*	2.74
Italy						
5 [80-98], hp1600	0.92 (0.20)*	2.08 (1.62)		.88 (0.05)*	4.25 (2.13)*	3.11
6 [80-98]	1.00 (0.21)*	1.91 (1.33)		.89 (0.05)*	4.27 (2.30)*	3.59

Note: See Notes to Table 2 for explanation of symbols and models. Estimation using Ordinary Least Squares.

There is also no evidence of asymmetric reactions to inflation shocks for France, and Italy while the net effect is negative for Germany (not shown). These results are broadly consistent with those found when forward-looking models are estimated. The same is generally true when the Blanchard-Quah decomposition is used to generate the output gap (results not shown). Indeed, the reaction functions begin to look more like the ones shown in Table 2. Finally, few, if any of the backward-looking estimates display any statistically significant reactions to asset prices, other than Banque de France's reaction to housing prices. Note also that, with the exception of Germany and Italy, the lowest RMSE is achieved when an asset price is added to the standard Taylor rule.

Comparing the RMSE for forward and backward-looking reaction functions, it is not clear whether one type is clearly preferred over the other, at least in purely empirical terms. In order to shed more light on this issue, we next perform encompassing tests of the kind suggested by Chong and Hendry (1986). Based on these, one cannot reject the null that actual interest rate movements represent a linear combination of forward and backward looking behavior in 2 of the three countries considered (Germany and Italy) while the backward looking estimates encompass the forward looking ones for France.

While Tables 2 and 3 provide reaction function estimates that are in varying degrees based on the past history of the time series of interest, Table 4 considers actual forecasts of inflation and the real GDP growth.[24] Once again we limit the discussion to plausible reaction function estimates and consider three different forecasts. These are: forecasts of inflation and the output gap from the OECD (OECD Main Economic Outlook, *various issues*), forecasts of inflation and real GDP growth from *The Economist* (Poll of Forecasters, *various issues*; see Siklos (2002) for details), and inflation and real GDP growth forecasts from *Consensus Economics* (www.consensuseconomics.com). Estimates rely on OLS where the current nominal interest rate is regressed on the inflation and output forecasts for the current quarter (at annual rates) made in the previous year (hence the label *t-1* in the Table). In the case of the OECD forecasts, as these are semi-annual, the raw data were converted to the quarterly frequency through interpolation while the forecasts from *The Economist*, available monthly, were converted to quarterly through simple averaging. Unfortunately, we do not have forecasts for the asset price variables considered earlier. However, to the extent these forecasts reflect anticipated asset price developments, a distinct possibility, the resulting estimates indirectly tell us something about the indicator role of asset prices.[25]

The results are striking for they suggest that if central banks reacted to these forecasts believe they would, in effect, have reacted very strongly to expectations of rising inflation, more so than any of the alternative estimates presented so far. Moreover, save the case of the lone inflation targeting country in our data set, central banks are still seen as reacting to output. Nevertheless, the impression is that forecast based reaction functions interpret the central bank in question as being far more aggressive than either the backward or forward-looking estimated Taylor rules shown here, in some cases approaching the "inflation nutter" type of central bank in the sense of King (1997).[26] Also striking is the fact that the forecast-based reaction functions

[24] Other than the OECD all other forecasts are for the rate of change in real GDP growth. We detrended these to obtain a proxy for the output gap.

[25] Obviously, we do not know the nature of the forecasting models in question. However, it is interesting to note that current quarter forecasts regressed on lagged asset prices produce highly significant regression results (not shown).

[26] The inflation "nutter" places an excessively large emphasis on inflation fighting and no concern for output. No plausible reaction function could be estimated if the forecast-based rule used two or more years ahead forecasts to generate a policy rule (not shown).

track interest rates better in many cases than either the forward or backward-looking varieties shown in Tables 2 and 3. Nevertheless, when the encompassing tests (not shown) are extended to include forecast-based estimates, these are never encompassed by either forward or backward looking models.[27]

Finally, we turn our attention to the issue of the stance of monetary policy in the euro area. Since the ECB took responsibility for monetary policy in 1999 member countries in the euro area can no longer respond to own inflation or output gap shocks. Since it is too soon to estimate a euro area reaction function for a sample beginning in 1999, we instead perform a counterfactual experiment by asking what might interest rates have been if the ECB's response ranged from the most responsive to the least responsive member of the euro area based on estimates that prevailed until the end of 1998.[28] The results are shown in Figures 1A and 1B. Both Figures plot the ECB's instrument of monetary policy, the repo rate, and the hypothetical interest rate path that would have prevailed if we relied instead on the range of inflation and output gap coefficients based on the variety of coefficient estimates in Table 2.[29] For the purposes of this experiment we assume that the ECB is forward-looking.

The results suggest that if the ECB reacted in the most aggressive fashion possible to inflation and the output gap (i.e., Max INF + GAP), based on historical estimates, interest rates would have been considerably higher and more volatile than the actual ECB's repo rate, at least until 2002. If, instead, we posited a euro area wide reaction function that permits an aggressive reaction either to stock prices (SP) or the BIS's measure of aggregate asset prices (AP), along with inflation and the output gap of course, interest rates in the euro would have become negative by 2001.[30] Since this is clearly an implausible result one can conclude that an aggressive response to asset prices in the euro area would have been excessive while a modest response to these

[27] The results of these encompassing tests cannot be directly compared to the same tests reported earlier because the sample size is shorter due to data constraints for forecast data. For Germany and Italy forward and forecast based rules encompass backward-looking rules. For France, backward and forecast based rules encompass forward-looking rules.

[28] Euroarea-wide data prior to 1999 re available though it is unclear under the circumstances how useful they are since the transfer of responsibility over monetary policy clearly represents a regime change.

[29] Figures 1 rely on standard Taylor rules. Using some of the estimated extended rules did not change the conclusions from this exercise and are, hence, omitted here.

[30] Euro area wide measures of inflation and real GDP were provided by the BIS. Euro area wide measures of stock returns and asset prices were generated as a weighted average of individual euro area member countries' estimates. See Siklos, Werner and Bohl (2004) for additional details.

same asset prices would have resulted in a looser monetary policy than the ECB actually implemented. More generally, the evidence suggests that it would have been difficult for the ECB to know which asset price to rely on since, prior to 1999, it is conceivable that different asset prices mattered to each of the then autonomous central banks.

However, it is notable that by 2002, ECB policy is too tight regardless of the representative coefficients used to generate the counterfactuals. This provides a little bit of evidence to support critics of ECB policy, especially from 2002 on. Our results, at least for the most recent observations, stand in contrast with those reported by Faust, Rogers and Wright (2001), and Clausen and Hayo (2002), both of whom reported that the ECB's monetary policy stance was looser relative to the one that would have been implemented by, say, a still independent Bundesbank.

5. Conclusions

This paper has considered the estimation of both standard and extended Taylor rules for select euro area countries. The latter incorporate asset prices in order to determine whether central banks may have been reacting to developments in the financial sector. Alternatively, we considered the possibility that asset prices may have served as forward-looking variables that played a role as instruments in estimates of forward-looking reaction functions. Based on priors of what constitutes "best practice" in the conduct of monetary policy, we find that forward-looking models describe central bank behavior quite well since the early 1980s and represent an even better description of their reaction to inflation and output since the beginning of the 1990s.

Nevertheless, in all such cases, more plausible estimates require the inclusion of asset prices as instruments in GMM estimates of forward-looking reaction functions. Turning to backward-looking estimates these cannot be rejected out of hand though they produce coefficient estimates that are not entirely consistent with the conduct of a successful monetary policy, as stipulated by Taylor. Finally, forecast-based reaction functions pre-suppose that monetary authorities are more aggressive than might be expected though the resulting reaction functions are generally superior to either forward or backward-looking versions, at least based on the RMSE criterion.

While the finding that asset prices are useful indicators in the conduct of monetary policy the ECB does face a potential difficulty since in the pre-ECB era, the asset price that appears to have been best suited to explaining interest rate movements varied across the countries examined. Although housing prices would be an acceptable candidate for such an indicator, the data are unavailable for the euro area. By contrast, using either a measure of aggregate prices or stock prices yields implausible estimates, at least based on the performance of the central banks prior to devolving their authority to the ECB. This is certainly an indication of additional difficulties faced by the fledgling central bank as it attempts to provide good monetary policy for the euro area.

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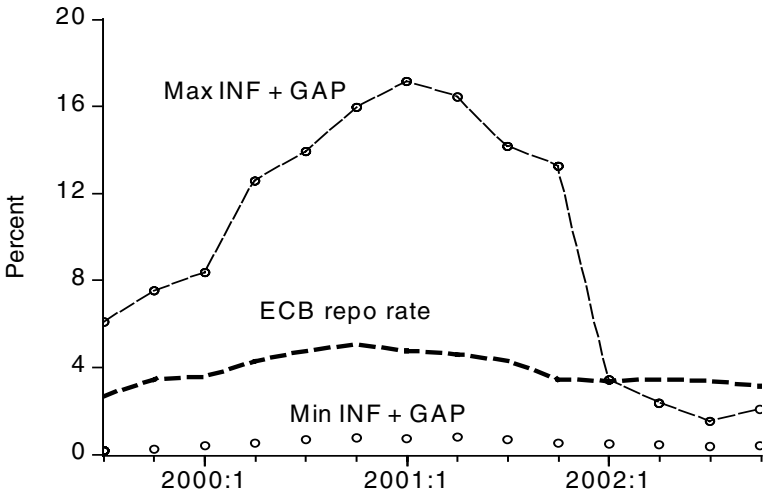
Table 4: Estimates of Coefficients in Forecasting Rules

Country-case [sample], filter	β	θ	ρ	α	RMSE
France					
1 [90-99], hp4800 $\tilde{y}, \pi^{E}$	3.67 (1.38)*	2.67 (2.42)	.88 (0.09)*	-2.67 (3.49)	2.93
2 [90-99], hp4800 $\tilde{y}, \pi^{O}$	0.38 (0.35)	2.00 (0.06)*	.92 (0.04)*	6.63 (2.61)*	4.08
3 [90-99], hp1600 $\tilde{y}, \pi^{C}$	4.21 (0.73)*	1.58 (1.71)	.76 (0.10)*	-3.58 (1.86)*	1.14
4 [90-99], hp4800 $\tilde{y}, \pi^{C}$	5.50 (1.20)*	1.60 (2.13)	.80 (0.11)*	-7.40 (3.11)*	1.26
Germany					
5 [78-98], hp4800 $\tilde{y}, \pi^{O}$	0.00 (0.47)	1.91 (0.71)*	.89 (0.04)*	6.73 (1.82)*	3.59
6 [90-98], hp1600 $\tilde{y}, \pi^{C}$	2.91 (0.88)*	0.00 (1.51)	.89 (0.06)*	-2.09 (0.07)*	0.86
Italy					
7 [90-99], hp4800 $\tilde{y}, \pi^{E}$	2.00 (0.29)*	0.15 (0.80)	.67 (0.12)*	0.39 (1.35)	1.83
8 [90-99], hp4800 $\tilde{y}, \pi^{O}$	0.67 (0.19)*	1.58 (0.63)*	.88 (0.03)*	6.83 (2.07)*	5.19
9 [90-99], hp1600 $\tilde{y}, \pi^{C}$	2.20 (0.40)*	3.15 (2.51)	.80 (0.10)*	-0.25 (1.62)	1.83
10 [90-99], hp4800 $\tilde{y}, \pi^{C}$	2.55 (0.39)*	1.41 (1.93)	.78 (0.10)*	-0.59 (1.46)	1.36

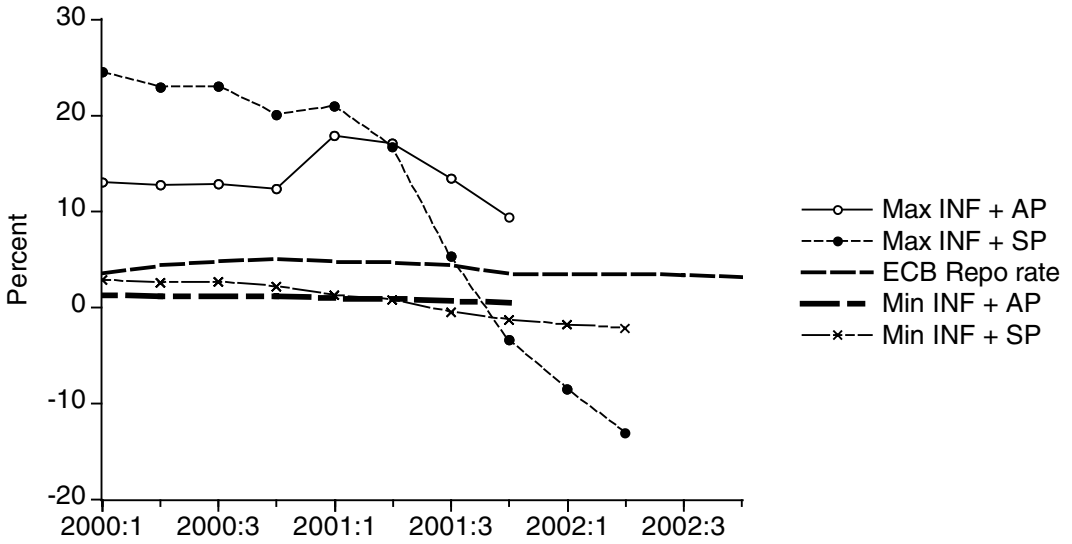
Notes: See Notes to Table 2 for explanation of symbols and models. Samples reflect data availability. Forecasts in question made at time *(t-1)* for time *t*. Sources of forecasts are: Consensus forecasts (C). Data are quarterly; semi-annual data from the OECD (O) were converted to quarterly via interpolation; data are monthly for *The Economist* (E) converted to quarterly via simple averaging. Estimation using Ordinary Least Squares.

Figure 1: Monetary Policy in the ECB Era: Some Counterfactual Experiments

A. Made in Germany Monetary Policy for the ECB



B. A Range of Policy Rates for the Euro Area



Notes: The top figure shows the actual euro area repo rate (ECB repo rate) and the repo rate under two counterfactual exercises: for Max INF + GAP we generate estimates from $i_t = 4.59 + 2\pi + 2.94\tilde{y}$ which corresponds to the largest values for the response to inflation and the output gap that was obtained (Austria). Here inflation and the output gap are for the euro area; in the case of Min INF + GAP the expression becomes $i_t = 0 + 0.29\pi + 0\tilde{y}$ again corresponding to the smallest coefficients obtained (Germany).

In Figure 1B, we apply the same principle now adding an asset price variable (either $\tilde{a}$ *or* $\tilde{s}$) with the coefficients ranging from 0.07 (Min) to 0.57 (Max), again using euro area wide measures for these variables. As available data for AP end in 2001 for AP and mid 2002 for SP we cannot extend the counterfactual estimates to the end of 2002.

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