The Robustness and Efficiency of Monetary Policy Rules as Guidelines for Interest Rate Setting by the European Central Bank

by

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Revised: February 1999

Abstract

This paper examines the implications of recent research on monetary policy rules for practical monetary policy making, with special emphasis on strategies for setting interest rates by the European Central Bank (ECB). The paper draws on recent research and new simulations of a large open economy model to assess the *efficiency* of a simple benchmark rule in comparison with other proposed rules. The paper stresses new results on the *robustness* of monetary policy rules in which each rule that is optimal or good according to one model or researcher is tested for robustness by other researchers using different models. Because of the large increase in the number of economists focussing on econometric evaluation of monetary policy rules for the interest rate instrument and because of the parallel increase in the variety of models being developed for this purpose, much more evidence is becoming available on the robustness of simple monetary policy rules for the interest rate than ever before.

This is a revised version of a paper prepared for the Monetary Policy Rules Conference sponsored by the Sveriges Riksbank and the Institute for International Economic Studies, Stockholm University, Stockholm, Sweden, June 12 and 13, 1998. I am grateful to Leonardo Leiderman, Ronald McKinnon, Akila Weerapana, Shu Wu and many participants at the conference for helpful comments and assistance. This research was supported by the Stanford Institute for Economic Policy Research.

Research on monetary policy rules has mushroomed since the early 1990s at universities, central banks, research institutes, and private financial firms. In a relatively short span of time, an enormous amount of information has been generated by this research effort. This heightened interest in policy evaluation has enabled researchers to examine the robustness of proposed policy rules with much more depth and rigor than ever before. By carefully studying the empirical evidence, the computer simulations, and the theoretical calculations in this research, I believe one can find much that is helpful for improving policy in the future, or, at least, for maintaining good monetary policy performance in those countries in which it has been good. In this paper I focus on the implications of this research for interest rate decisions at the European Central Bank

Economists conducting research on monetary policy rules take as given that central banks should have a goal, or target, for the rate of inflation. The target may be explicit as in Canada, New Zealand, Sweden, and the U.K. or implicit as in the United States or Germany; the target may be a range of inflation rates or an average inflation rate over a period of time. Most economic researchers also take as given that the central bank should endeavor to keep inflation close to the target through the guidance of a monetary policy rule, or perhaps a portfolio of such rules, in which their instrument of policy—most always the short-term interest rate—is adjusted in response to developments in the economy. The key question posed in this research is: what type of monetary policy rule should the central bank use to guide its decisions, and, in particular, how responsive, if responsive at all, should the central bank's interest rate decisions be to real output, the exchange rate, the lagged interest rate, and the inflation rate itself? The degree to which the actual inflation rate fluctuates around the target is a key measure of performance used in these studies, but it is not the only performance measure: fluctuations in real output, employment, the interest rate, and unanticipated inflation are also given weight in the objective functions. The recent research has included historical studies of individual countries, cross-section studies comparing different countries, time-series econometric studies, and impressive advances in theoretical modeling.[1]

Much of this research has focussed on whether simple benchmark monetary policy rule for the interest rate could be usefully amended or altered in order to improve economic performance.[2] For example, would an interest rate response to the *forecast* of the inflation rate work better than an interest rate response to the actual inflation rate and to real output separately as in the benchmark rule? Should the interest rate respond to actual inflation or real output by a larger or smaller amount than the benchmark rule? Or would responding to the exchange rate or to the lagged interest rate as well as to real output and inflation improve economic performance?

I have been struck by several of the empirical findings and model simulation results. There are significant correlations, both over time and across countries, between

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[1] New research on theoretical models of staggered wage and price setting has closely paralleled the recent research on monetary policy rules because price and wage rigidities are the source of short-run monetary neutrality in the models used for evaluating alternative policy rules. A review of the recent work on price and wage rigidities in macroeconomics is provided in Taylor (1999a).

[2] An example is the simple policy rule I proposed several years ago (Taylor 1993a) as a guide for the Federal Reserve’s decisions about the federal funds rate. To the degree that research in the late 1990s is looking to more complex rules with more variables than simple benchmark rules, it contrasts with the research in the early 1990s

policy rules for the interest rate and economic performance; these correlations validate theoretical predictions about how policy should affect performance. Model simulations show that simple policy rules work remarkably well in a variety of situations; they seem to be surprisingly good approximations to fully optimal policy. Simulation results also show that simple policy rules are more robust than complex rules across a variety of models. Introducing information lags as long as a quarter does not affect the performance of the policy rules by very much. Moreover, the basic results about simple policy rules designed for the United States seem to apply broadly to many countries.

Some of the findings of the research are useful for telling us what we do not know. For example, there is uncertainty about how useful it is for central banks to react to the exchange rate when setting interest rates, or to use a monetary conditions index which automatically takes exchange rates into account. Model simulations are not definitive about the value of a policy that responds to the *lagged* interest rate, a response that is sometimes referred to as interest rate smoothing, though the results show that the term "smoothing" is misleading. There is also disagreement about whether the interest rate should respond solely to a measure of *expected future* inflation, rather than actual observed values, a response that is sometimes called forward-looking, though the results show that the term "forward-looking rules" connotes a misleading contrast with the benchmark rules. And there is still great uncertainty about measuring potential GDP and the equilibrium real interest rate, though this is a problem for any monetary policy. Even in these cases of disagreement, however, the research findings have been helpful in

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which tried to simplify the complex policy rules implied by econometric models with many variables and many lags.

telling us the reasons for the disagreements and thus pointing out ways to resolve this uncertainty with further research. For example, the degree to which a model uses rational expectations greatly influences whether a policy rule that reacts to lagged interest rates is a good or bad policy.

1. A General Framework for Evaluation of Policy Rules

As shown in Table 1, researchers are using many different types of models for evaluating monetary policy rules, including small estimated or calibrated models with or without rational expectations, optimizing models with representative agents, and large econometric models with rational expectations. Some models are closed economy models, some are small open economy models, and some are multicountry models. Monetary policy rules are also being evaluated by policy makers themselves drawing on their own practical experience using monetary policy rules as inputs to the policy making process. Examples of different policy maker's perspectives on policy rules are also listed in Table 1. Of course formal modeling is also usefully supplemented with historical or comparative analysis across countries. Seeking robustness of the rules across a wide range of models, viewpoints, historical periods, and countries is itself an important objective of policy evaluation research (Bryant, Hooper, and Mann (1993), McCallum (1999)).

Despite the differences in the models, there are some important common features. First, virtually all the models are dynamic and stochastic; the covariance matrix of the shocks is just as important a parameter in these models as are the interest rate elasticities or production function parameters. Second, the models are general equilibrium models in the sense that they describe the behavior of the whole economy, not only one sector of the economy. Third, all the models used in this research incorporate some form of nominal rigidity, usually through some version of staggered wage or price setting.

The following notation provides a general framework for describing the models and the methods most commonly used for evaluating monetary policy rules. Consider a set of dynamic stochastic equations of the form

$$y_t = A(L,g)y_t + B(L,g)x_t + u_t, \qquad (1)$$

$$x_t = G(L)y_t \qquad (2)$$

where y_t is a vector of endogenous variables (such as the rate of inflation, real output, and the exchange rate), x_t is the policy variable (the short term interest rate in all the research discussed in this paper), u_t is a serially uncorrelated vector of random variables with variance-covariance matrix Σ, and A(L,g), B(L,g), and G(L) are matrix or vector polynomials in the lag operator (L). The vector g consists of all the parameters in G(L).

Equation (1) is the reduced form solution to the dynamic stochastic rational expectations model used for the evaluation of a monetary policy rule. Equation (2) is the monetary policy rule to be considered. The policy rule is assumed to be known and taken as given by all households and firms described by the model. The notation emphasizes that A and B depend on the parameters (g) of the policy rule.[3] Substitution of the policy

[3] In the special case where the model is not a rational expectations model (no forward-looking), equation (1) is simply the model itself. If there are forward-looking expectations variables in the model (perhaps through the Euler equations of an optimizing model), then we assume that these expectations variables have been solved out using a rational expectations solution method to get the reduced form of the model in (1). If the

rule (2) into the reduced form equation (1) results in a vector autoregression in y_t and its lagged values. From this vector autoregression one can easily find the steady state stochastic distribution of y_t, characterized, for example, by the autocovariance matrix function or the spectral density of y_t. It is clear that the steady state stochastic distribution is a function of the parameters (g) of the policy rule along with Σ and the other parameters in A and B. Hence, for any choice of parameters g in the policy rule one can evaluate any objective function that depends on the steady state distribution of y_t. For example, if the loss function is a weighted average of the variance of inflation and the variance of real output, then the two diagonal elements of the covariance matrix corresponding to inflation and real output are all that is needed. With this method of evaluation of the loss function, one can compare the performance of different policy rules—perhaps complex rules versus simple rules—or compute the optimal policy rule by maximizing the welfare function with respect to the parameters of the policy rule using a nonlinear optimization algorithm.

Specific examples of models used for policy evaluation work that fit into this general framework are the simple non-rational expectations models of Ball (1997, 1998) and Svensson (1997), the time-series econometric model of Rudebusch and Svensson (1999), the Federal Reserve's large scale rational expectations econometric model described by Brayton, Levin, Tryon, and Williams (1997), the small forward-looking models of Clarida, Gertler, and Gali (1997b), and Fuhrer and Moore (1995), the multicountry rational expectations model of Taylor (1993b), and the representative agent

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underlying model is nonlinear (as in Taylor (1993b)), then (1) will be nonlinear and y_t will have to be determined with a nonlinear solution algorithm. In this case we can interpret (2) as a linear approximation of the solution.

optimizing models of Goodfriend and King (1997), McCallum and Nelson (1999), Rotemberg and Woodford (1999), Svensson (1998), and Chari, Kehoe, and McGrattan (1999).

The Role of Money in Interest Rate Rules

Several important features of most research evaluating monetary policy rules should be emphasized in the context of equations (1) and (2). One relates to the role of money when the central bank uses the interest rate as its instrument in its policy rule as assumed in all the papers discussed here. In principle, one of the elements in the vector equation (1) should be an equation describing money, perhaps through a money demand equation or perhaps through the first order conditions of an optimization problem with money in the utility function. However, if the policy rule in equation (2) describes the behavior of the interest rate, then the money supply is endogenous because the central bank must vary the money supply in order to achieve its desired interest rate settings. The path for the endogenous money supply can be determined from the money equation in (1). For example, money is endogenous in the model of McCallum and Nelson (1999) and in the multicountry model of Taylor (1993b) when the central bank follows an interest rate rule. In these models, an increase in the target inflation rate (a shift in the policy rule for the interest rate) implies that the central bank must eventually increase the rate of money growth by the amount that the target inflation rate increases. Hence, the path for money growth followed by the central bank in the long run is exactly the rate that would be followed if money growth were the instrument of policy. However, because the change in money growth does not feed back into the model, money growth need not be computed; indeed, in some models (e.g. Rotemberg and Woodford (1999)) money growth is ignored. But using an interest rate rule does not eliminate the concept of money demand and money supply; it simply makes money endogenous.

Just as an interest rate rule has implications for the money supply, so does a money supply rule have implications for the interest rate. In fact, a fixed money growth rule will generally imply a reaction of interest rates to the inflation rate and to real output that is the same in sign though not necessarily same in size or timing as interest rate policy rules. In my view this connection between money supply rules and interest rate rules can be useful in formulating policy. When inflation gets very high or negative, interest rate rules lose their usefulness because expectations of inflation shift around a lot and are hard to measure. In these circumstances interest rate rules lose their advantages over money supply rules and can break down completely (see Taylor (1995)). For this reason it is useful for central banks to keep track of the money supply and perhaps monitor policy rules for the money supply or monetary base even when they are using interest rate rules as a guideline. For example, the St. Louis Federal Reserve Bank now publishes an interest rate rule that I proposed along with a rule for the monetary base developed by Bennett McCallum.[4]

Institutional Commitment to the Policy Rule

A second important point is that by assuming that the private sector takes the monetary policy rule (2) as given and by assuming that this policy rule is followed

[4] See *Monetary Trends*, January 1998

consistently by the central bank, most econometric policy evaluation researchers implicitly assume that the dynamic inconsistency problem is solved by some appropriate institutional design which takes incentives and politics into account. In other words, the implicit assumption is that the central bank is committed to following the policy rule. Of course, a large amount of useful monetary policy research has focussed on issues related to establishing such a commitment. But these issues are usually abstracted from in research on the evaluation of monetary policy rules. Virtually all of the econometric work on monetary policy evaluation assumes that the policy makers do not change the policy rule.[5]

A Simple Representative Model

It is helpful to examine a simple model which is both an example of equations (1) and (2) and representative of the different types of models used in the research on policy rules. Consider the following model:

$$y_t = -\beta(i_t - \pi_t - r) + u_t \qquad (3)$$

$$\pi_t = \pi_{t-1} + \alpha y_{t-1} + e_t \qquad (4)$$

$$i_t = g_\pi \pi_t + g_y y_t + g_0 \qquad (5)$$

where y_t is the percentage deviation of real GDP from potential GDP, i_t is the short-term nominal interest rate, π_t is the inflation rate, and e_t and u_t are serially uncorrelated

[5] A recent review of the literature on commitment, time inconsistency, and its implications for the design of monetary policy institutions is provided in Persson and Tabellini (1999).

stochastic shocks with a zero mean.. The parameters of the model are α, β, r (all positive) and the covariance matrix of the shocks u_t and e_t. The policy parameters are g_π, g_y, and g_0.

Observe that equations (3) and (4) together correspond to the vector equation (1) and that equation (5) corresponds to the policy rule in equation (2). In general α, β, and r are reduced form parameters that will depend on the policy parameters g_π, g_y, and g_0. For example, equation (3) could be the reduced form of an optimizing "IS" curve with future values of the real interest rates as in the model of McCallum-Nelson (1999) and Rotemberg and Woodford (1999); equation (4)—a price adjustment (PA) equation showing how prices adjust slowly over time—could be the reduced form of a rational expectations model with staggered wage and price setting, in which expectations of future wages and prices have been solved out. If the parameters do not change very much when the policy parameters change, then treating equations (3) and (4) as policy invariant—as is done in the models of Svensson (1997) and Ball (1997)—will be a good approximation. But if the parameters do change by a large amount in response to policy, then the changes must be taken into account in the policy evaluation. Nevertheless, when viewed as a reduced form, these equations summarize more complex forward-looking models and are useful for illustrating key points.

2. Getting the Sign Right on the Slope of Aggregate Demand

One of the most important policy implications of recent research on interest rate rules is actually quite a simple idea. The research shows that it is crucial to have the interest rate response coefficient on the inflation rate (or a suitable inflation forecast or smoothed inflation rate) above a critical “stability threshold” of one. In fact, a simple way to characterize the better monetary policy performance in the United States in the 1980s and 1990s compared with the 1960s and 1970s is that this response coefficient increased from below this stability threshold to above the threshold. If the European Central Bank chooses to use the short term interest rates as its instrument, then I believe that having a response coefficient greater than one will be the first step to achieving good performance.

The Response of the Interest Rate to Inflation and Macroeconomic Stability

The theoretical basis for this result can be shown graphically using the representative model in equations (3), (4), and (5). The two top graphs in Figure 1 show two different policy rules corresponding to different parameters in equation (5). These two rules lead to remarkably different economic performance according to the model.[6] The policy rule in the upper left is stabilizing and the one on the upper right is destabilizing. To see this, substitute equation (5) into equation (3) to get an aggregate demand (AD) relationship between π and y. The slope of this AD relationship is

$$-\beta(g_\pi -1)/(1+\beta g_y).$$

Clearly the slope of the relationship depends on the parameters of the policy rule. As shown in the lower panels in Figure 1, the relationship can be graphed in a diagram with the inflation rate on the vertical axis and real output on the horizontal axis.

[6] For simplicity we set g_y to zero in these diagrams, but the same argument applies if g_y is not zero.

The price adjustment (PA) equation (4) can also be graphed in the two lower panels and is shown as a flat line; the line is flat because the current inflation rate does not appear in equation (4). The PA line will gradually move up when y is greater than zero and gradually move down when y is less than zero, generating dynamic movements over time. A price shock (e) will also shift the price adjustment line, as shown in the lower panels of Figure 1.

Now consider the two cases in Figure 1. The dashed line in the upper panels has a slope of one. Hence, it is clear that for the rule on the left, g_π is greater than one, and for the rule on the right, g_π is less than one. Observe that the slope of the aggregate demand relationship is negative if the response of the interest rate to inflation (g_π) is greater than one and it is positive if g_π is less than one. The case on the left is the stable case because an upward shift in the price adjustment line (an inflation shock e) results in a decline in y below zero which brings the inflation rate (and the price adjustment line) back down. The case on the right is unstable because, with a positively sloped aggregate demand curve, an upward shock to inflation (e) causes y to rise and tends to increase inflation further. This relationship between the stability of inflation and the size of the interest rate coefficient in the policy rule is a basic prediction of monetary models used for policy evaluation research. In fact, because many models are dynamically unstable when g_π is less than one—as illustrated in Figure 1—the simulations of the models usually assume that g_π is greater than one.

International Comparisons and Historical Evidence.

Before examining these simulations it is useful to ask whether this basic prediction of the theory is validated by the data. In fact, several recent cross section and historical studies do lend support for this result. The size of the policy parameters differ over time and across countries and these policy differences translate into differences in inflation stability much like the simple illustrative model predicts.

Consider Wright's (1997) recent international comparison study of Germany, the United Kingdom, and the United States. Wright (1997) first documents that inflation has been much less stable in the United Kingdom than in Germany and that the United States has been somewhere in between, but closer to Germany than to the United Kingdom. Wright's measure of stability is the degree to which the long run inflation rate in each county could have been predicted during the 1961 to 1994 period. In particular, he finds that the 95 percent confidence interval for the steady state inflation is somewhat larger in the United States than in Germany, and much larger than in the United Kingdom than in either Germany or the United States. Second, Wright estimates the inflation response coefficient (analogous to g_{π}), for Germany, the United States and the United Kingdom. He finds that the relative size of these response coefficients is exactly as predicted by the theory.[7] "The responses to an inflation shock…appear to confirm prior expectations:

[7] While Wright's (1997) strong negative correlation between the response coefficients and inflation stability validates the theory, he also sometimes finds response coefficients that are near or even somewhat less than one which raises questions about the simple version of the theory in equations (3) and (4). These findings may be due to the fact that his sample period includes the late 1960s and 1970s when policy was less aggressive than it is today, as discussed below. However, Wright (1997) argues that the *nominal* interest rate may also be a factor in the IS equation (equation (3) in this paper). If so, then increases in the interest rate by less than one in response to inflation could still be

both the Bundesbank and the Federal Reserve respond actively to an inflation shock; but the Bank of England response is, in contrast, minimal. It is noteworthy that the Bundesbank's response is much the most rapid and aggressive of the three." (Wright (1997), p.19).

Historical analysis of policy rules adds further evidence to the importance of the interest rate response to inflation. Clarida, Gali, and Gertler (1997b), Judd and Rudebusch (1998), and Taylor (1999b) report results showing that the inflation response coefficient (analogous to g_π) was much larger in the 1980s and 1990s in the United States than it was during the late 1960s and 1970s. For example, the estimate of g_π in Taylor (1999b) is about .8 for the early period and about 1.5 in the later period, nearly twice as large. Since the inflation rate was much more stable in the later period than in the earlier period this result also supports the theory.[8]

Implications of the Policy Rule for the Long Run Average Inflation Rate

According to the representative model, the long run steady inflation rate occurs where $y = 0$ and is equal to

$$\pi = (g_0 - r)/(1 - g_\pi) \qquad (6)$$

which can be interpreted as the target inflation rate implied by the policy rule. By choosing the intercept in the policy rule, the central bank determines the target inflation rate. For example, if the target inflation rate is 2 percent, then the central bank should set

stabilizing. But the more basic point that higher values of g_π are associated with more stable inflation still holds in a model with a role for nominal interest rates in the IS equation.

$g_0 = r + 2(1- g_\pi)$. If $g_\pi = 1.5$ and r = 2 then the intercept should be one. To determine this coefficient the central bank needs to estimate the equilibrium interest rate r.

Equation (6) illustrates an important practical problem faced by central bankers who use the interest rate as an instrument. It shows that uncertainty about the equilibrium real interest rate r causes uncertainty about the long run inflation rate. However, uncertainty about the real interest rate does not cause an unstable inflation rate. Rather it results in a mistake in the level of the long run inflation rate. Note that the size of the inflation mistake due to uncertainty about the equilibrium real interest rate depends on the inflation response coefficient. Values of g_π close to one imply that mistakes about the real interest rate will causes big mistakes in the inflation rate; this is another reason to keep this parameter well above one.[9]

3. The Response to Output and the Lagged Interest Rate: Robustness Results

While keeping the interest rate response to inflation well above the critical threshold of one is a useful first step in formulating a monetary policy, it is also necessary to know how large the coefficients on inflation (and output) should be, and whether the policy makers should take account of the lagged level of the interest rate. Theoretical calculations are less useful for these questions because the answers depend on the model and the parameters of the model used by the researcher. In fact, there is some

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[8] The response coefficient appears to be even lower in the international gold standard period (Taylor (1999b)) when inflation (at least in the short run) and real output were less stable.

[9] Uncertainty about potential GDP (for example, the central bank may not know the steady state value of y) will cause similar errors in the long run inflation rate. As discussed in Taylor (1996) these errors can grow if the growth rate of potential is mistaken.

disagreement about the appropriate size of the response because of the differences in the models. To explore these issues there is no substitute for examining model simulations from a number of different models.

Table 2 provides such information about some recent simulation studies. It shows the results of five different policy rules simulated in nine different models. The models fall into the general framework of equations (1) and (2). They are dynamic, stochastic, general equilibrium models with nominal rigidities. They differ in size, degree of forward-looking, goodness-of-fit to the data (estimated or calibrated), and whether they are closed economy, small open economy, or multicountry models . The models are:[10]

Ball (1999) Model	(B)
Haldane and Batini Model	(HB)
McCallum and Nelson Model	(MN)
Rudebusch and Svensson Model	(RS)
Rotemberg and Woodford Model	(RW)
Fuhrer and Moore Model	(FM)
Small Fed Model	(MSR)
Large Fed Model	(FRB)
Taylor Multicountry Model (1993b)	(TMCM)

Because of the differences among the models they serve as a good robustness test of policy rules. The five different policy rules simulated in these models are of the form

$$i_t = \rho i_{t-1} + g_\pi \pi_t + g_y y_t + g_0 \qquad (7)$$

[10] The results in Table 2 are drawn from papers presented at a conference on monetary policy rules sponsored by the National Bureau of Economic Research. See Taylor (1999c).

with the coefficients:

	g_π	g_y	ρ
Rule I	3.0	0.8	1.0
Rule II	1.2	1.0	1.0
Rule III	1.5	0.5	0.0
Rule IV	1.5	1.0	0.0
Rule V	1.2	.06	1.3

Rules I and II each have a coefficient of one on the lagged interest rate, with Rule I having a high weight on inflation relative to output and Rule II having a smaller weight on inflation relative to output. Because the central bank partially adjusts its interest rate from the current rate in these two rules, they are sometimes referred to as interest rate smoothing rules, though they sometimes result in more interest rate volatility than rules which do not involve partial adjustment.

Rule III is the simple benchmark rule proposed in Taylor (1993a). Rule IV is a variant of Rule III with a higher coefficient (1.0 rather than 0.5) on real output; this rule reflects the suggestions of Ball (1997) and Williams (1998) that the interest rate should be adjusted more aggressively in response to changes in output.

Rule V is based on a proposal of Rotemberg and Woodford (1999); contrary to Ball (1997) and Williams (1997), Rotemberg and Woodford (1999) propose placing a very small weight on real output. Also noteworthy about Rule V is that it places a very high weight on the lagged interest rate.

The policy rules in Table 2 certainly do not exhaust all possible policy rules even if we restrict ourselves to the functional form in equation (1). In fact, it is likely that there is some other policy rule that would do better than any of the other policy rules. However, the rules in Table 2 do provide several of the kinds of perturbations of the benchmark rule that different researchers have suggested, and they therefore represent the degree of disagreement that exists about the most appropriate form for policy rules.[11]

The standard deviations of the inflation rate (around the target inflation rate), of real output, and of the interest rate are reported in Table 1. These are all steady state values obtained from the covariance matrix of the endogenous variables as explained in the discussion of the general framework above. Several conclusions can be drawn from the standard deviations in Table 2.

First, in order to assess the improvement in economic performance that could come from a higher weight on output than in the benchmark rule, compare the benchmark Rule III with Rule IV which has a higher output coefficient. It is clear that Rule IV does not dominate the benchmark Rule III. For all models, Rule IV gives a lower variance of output compared with Rule III, which is not surprising with the higher weight on output in Rule IV. But for six of the nine models Rule IV gives a higher variance of inflation. Raising the coefficient on real output from 0.5 to 1.0 represents a movement along the output-inflation variance tradeoff curve, rather than a movement toward or away from such a curve. Averaging across all the models also shows such a tradeoff, though the increase in the average inflation variability is small compared with the decrease in average output variability when rule IV replaces rule III. If we include the variability of the interest rate in the objective function, then there is even more evidence that rule IV does not dominate rule III because the variance of the interest rate is higher for rule IV for all but one model for which we have data (data is missing in one other model). The average interest rate variance across models is higher with Rule IV. To be sure Table 2

[11] An important topic for future research is to test the robustness of other proposed rules.

does not prove that there is not some other rule with a higher coefficient on real output (say 0.8) that dominates the benchmark rule.

Second, compare the three rules I, II, and V which respond to the lagged interest rate (interest rate smoothing rules), with rules III and IV in which the lagged interest rate does not appear. Again it is clear that the interest rate smoothing rules do not dominate the benchmark rule. Surprisingly, for many models the variance of the interest rate is higher in the rules which react to the lagged interest rate. Table 2 also indicates a certain lack of robustness in the rules with lagged interest rates (at least with these high coefficients): for a number of models these rules are unstable (shown by an infinite variance). The models in which the lagged interest rate rules work most poorly are the models without rational expectations. This is due to the reliance of such rules on the expectations they generate of future policy changes: if inflation does not come down, then the interest rate can be expected to move by an even larger amount in the future. However, in models without rational expectations, such expectation effects are not relevant. Rule V, which exploits these expectations effects to the greatest extent with a lagged interest rate coefficient greater than one, is less robust than the other rules, though it does very well in the Rotemberg-Woodford models for which it was designed to do well.

Simple Rules Compared With Complex Rules: Optimality and Robustness

All the rules in Table 2 are relatively simple rules, so the results are not useful for determining how well simple rules perform compared to complex rules. However, a number of researchers, including Rudebusch and Svensson (1999), find that simple rules perform nearly as well as the optimal rule in their model. Usually rules with only two factors—a nominal factor like the inflation rate and a real factor like real GDP—come very close to the fully optimal rule, which would include every variable in the model. This finding corresponds to that of business cycle research studies that have found that a two factor model can explain a large fraction of the business cycle variance.

A related and important result found in the simulations of Levin, Wieland, and Williams (1999) is that simple rules are more robust across models than more complex optimal rules. Focussing on the last four models listed in Table 2, Levin, Wieland and Williams perform a robustness analysis of simple rules versus optimal rules. They find that the fully optimal rules are much less robust. The optimal rules from one model perform much worse than the simple rules when simulated in other models. This result makes intuitive sense, because in order to do better than a simple rule in one model, the optimal rule exploits properties of that model that are model-specific. When the optimal rule is then tested out in another model those properties are likely to be different and the optimal rule works poorly.

Relevance of the Robustness Results for the European Central Bank

Taken literally the simulation results in Table 2 pertain mainly to Federal Reserve policy, because the researchers focussed on the United States economy and Fed policy. However, the general conclusions discussed above might apply nearly as well to the European Central Bank. For the multicountry model in Table 2 it is possible to do simulations of an interest rate rule for the ECB instead of the Fed and I report such simulations below. But the results for the smaller models may be relevant for the ECB in their current form. For example, for the closed models in which a large fraction of the parameters are calibrated with standard IS elasticities or utility function parameters rather than estimated parameters (Ball, Haldane-Batini, McCallum-Nelson, and Rotemberg-Woodford), the results would apply nearly as well to an economic region similar in size to the United States. With little information about the nature of wage and price setting in a single currency, I suspect that EMU versions of these models would be calibrated in a way similar to how they are calibrated now.

For the estimated time-series models such as Rudebusch-Svensson, the estimates would of course be different with EMU data. To give a feel for the magnitude of the differences, Table 3 reports estimates of the Rudebusch-Svensson model where real GDP and inflation are computed from an aggregate of Germany, France, and Italy during the years 1971.1 through 1994.4 with output detrended with a HP filter. The general form of the Rudebusch-Svensson model works remarkably well for this particular European aggregate. Using the same number of lags as in the United States there is virtually no serial correlation in the European model, and the coefficient on output in the inflation equation is very similar in magnitude. The main difference is in the size of the short run real interest rate elasticity term in the IS equation and the small size of the estimated IS shocks for the German, French, and Italian aggregate. Although only a rough estimate of the behavior to be expected in the future, these results suggest that simulation results from the United States for the Fed are relevant for the ECB. (Weymark (1997) shows that this type of model fits well in France, Germany, and Italy individually using annual data.)

Table 4 presents simulations of the benchmark monetary policy rule for the ECB using the estimates in Table 3 and compares them with the simulations from the Rudebusch-Svensson model. The resulting variability of inflation, output, and the interest rate is less in the EMU than in the United States. This provides some preliminary evidence that a rule as simple as the benchmark rule proposed as a guideline for the Fed would also provide a useful guideline for the ECB.

4. Simulating ECB Interest Rate Rules in a Dynamic Stochastic Multicountry Model

To answer more detailed questions about ECB policy, it is necessary to use an open economy model with exchange rates and interest rate links between countries. For this purpose I use a large open economy, rational expectations, econometric model developed explicitly for evaluating policy rules (Taylor (1993b). The model includes seven large countries: France, Italy, Germany, the U.K., Japan, Canada, and the United States. It is a dynamic stochastic model with an estimated variance-covariance matrix for use in stochastic simulations. The model has detailed descriptions of staggered wage and price setting in each country.

To simulate the model for ECB interest rate policy, I assume that exchange rates between France, Italy, and Germany are fixed permanently and that there is a single short term Euro interest rate. I call this Euro interest rate the ECB interest rate and assume that it can be set in the short run by ECB open market operations in Euro denominated bonds. I also assume that exchange rates between the Euro and the U.S. Dollar, the Yen and the Canadian dollar are perfectly flexible. I have not respecified the wage and price equations of France, Italy, and Germany to capture the effects of a single currency, but that would be a feasible future research project with this model.

Figure 2 shows the impact of a single fiscal shock in Germany for two different policy rules for the ECB. For both rules the Euro interest rate is increased or decreased according to the simple benchmark rule proposed in Taylor (1993a). In Rule G inflation and real output in the rule are measured by German inflation and output; that is,

$$i = 1.5\pi_{GER} + .5y_{GER} \quad \text{(Rule G)}$$

while in Rule E they are measured by a weighted average of inflation and output in Germany, France, and Italy.[12] That is,

$$i = 1.5\pi_{EMU} + .5y_{EMU} \qquad \text{(Rule E)}$$

For the single fiscal shock the more symmetric Rule E results in a smaller effect in France and Italy than the policy Rule G that reacts only to German variables. However, the effect of the shock in Germany with Rule E is larger. To the extent that the ECB decisions entail a greater focus on European aggregates than in the past, this kind of sharing of the effect of shocks throughout the region seems inevitable.

Stochastic simulations give a better estimate of the overall difference between Rule G and Rule E, because in fact the European economy is subject to many shocks in

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[12] Wieland (1996) reports similar results using the same model and a different policy rule, and assuing that the U.K was in the EMU. Dornbusch, Favero and Giavazzi (1998) report some Federal Reserve Board simulations.

additional to fiscal shocks. The stochastic simulations indicate a similar sharing of the impact of shocks, though the total effect is fairly small. The effect of switching from German inflation and output to EMU inflation and output in the ECB policy rule is relatively small on output fluctuations in Germany. The size of output fluctuations around trend go up in Germany by 13 percent (a 1 percent fall in real GDP would become a 1.13 percent fall), and they go down in France by 11 percent, and down in Italy by 16 percent. Importantly, the change from Rule G to Rule E has virtually no effect on German inflation and improves inflation performance in France and Italy.

Role of the Exchange Rate

Ball (1999) found that adding the exchange rate to the benchmark policy rule could improve macroeconomic performance somewhat in a small open economy model. The exchange rate is added to the policy rule in two ways in Ball's analysis: First the central bank uses a monetary conditions index (MCI) in place of the interest rate as its instrument. (An MCI is a weighted average of the interest rate and the exchange rate; for Ball the weight on the interest rate is .7 and the weight on the exchange rate is .3). Second, the lagged exchange rate is added as a variable to the policy rule. The net effect of these two changes is to add the current and lagged exchange rate to the right hand side of the policy rule. Ball found that, for the same amount of inflation variability, output variability could be reduced by 17 percent (that is, a 1 percent temporary fluctuation in output around potential would become a 1.17 percent fluctuation) by adding the exchange rate to the policy rule in this way. Because many of the models in Table 2 are closed economy models, there are no robustness results available for this type of policy rule.

To examine the effects of this type of policy rule for the ECB I simulated a policy rule for the ECB interest rate which includes the exchange rate as well as output and inflation in the multicountry model. The results are reported in Table 5 which shows the results of stochastic simulations of the multicountry model with the benchmark rule ($i = 1.5\pi_{EMU} + .5y_{EMU}$) and with the rule

$$i = 1.5\pi_{EMU} + .5y_{EMU} - 0.25e + 0.15e(-1)$$

where here the variable e is the U.S. Dollar-Euro exchange rate. This is the type of policy rule proposed by Ball (1999). Table 5 shows that such a rule for the ECB can improve performance in some countries. However, the differnces are fairly small and neither rule strictly dominates the other according to this model. The variability of inflation goes down in Germany, France, and Italy with the exchange rate in the rule, and the variability of output declines in France and Italy, but it increases in Germany. Hence, further research with alternative policy rules and models is certainly warranted to assess the impact of rules for the ECB that use exchange rates.

Role of the Forecast of Inflation

Haldane and Batini (1999) and Rudebusch and Svensson (1999) considered the effects of policy rules in which the central bank adjusts its interest rate in response to forecasts of future inflation rather than to current inflation and real output. Sometimes these rules are called forward looking rules because the forecast of inflation is used rather than the actual inflation. But in reality, forward-looking rules are based on current and/or lagged data because forecasts of the future are based on current and lagged data. Hence, inflation forecast rules are no more forward looking than rules that explicitly react to current and/or lagged variables.

The potential advantage of forecasting rules over simple benchmark rules such as the one proposed in Taylor (1993a), is that they incorporate other variables besides output and inflation that might be relevant for the forecast. Rudebusch and Svensson (1999) show that there are several variants on inflation forecasting rules including different forecast horizons, different response coefficients, and different reactions to lagged interest rates. Both Haldane and Batini (1999) and Rudebusch and Svensson (1999) find in their models that performance can be improved relative to other simple benchmark rules if one uses forecast rules. However, the improvement in performance is fairly small according to the simulations. For example, using a forecast inflation rule with a forecast horizon of 6 quarters, the standard deviation of inflation is 1.3 percent rather than 1.4 percent with the benchmark rule and the standard deviation of output is 0.9 percent rather than 1.1 percent according the Haldane-Batini calculations.

How do these results stand up when applied to ECB interest rate setting using this multicountry model? Table 5 compares the benchmark rule ($i = 1.5\pi_{EMU} + .5y_{EMU}$) with the following inflation forecast rule considered by Haldane and Batini (1999):

$$i = 0.32i(-1) + 2.62E_t\pi(+8) \qquad \text{(Inflation forecast rule)}$$

Table 5 shows that using the inflation forecast rule in the EMU would raise the variability of both output and inflation in Germany, France, and Italy compared with the benchmark rule. Hence, the forecast inflation rule is dominated by the benchmark rule according to this multicountry model.

8. Concluding Remarks

The purpose of this paper has been to draw implications from recent research and new policy simulations for interest rate setting at the European Central Bank. The new simulation results came mainly from trying out different interest rate rules for the ECB in a seven-country large open economy model, in which France, Italy, and Germany are inside the EMU, and the United Kingdom is outside the EMU with Canada, Japan and the United States. Drawing implications for the ECB from the stochastic simulations of econometric models may seem to reflect a great amount of hubris, but framing the discussion of the results in this practical way makes the results more useful than they otherwise would be. At the least, the approach is useful for helping to find good research topics constructive for developing a monetary policy strategy at the ECB in the months ahead. To be sure, there is much more research to do. Most important in my view are more extensive robustness testing of simple rules and modeling how the move to a single currency will change the wage and price determination equations in the multicountry model used for simulations in this paper.

The research reported here shows the efficiency and robustness of simple policy rules in which the reaction of the interest rate to inflation is above a critical threshold. It appears that a simple benchmark rule, such as the one I proposed in 1992 with some adjustment of the response coefficients, would be worth using as a guideline for the ECB. In this respect the remarks of Federal Reserve Governors in the papers listed in Table 1 would be particularly relevant. However, because of the uncertainty about the appropriate size of some of the coefficients in the benchmark policy rule and because the structure of the economies (especially in wage-price determination) of the EMU will change in unknown ways as a result of the formation of a single currency, it is wise to have a portfolio of rules to supplement the benchmark rule. Such a portfolio would include rules with higher and lower coefficients on output as well as lagged variables. In fact, in proposing a benchmark policy rule in 1992 I suggested that this rule be used in conjunction with a portfolio of other policy rules. The idea was to learn by *using* policy rules, and this learning process could benefit from the same type robustness analysis as is currently benefiting econometric policy evaluation research itself.

Table 1. Testing Grounds for Robustness: Recent Econometric Policy Evaluation Research where the Interest Rate is the Instrument in the Policy Rule

Small Estimated or Calibrated Models without Rational Expectations

Ball (1997)
Ball (1999)
Rudebusch and Svensson (1999)
Svensson (1997)

Small Estimated or Calibrated Models with Rational Expectations

Clarida, Gali, Gertler (1997b)
Fuhrer and Madigan (1997)
Haldane and Batini (1999)
Orphanides and Wieland (1997)

Optimizing Models with Representative Agents

Chari, Kehoe and McGrattan (1999)
Goodfriend and King (1997)
King and Wolman (1999)
McCallum and Nelson (1999)
Rotemberg and Woodford (1997)
Rotemberg and Woodford (1999)
Svensson (1998)

Large Econometric Models with Rational Expectations

Brayton, Levin, Tryon, and Williams (1997)
Levin, Wieland, and Williams (1999)
Taylor (1995)
Williams (1997)

Historical or International Comparisons

Clarida, Gali, Gertler (1997a)
Judd and Trehan (1995)
Judd and Rudebusch (1998)
Orphanides (1997)
Taylor (1999)
Thumann, Alzola, and Monissen (1998)
Weymark (1997
Wright (1998)

Policy Perspectives on Rules by Monetary Policymakers

Blinder (1996)
Gramlich (1998)
Greenspan (1997)
Meyer (1996)
Yellen (1996)

Table 2. Robustness Results for Alternative Interest Rate Rules

		Standard Deviation of:		
		Inflation	Output	Interest Rate
Rule I				
	B	2.27	23.06	--
	HB	0.94	1.84	1.79
	MN	1.09	1.03	5.14
	RS	∞	∞	∞
	RW	0.81	2.69	2.50
	FM	1.60	5.15	15.39
	MSR	0.29	1.07	1.40
	FRB	1.37	2.77	7.11
	TMCM	1.68	2.70	6.72
Rule II				
	B	2.56	2.10	--
	HB	1.56	0.86	0.99
	MN	1.19	1.08	4.41
	RS	∞	∞	∞
	RW	1.35	1.65	2.53
	FM	2.17	2.85	8.61
	MSR	0.44	0.64	1.35
	FRB	1.56	1.62	4.84
	TMCM	1.79	1.95	5.03
Rule III				
	B	1.85	1.62	--
	HB	1.38	1.05	0.55
	MN	1.96	1.12	3.94
	RS	3.46	2.25	4.94
	RW	2.71	1.97	4.14
	FM	2.63	2.68	3.57
	MSR	0.70	0.99	1.01
	FRB	1.86	2.92	2.51
	TMCM	2.58	2.89	4.00
	Average	2.13	1.94	2.82
Rule IV				
	B	2.01	1.36	--
	HB	1.46	0.92	0.72
	MN	1.93	1.10	3.98
	RS	3.52	1.98	4.97
	RW	2.60	1.34	4.03
	FM	2.84	2.32	3.83
	MSR	0.73	0.87	1.19
	FRB	2.02	2.21	3.16
	TMCM	2.36	2.55	4.35
	Average	2.16	1.63	3.03
RuleV				
	B	∞	∞	--
	HB	∞	∞	∞
	MN	1.31	1.12	2.10
	RS	∞	∞	∞
	RW	0.62	3.67	1.37
	FM	7.13	21.2	27.2
	MSR	0.41	1.95	1.31
	FRB	1.55	6.32	4.67
	TMCM	2.06	4.31	4.24

Note: See the discussion around equation (7) of the text for identification of acronyms and definitions of the five policy rules.

Table 3. Comparison of Rudebusch-Svensson Inflation-Output Equations: US and EMU

Inflation Equation (π):	$\pi(-1)$	$\pi(-2)$	$\pi(-3)$	$\pi(-4)$	$y(-1)$	σ_u	DW
US	.70	-.10	.28	.12	.14	1.01	1.99
EMU	.70	.06	.05	.05	.11	1.37	1.99
Output Equation (y):	$y(-1)$	$y(-2)$	$r(-1)$			σ_v	DW
US	1.16	-.25	-.10			.82	2.05
EMU	1.25	-.42	-.02			.53	2.19

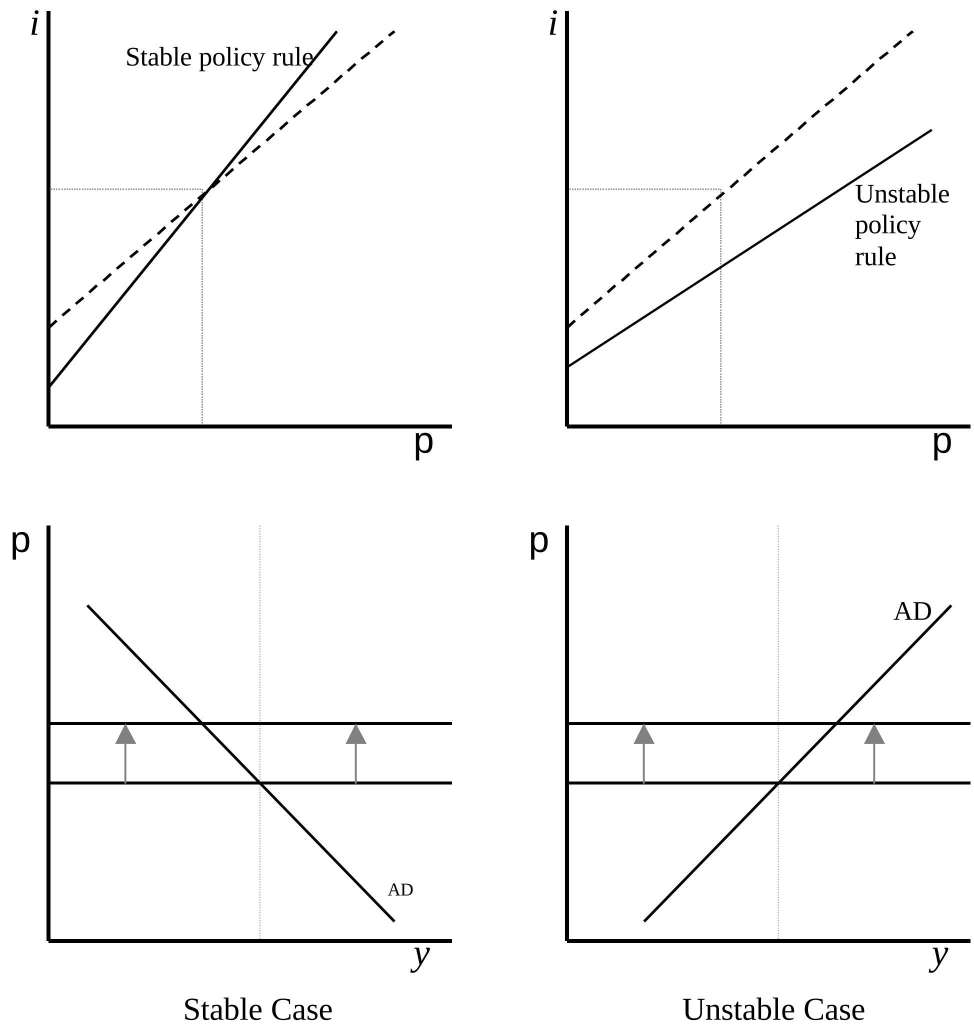
Note: The estimated equations for the United States are from Rudebusch and Svensson (1998) for the sample period 1961.1 to 1996.2. The estimates for the "EMU" are based on a weighted GDP and inflation for an aggregate of Germany, France, and Italy for the sample period 1971.1 to 1994.4.

Table 4. Simple Benchmark Rule Parameters and Resulting Inflation and Output Performance based on Rudebusch-Svensson Equations in Table 3: US versus EMU.

	g_π	g_y	σ_π	σ_y	σ_i
US	1.50	.50	3.58	2.47	5.16
EMU	1.50	.50	2.98	1.21	4.55

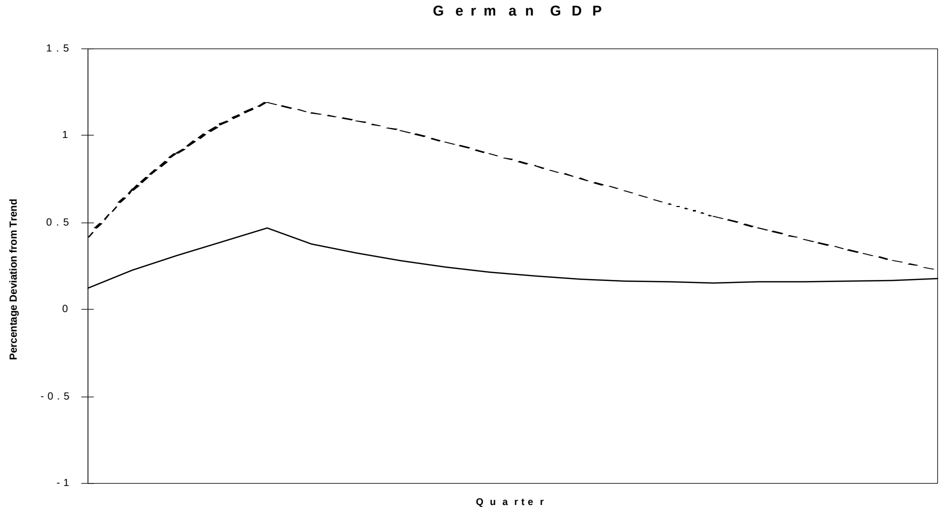
Table 5. Multicountry Model Simulations Comparing Three Alternative Monetary Policy Rules for the ECB Interest Rate. (The standard deviation of inflation (σ_π) and the standard deviation of output (σ_y) are estimated from 50 stochastic simulations of the model over 40 quarterly time periods).

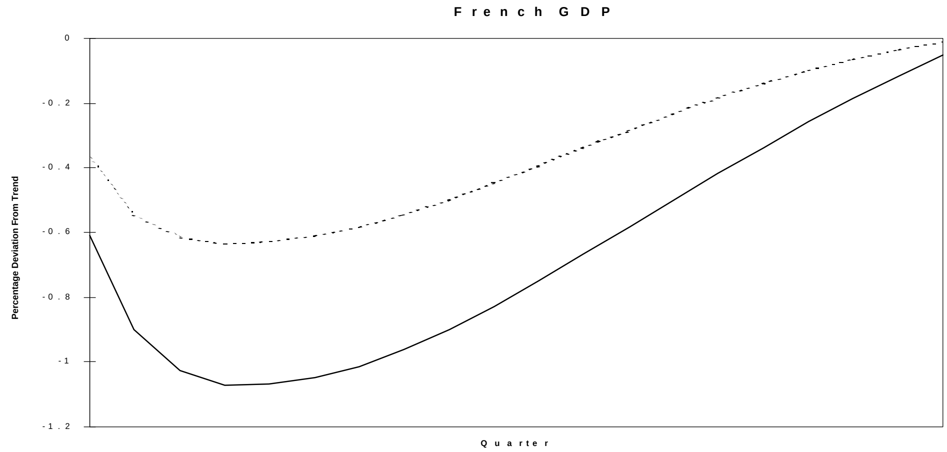
	Germany		France		Italy	
	σ_π	σ_y	σ_π	σ_y	σ_π	σ_y
(1) Benchmark Policy Rule for EMU ($i = 1.5\pi_{EMU} + .5y_{EMU}$)	1.82	2.23	2.45	3.86	5.63	3.70
(2) EMU Inflation Forecast Policy Rule ($i = 0.32i(-1) + 2.62E_t\pi(+8)$)	2.42	4.55	2.82	5.18	5.98	4.58
(3) Dollar-Euro Exchange Rate Added to Benchmark Rule ($i = 1.5\pi_{EMU} + .5y_{EMU} - 0.25e + 0.15e(-1)$)	1.77	2.72	2.43	3.72	5.41	3.64

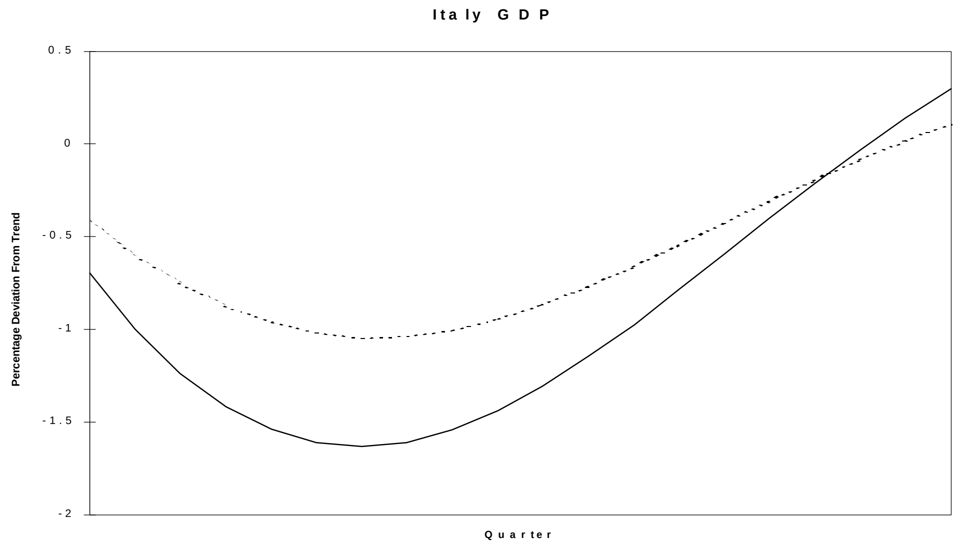


<u>Figure 1. Illustration of Stable versus Unstable Monetary Policy Rules.</u> On the left the slope of the policy rule is greater than one and aggregate demand is negatively sloped, causing y to fall following an inflation shock, which is stabilizing. On the right the slope of the policy rule is less than one and aggregate demand is upward sloping, which is destabilizing.

Figure 2. Effect of a Fiscal Shock in Germany (20 quarters). Rule 1 (solid): ECB interest rate reacts to German variables. Rule 2 (dashed): ECB interest rate reacts EMU variables.







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