Monetary policy rules in practice
Some international evidence

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Abstract

This paper reports estimates of monetary policy reaction functions for two sets of countries: the G3 (Germany, Japan, and the US) and the E3 (UK, France, and Italy). We find that since 1979 each of the G3 central banks has pursued an implicit form of inflation targeting, which may account for the broad success of monetary policy in those countries over this time period. The evidence also suggests that these central banks have been forward looking: they respond to anticipated inflation as opposed to lagged inflation. As for the E3, even prior to the emergence of the 'hard ERM', the E3 central banks were heavily influenced by German monetary policy. Further, using the Bundesbank's policy rule as a benchmark, we find that at the time of the EMS collapse, interest rates in each of the E3 countries were much higher than domestic macroeconomic conditions warranted. Taken all together, the results lend support to the view that some form of inflation targeting may be superior to fixing exchange rates, as a means to gain a nominal anchor for monetary policy. © 1998 Published by Elsevier Science B.V. All rights reserved.

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1. Introduction

This paper characterizes empirically how the major central banks of the world have conducted monetary policy since 1979. Specifically, we estimate monetary policy reaction functions for two sets of countries: 'the G3', which includes Germany, Japan, and the US; and 'the E3', which consists of Germany's major economic partners in Europe, the UK, France and Italy.

Two sets of issues motivate our investigation. First, after nearly a decade of high inflation, a number of important central banks began in 1979 a concerted effort to reign in inflation. The net effect was transition from a global environment where inflation seemed a virtually intractable problem to the current era where the major economies of the world enjoy relative price stability. While world monetary policy was largely viewed as being out of control during the 1970s, it is now, for the most part, held in high regard.[1] For this reason, we first study the G3. Here the motive is to assess how policy was conducted in the post-1979 era by the central banks of the world that not only have the greatest influence over global monetary conditions, but also the greatest autonomy in policy management. By doing so, we can identify the features of monetary policy that prevailed during an era where policy-making was considered effective. This exercise will not only supply lessons for future policy-making in the G3, it will also provide insight for how the new European Central Bank should manage policy.

Second, though inflation is under reasonable control in the current environment, international monetary policy has not been free of turmoil. Exchange rate management in Europe has not proceeded smoothly. A manifestation of this tension was the collapse of the EMS in late 1992. The inability of the major European central banks to sustain the existing exchange rate system raises issues about how the planned monetary union will fare. For this reason, we study the E3. Here we try to understand how the constraints of EMS influenced the policies of these countries. We use the policy rules estimated for the G3 as guidelines to evaluate policy-making in the E3. The purpose of the exercise is to shed additional insight for the future of monetary-policy making in Europe.

Section 2 below describes the methodology. It first presents an estimable policy reaction function. The baseline specification has a central bank adjust the nominal short-term interest rate in response to the gaps between expected inflation and output and their respective targets. It is essentially a forward looking version of the simple backward looking reaction function popularized by Taylor (1993). It is the kind that Clarida and Gertler (1997) have argued

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[1] The recent decision of the Labour party to grant the Bank of England independence is a symptom of this change in attitude.

provides a good description of Bundesbank monetary policy. In addition, we use a novel methodology for estimating policy reaction functions with expectations variables that we initially employed in our study of US monetary policy (Clarida et al., 1997). In contrast to the approach of Clarida and Gertler (1997), the methodology used here does not impose arbitrary constraints on the information set used by central banks to form expectations. In addition, it provides a way to test the model's overidentifying restrictions.

We also present an alternative to the baseline specification that permits the central bank to respond to variables other than inflation and output. The alternative is particularly pertinent to the E3, since these countries faced significant external constraints on monetary policy. That alternative also permits a test of the forward looking versus the backward looking specifications of the reaction functions.

Section 3 presents the analysis of the G3. Overall, we find that the baseline specification of the reaction function does quite a good job of characterizing monetary policy for these countries, post-1979. Indeed, the coefficient estimates are remarkably similar. The kind of rule that emerges is what one might call 'soft-hearted' inflation targeting: In response to a rise in expected inflation relative to target, each central bank raises nominal rates sufficiently enough to push up real rates. This behavior is statistically significant and quantitatively important for each country. The estimated rules thus imply a clear focus on controlling inflation. At the same time, however, there is a modest pure stabilization component to each rule: Holding constant expected inflation, each central bank adjusts rates in response to the state of output. We illustrate further that in the inflationary pre-1979 environment, policy worked quite differently. Finally, we show that our baseline forward-looking specification works quite well against various alternatives, including the backward-looking specification.

Evaluating policy rules for the E3 countries is a more complex task since these nations were clearly constrained by their EMS commitments. We first document the strong influence of the Bundesbank on monetary management within these countries. A practical implication was that each of the countries pursued policies of high real short-term rates that have persisted into the current era of low inflation. To assess the implications, we perform the following counterfactual exercise: We ask how within each month a country would set its target interest rate if it were applying the same rule as used by the Bundesbank, i.e., setting a target interest rate based on (domestic) inflation and output gaps, using the same coefficients as estimated for the Bundesbank. By using the Bundesbank rule as a gauge, we get a sense of whether the course of interest rates for each country was reasonable from the perspective of domestic economic conditions. We also show that this methodology provides a useful way to assess the sources of the breakup of the EMS.

Concluding remarks are in Section 5.

2. A monetary policy reaction function: Specification and estimation

In this section we specify a monetary policy reaction function and then describe our estimation procedure.[2] Our framework pertains to a central bank that has at least some degree of autonomy over its monetary policy. The baseline case we present presumes that domestic monetary policy is not subject to any significant external constraints (i.e., the need to meet exchange rate agreements). It is thus mainly relevant for the G3 central banks. We then describe how to extend the analysis to the case where, for at least part of the sample, a central bank participates in an exchange rate system, but retains some degree of monetary control, either via capital controls or realignments. The latter scenario, we will argue characterizes the E3 central banks until the late phase of the EMS.

We start with the observation that, for the major central banks, the main operating instrument of monetary policy is a short-term interest rate. Typically, the instrument is an interbank lending rate for overnight loans. Accordingly, the empirical policy reaction functions we develop characterize how central banks choose the level of the short-term rate from period to period. As we discuss, however, our approach allows for the possibility that within an operating period a central bank actually targets a narrow reserve aggregate, as long as the target for reserves is based on an implied objective for the expected short-term interest rate.

To make sense of the class of policy reaction functions we study, our analysis appeals to existence of temporary nominal wage and price rigidities. With nominal rigidities, of course, monetary policy affects real activity in the short run; by varying the nominal rate, a central bank can effectively vary the real interest rate and the real exchange rate. Further, while there is debate over the exact details, the process of imperfect wage and price adjustment gives rise to a positive short-run relationship between output and inflation. Though this trade-off exists only in the short run, it may significantly constrain how a central bank manages policy. It implies, for example, that reducing inflation may require a period of output reduction, depending on the degree of nominal stickiness. It is in this kind of textbook environment that we envision a central bank choosing the course of short-term interest rates.[3]

Given this background scenario, policy reaction works as follows: We assume that within each operating period the central bank has a target for the nominal short term interest rate, r_t^*, that is based on the state of the economy. In the

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[2] The discussion of the policy reaction function and the estimation procedure follows closely Clarida et al.'s (1997) analysis of US monetary policy.

[3] For a review of contemporary macroeconomic frameworks that have these 'textbook' features, see Goodfriend and King (1997).

baseline case, we assume that the target depends on both expected inflation and output. Specifically,

$$r_t^* = \bar{r} + \beta(E[\pi_{t+n} \mid \Omega_t] - \pi^*) + \gamma (E[y_t \mid \Omega_t] - y_t^*) \qquad (2.1)$$

where $\bar{r}$ is the long-run equilibrium nominal rate, π_{t+n} is the rate of inflation between periods t and $t + n$, y_t is real output, and π^* and y_t^* are respective bliss points for inflation and output. We assume that y_t^* is given by potential output, defined as the level that would arise if wages and prices were perfectly flexible. In addition, E is the expectation operator and Ω_t is the information available to the central bank at the time it sets interest rates. It is highly possible that when choosing the target interest rate, the central bank may not have direct information about the current values of either output or the price level. Our specification allows for this possibility.

It is instructive to consider the implied target for the ex ante real interest rate, $rr_t \equiv r_t - E[\pi_{t+n} \mid \Omega_t]$.[4] Rearranging Eq. (2.1) yields

$$rr_t^* = \overline{rr} + (\beta - 1) (E[\pi_{t+n} \mid \Omega_t] - \pi^*) + \gamma (E[y_t \mid \Omega_t] - y_t^*) \qquad (2.2)$$

where $\overline{rr}$ is the long-run equilibrium real rate of interest. Given the economic environment we are presuming, purely real factors determine $\overline{rr}$. According to Eq. (2.2), the target real rate adjusts relative to its natural rate in response to departures of either expected inflation or output from their respective targets. A straightforward but critical point is that the magnitude of the parameter β is key. If $\beta > 1$, the target real rate adjusts to stabilize inflation, as well as output (given $\gamma > 0$). With $\beta < 1$, it instead moves to accommodate changes in inflation: Though the central bank raises the nominal rate in response to an expected rise in inflation, for example, it does not increase it sufficiently to keep the real rate from declining. In this 'accommodative' regime, self-fulfilling bursts of inflation and output may be possible (Bernanke and Woodford, 1996; Clarida et al., 1997). The estimated magnitude of the parameter β thus provides an important yardstick for evaluating a central bank's policy rule.

Plausibility is our main justification for considering a rule like Eq. (2.1). However, a number of recent papers have provided explicit theoretical motivation for this type of specification. Approximate and in some cases exact forms of this rule are optimal for a central bank that has a quadratic loss function over inflation and output, given the kind of macroeconomic environment we have assumed.[5] Optimizing behavior, further, imposes a number of restrictions that are testable in principle: the coefficients in the policy rule, for example, are linked

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[4] Because the maturity of r_t may be less than the inflation forecast horizon we should think of rr_t as an 'approximate' real rate.

[5] See for example, Svensson (1996, 1997), Bernanke and Woodford (1996), and Ball (1997).

in a precise manner to both the underlying structure of the economy, as well as to the weight the central bank places on inflation versus output deviations. Because these types of restrictions depend intimately on the underlying macro-economic framework, we choose not to investigate them in this paper. A virtue of the weakly restricted specification given by Eq. (2.1) is that it is sensible in the context of a wide variety of macroeconomic frameworks.

It is also worth emphasizing that the target policy is a generalization of the type of the simple interest rate rule proposed by Taylor (1993), Henderson and McKibbin (1993) and others. This rule, which has received widespread attention, has the central bank respond to lagged inflation as opposed to expected future inflation. Our specification, however, nests the 'Taylor' rule: If either lagged inflation or a linear combination of lagged inflation and the output gap provides a sufficient statistic for inflation, then the specification reduces to the simple Taylor rule. However, our more general specification has several virtues. First, explicitly incorporating expected inflation in the reaction function makes it easier to disentangle the link between the estimated coefficients and central bank objectives. It is not clear from the simple Taylor specification, for example, whether the central bank responds to the output gap independently of concern about future inflation. Second, by having the central bank respond to forecasts of inflation and output we incorporate a very realistic feature of policy-making, namely that central banks consider a broad array of information. In our baseline case, they use all pertinent information to form beliefs about inflation and output. In extensions of the baseline case, we consider other independent objectives, e.g., real exchange rates. As we discuss, however, any restrictions we impose on how central banks process information are directly testable.

We now proceed to an empirical specification. An immediate concern is that a simple rule like Eq. (2.1) cannot capture the tendency of central banks to smooth changes in interest rates (see, e.g., Goodfriend, 1991). Traditional ex-planations for smoothing interest rate changes include: fear of disrupting capital markets, loss of credibility from sudden large policy reversals, the need for consensus building to support a policy change, etc. Explicitly capturing these factors is obviously quite difficult. Instead, we simply assume that the actual rate partially adjusts to the target, as follows:

$$r_t = (1 - \rho)r_t^* + \rho r_{t-1} + \upsilon_t \qquad (2.3)$$

where the parameter $\rho \in [0, 1]$ captures the degree of interest rate smoothing.[6]

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[6] Svensson (1997) motivates a partial adjustment rule by entering the gap between the current and lagged interest rates into the loss function. Notice that with partial adjustment the condition $\beta > 1$ does not guarantee that the real rate goes up when expected inflation rises, only that it 'eventually' goes up. Of course, such an expected increase may be reflected immediately in real long-term yields. On the other hand, the short-term real rate will also rise immediately if inflation is expcted to pick up further down the road.

The specification also includes an exogenous random shock to the interest rate, v_t. Importantly, we assume that v_t is i.i.d.[7] Several interpretations are possible. First, v_t could reflect a pure random component to policy, of the type stressed in the recent identified VAR literature on monetary policy.[8] Second, it could arise because the central bank imperfectly forecasts idiosyncratic reserve demand and, for some reason, does not instantly supply reserves to offset the shock. Under this scenario, the interest rate jumps in response to an unexpected movements in reserve demand that are orthogonal to movements in inflation and output.

To obtain an estimable equation, we first define $\alpha \equiv \bar{r} - \beta\pi^*$ and $x_t \equiv y_t - y_t^*$. We then rewrite Eq. (2.1) as

$$r_t^* = \alpha + \beta E[\pi_{t+n} \mid \Omega_t] + \gamma E[x_t \mid \Omega_t]. \tag{2.4}$$

Combining the target model (2.4) with the partial adjustment mechanism (2.3) yields

$$r_t = (1 - \rho)\,\alpha + \beta E[\pi_{t+n} \mid \Omega_t] + \gamma E[x_t \mid \Omega_t] + \rho r_{t-1} + v_t. \tag{2.5}$$

Finally, we eliminate the unobserved forecast variables from the expression by rewriting the policy rule in terms of realized variables as follows:

$$r_t = (1 - \rho)\alpha + (1 - \rho)\beta\pi_{t+n} + (1 - \rho)\gamma x_t + \rho r_{t-1} + \varepsilon_t \tag{2.6}$$

where the error term $\varepsilon_t \equiv -(1 - \rho)\{\beta(\pi_{t+n} - E[\pi_{t+n} \mid \Omega_t]) + \gamma(x_t - E[x_t \mid \Omega_t])\} + v_t$ is a linear combination of the forecast errors of inflation and output and the exogenous disturbance v_t.[9] Finally, let u_t be a vector of variables within the central bank's information set at the time it chooses the interest rate (i.e., $u_t \in \Omega_t$) that are orthogonal to ε_t. Possible elements of u_t include any lagged variables that help forecast inflation and output, as well as any contemporaneous variables that are uncorrelated with the current interest rate shock v_t.[10]

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[7] This assumption is testable in the following respect: If we fail to reject the overidentifying restrictions of the model, then either the assumption is valid (i.e., v_t is i.i.d.) or this shock is not economically important. For the main cases of interest, in fact, we do not reject the overidentifying restrictions.

[8] See, for example, Bernanke and Mihov (1995).

[9] Our econometric approach relies on the assumption that, within out short samples, short-term interest rates and inflation are $I(0)$. Standard Dickey–Fuller tests of the null that inflation in the G3 countries is $I(1)$ is rejected in favor of the alternative of stationarity. Also for Germany, we reject that that the short-term interest rate is $I(1)$. For the US and Japan there is less evidence against the null that short-term interest rates are $I(1)$. However, we know that the Dickey–Fuller test has low power against the alternative of stationarity for the short sample we are studying.

[10] Thus, for example, lagged values of the exchange rate are legitimate candidates, but the current exchange rate is not. If current ouput were observable by the central bank, then it would be a legitimate candidate if it also was unaffected by the current the interest rate (i.e., if interest rates only affect output with a lag), under our assumption of serially uncorrelated v_t.

Then, since $E[\varepsilon_t \mid u_t] = 0$, Eq. (2.6) implies the following set of orthogonality conditions that we exploit for estimation:

$$E[r_t - (1 - \rho)\alpha - (1 - \rho)\beta\pi_{t+n} - (1 - \rho)\gamma\hat{y}_t - \rho r_{t-1} \mid u_t] = 0. \qquad (2.7)$$

To estimate the parameter vector $[\beta, \gamma, \rho, \alpha]$ we use generalized method of moments.[11] In our baseline model the instrument set u_t includes lagged values of output, inflation, interest rates, and commodity prices.[12] Each of these variables is potentially useful for forecasting inflation and output and is exogenous with respect to the interest rate, given our identifying assumptions.[13] Since the potential instrument set – and hence the number of orthogonality conditions – exceeds the parameter vector, the model is overidentified, in which case it is straightforward to test the over-identifying restrictions (Hansen, 1982). The interpretation of this test is quite intuitive. Under the null, the central bank adjusts the interest rate each period so that Eq. (2.5) holds, with the expectations on the right-hand side based on all the relevant information available to policymakers at that time (which includes r_t itself, since expected inflation and output will not be invariant to it). Under our assumptions, that implies the existence of values for $[\beta, \gamma, \rho, \alpha]$ such that the implied residual ε_t is orthogonal to the variables in the information set Ω_t. Under the alternative, however, the central bank adjusts the interest rate in response to changes in some current and/or lagged variables, but not necessarily in connection with the information that those changes contain about future inflation and output. In that case, some relevant 'explanatory variables' are being omitted from interest rate Eq. (2.6). To the extent that some of those variables are correlated with u_t, the set of orthogonality conditions (2.7) will be violated,

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[11] The composite disturbance term for our model has an $MA(n - 1)$ representation (Hansen and Hodrick, 1980). In this case the GMM estimator of the parameter vector is a two-step nonlinear two-stage least squares estimator (Hansen, 1982) when the model is overidentified. In the first step, we use traditional non-linear two-stage least squares to obtain an inital estimate of the parameters. We then use these initial parameter estimates to construct an optimal weighting matrix. Of course, some caution is required in interpreting the standard errors obtained from this exercise, since they are based on an asymptotic theory that may not hold well in small samples.

[12] As a measure of commodity prices for the US we use commodity price index series drawn (PSCCOM) from Citibase.

[13] For other countries we use a world commodity price index. Our econometric approach relies on the assumption that, within out short samples, short-term interest rates and inflation are $I(0)$. Standard Dickey–Fuller tests of the null that inflation in the G3 countries is $I(1)$ is rejected in favor of the alternative of stationarity. Also for Germany, we reject that that the short-term interest rate is $I(1)$. For the US and Japan there is less evidence against the null that short-term interest rates are $I(1)$. However, we know that the Dickey–Fuller test has low power against the alternative of stationarity for the short sample we are studying.

which would lead to a statistical rejection of the model (given a sufficiently large sample).[14]

It is also possible to use the parameter estimates β and α to recover an estimate of the central bank's target inflation rate, π^*. While the empirical model does not separately identify π^* and $\overline{rr}$, the long-run equilibrium real rate of interest, it does provide a relation between the two variables that is conditional on α and β. Specifically, given that $\alpha \equiv \bar{r} - \beta\pi^*$ and $\bar{r} = \overline{rr} + \pi^*$, $\alpha \equiv \overline{rr} + (1 - \beta)\pi^*$, which implies

$$\pi^* = (\overline{rr} - \alpha)/(\beta - 1). \tag{2.8}$$

If the sample is sufficiently long, we can use the sample average real rate to provide an estimate of $\overline{rr}$.[15] With this estimate it is then possible to construct an estimate of π^*.

For each central bank we estimate the baseline specification over periods where there was at least some degree of autonomy over domestic monetary policy. It is quite possible, of course, that there may be other important factors that influence rate setting besides those captured in the baseline model. For example, while some of the central banks in our sample may have not completely sacrificed monetary control, they may have pursued policies to maintain exchange rates within reasonable bounds.[16] Exchange rates may thus have influenced policy, independently of the information they contain about inflation and output. In addition, it is argued that some central banks, such as the Bundesbank, mainly pay attention to monetary aggregates. To account for these various possibilities we consider a number of simple alternatives to the baseline policy. Let z_t denote a variable besides inflation and output that may potentially influence rate setting (independently of its use for forecasting). For each alternative specification, we then replace the relation for the target given by Eq. (2.4) with the following:

$$r_t^* = \alpha + \beta E[\pi_{t+n} \mid \Omega_t] + \gamma E[x_t \mid \Omega_t] + \xi E[z_t \mid \Omega_t].$$

We then proceed to estimate the alternative model in the same fashion as the baseline, except that we expand the parameter vector to include the coefficient

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[14] A failure to reject orthogonality is a potentially interesting result, since it implies that lagged variables enter the reaction function only to the extent that they forecast future inflation or output. As pointed out by Persson and Tabellini (1997), one of the few testable implications in the literature on monetary policy credibility is the a central bank operating under discretion should respond to shocks that alter the benefits to monetary expansion.

[15] By using the sample average real rate to proxy for $\overline{rr}$, our estimate of π^* cannot differ too much from the sample average of π. Of course, if the central bank if following the rule we are estimating we would not expect it to. (We thank Torsten Persson for this observation.)

[16] As we discuss in Section 4, this scenario is pertinent to some of the E3 central banks, prior to the collapse of the ERM in 1992.

ξ on the additional variable z_t, and expand our instrument list to include lagged values of that variable. It is then straightforward to evaluate whether the direct effect of z_t on policy is quantitatively important. The alternative variables we consider include: real exchange rates, foreign interest rates, and the money supply. We also consider the change in prices over the previous year (i.e., lagged inflation). By doing so, we obtain a direct test of our forward looking specification, versus the 'backward-looking' specification of the Taylor rule.

Before proceeding, we need to consider the horizon of the inflation forecast that enters the reaction function, i.e., we need to pick a value for n. Based on our casual sense of the way central banks operate, we choose a horizon of one year (so that, with monthly data, $n = 12$). Policy-makers, we believe, are relatively unconcerned about the month to month variation in inflation and instead are more concerned about medium- and longer-term trends. In this respect, the year ahead forecast seems a good indicator of the medium term trend in inflation. Since forecasts over near-term horizons are highly collinear, our results are not sensitive to small changes in the horizon we assume (e.g., changes in either direction of less than six to nine months).[17]

3. Monetary policy rules for the G3, post-1979

We now proceed to estimate monetary policy reaction functions for the central banks of the G3 countries, the Bundesbank, the Bank of Japan, and the Federal Reserve. Each of these central banks has virtually autonomous control over its domestic monetary policy. Though for many years the Bundesbank has operated within a regime of fixed but adjustable exchange rates with other European central banks, it is well understood that it effectively acts as the leader in this environment (see, e.g., Giavazzi and Giovannini, 1988). Our baseline specification, which has policy respond purely to domestic macroeconomic conditions, is thus most relevant to the G3.

As we discussed in the introduction, there was a fundamental shift in the way these central banks conducted monetary policy, beginning in each case some time during 1979. For each central bank, controlling inflation became a major focus of monetary policy. Fig. 1 lends some informal support to this view. For each country, the figure plots the rate of consumer price inflation versus a short term interest rate (the respective inter-bank lending rate). The period is 1974 to 1993. The vertical line in each panel denotes the approximate time we believe each central bank changed the course of policy. For the Federal Reserve, this task is simplest: we pick October 1979, when Volcker clearly signalled his

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[17] Our results are also robust to conditioning policy on the near-term forecast of future output, (three to six months ahead) as opposed to current output.
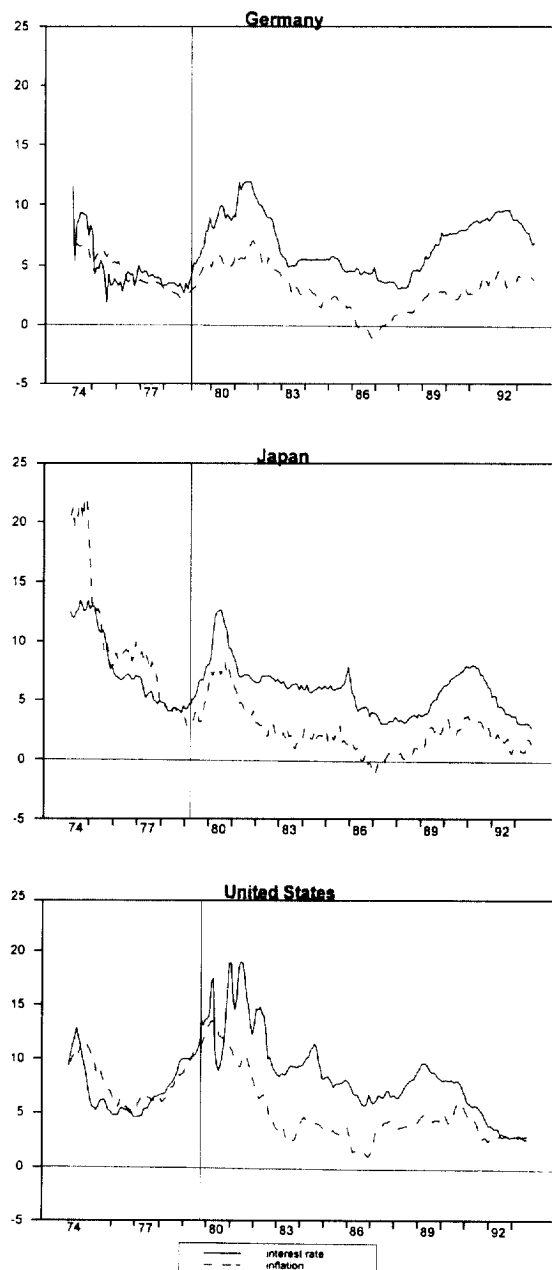
Fig. 1. G3 interest rates and inflation.

intention to reign in inflation. For the Bundesbank, we pick March 1979, the time it entered the EMS.[18] For the Bank of Japan the appropriate starting date is somewhat less clear; however, we pick April 1979, a period of significant financial market deregulation. At this time, the interbank lending rate became the chief operating instrument of monetary policy and all capital controls were finally abandoned (see, e.g., Batten et al., 1990).

Note first that the global pattern of inflation clearly emerges. Between OPEC I and II each country experienced high inflation. There was also a common period of disinflation, beginning in the early 1980s. Despite a slight uptick in each case during the latter part of the 1980s, inflation remained relatively low to the end of the period: The disinflations were all successful. What is striking, however, is the change in the pattern of behavior of short-term interest rates for each country that occurs roughly at the time of the hypothesized policy shifts. Prior to 1979, each central bank kept short term interest rates at or below the rate of inflation. Real short-term rates accordingly hovered around zero and below. During 1979, however, real as well as nominal short-term rates moved up significantly. Though real rates vary over the rest of the sample, they remain significantly above zero.

What is key is not the secular behavior of real rates after 1979 – monetary policy cannot account for the long-term behavior of real rates – but rather their comovement with inflation.[19] After 1979, it appears that each central bank raised short-term real rates in periods of high inflation. This world-wide shift in monetary policy, further, provides the most natural explanation for the dramatic rise in real rates in the early 1980s. The US fiscal expansion, a leading alternative possibility, did not begin until early 1983. Overall, the figure suggests that systematically adjusting real rates to offset inflationary pressures appears to be a key feature of G3 monetary policy-making since 1979. We investigate this conjecture formally by estimating policy reaction functions of the type described in Section 2.

We use monthly data. For each country we use the consumer price index to measure inflation and an index of industrial production to measure output. To obtain a measure of the output gap, we detrend the log of industrial production using a quadratic trend. The interest rate is the respective interbank lending rate: the 'day-to-day' rate for Germany; the 'call-money' rate for Japan; and the 'Federal Funds Rate' for the US.[20] The starting point for the sample period in

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[18] Clarida and Gertler (1997) present both formal and informal evidence that the Bundesbank's commitment to fight inflation waned somewhat during the period between the two major oil shocks. In 1979 it conceded that this had been a mistake and reaffirmed its commitment to keep inflation low.

[19] Here we abstract from possible effects of anticpated inflation on real rates.

[20] For some evidence that it is reasonable to use each of these rates as the instrument of monetary policy for the respective central bank, see Clarida and Gertler (1997) for Germany, and Bernanke and Mihov (1995) for the US.

each case is the time we date the policy shift. The ending point is twelve months prior to the latest available data (in our possession): We end twelve months early because the year-ahead ex post inflation rate is one of our right-hand side variables.

We begin with the Bundesbank. We first estimate our baseline specification for policy, given by Eq. (2.5). The sample is from 1979:4 to 1993:12. Unification, of course, complicates the use of German data. To obtain a consistent measure of output, we use a series on West German industrial production that is available through 1994. Conventional wisdom is that in the early stages of unification, the West German economy remained largely independent of East German economic activity. Finally, the instrument set includes 1–6, 9, 12 lagged values of: the output gap y_t, inflation π_t, the log difference of a world commodity price index o_t, the day-to-day rate, r_t, and the log difference of the dm/dollar real exchange rate, q_t.

The top line of Table 1 reports the results for the baseline specification. The key result is the estimate of the coefficient on the inflation gap, β: 1.31 with

Table 1
Bundesbank reaction functions

	β	γ	ρ	α	ξ
Baseline	1.31	0.25	0.91	3.14	—
	(0.09)	(0.04)	(0.01)	(0.28)	
Adding:					
Lagged inflation[a]	1.10	0.28	0.91	3.26	0.12
	(0.20)	(0.04)	(0.01)	(0.71)	(0.14)
Money supply[b]	1.29	0.28	0.91	3.12	0.7
	(0.08)	(0.03)	(0.01)	(0.29)	(0.07)
Fed funds rate	1.23	0.25	0.91	2.71	0.07
	(0.06)	(0.04)	(0.01)	(0.84)	(0.02)
Real DM/$ rate[c]	1.37	0.35	0.91	− 0.93	0.05
	(0.09)	(0.04)	(0.01)	(0.82)	(0.01)

Test of overidentifying restrictions for baseline specification $J = 13.1$, chi-squared(37) with p-value $= 0.999$.
Estimate of π^* for baseline specification $\pi^* = 1.97$.
The sample is 1979:3–1993:12. The instruments are 1, $y_{t-1}, \ldots, y_{t-6}, y_{t-9}, y_{t-12}, \pi_{t-1}, \ldots, \pi_{t-6}, \pi_{t-9}, \pi_{t-12}, o_{t-1}, \ldots, o_{t-6}, o_{t-9}, o_{t-12}, r_{t-1}, \ldots, r_{t-6}, r_{t-9}, r_{t-12}, z_{t-1}, \ldots, z_{t-6}, z_{t-9}, z_{t-12}, q_{t-1}, \ldots, q_{t-6}, q_{t-9}, q_{t-12}$, where q is the change in the log dm/$ real exchange rate. Estimates are obtained by GMM with correction for MA(12) autocorrelation. Optimal weighting matrix obtained from first step two-stage least squares parameter estimates. Estimate of π^* assumes that long-run equilibrium real interest rate is equal to sample average of $rr = 3.76$.
[a] π_{t-12}, t.
[b] Deviation of log money stock (Central Bank Money before 1988; M3 after) from announced target path.
[c] Lagged levels of real DM/$ exchange rate also included in instrument list.

a standard error of 0.09. A rise in expected annual inflation of one percent induces the Bundesbank to raise real rates by 31 basis points. Because β is significantly greater than one, the prediction that the Bundesbank raises real rates in response to inflationary pressures is indeed statistically significant. Another interesting result is that the estimate of the coefficient on the output gap is positive and also statistically significant: 0.25 with a standard error of 0.04. Thus, holding constant expected inflation, a one percent rise in the output gap induces the Bundesbank to increase nominal (and thus real) rates by 25 basis points. The implication, of course, is that the Bundesbank responds to real economy independently of its concern about inflation. The point estimates of β and γ are close to those obtained by Clarida and Gertler (1997). In contrast with the latter paper, the GMM estimation procedure used here yields (asymptotically) correct standard errors, thus enabling us to confirm the statistical significance of the results. Finally, the J-statistic implies that we do not reject the overidentifying restrictions of the baseline model.

We also obtain a plausible estimate of the long-run inflation target, π^*. The sample average real rate – which we take as the estimate of the long run real rate – is 3.76. Eq. (2.8) then implies a value for π^* of 1.97%. This estimate is somewhat remarkable, given that the Bundesbank official target for inflation is 2%.

Next, we consider alternatives to the baseline specification. First, we allow lagged inflation to enter the reaction function, along with expected inflation and output. Lagged inflation is not statistically significant. Adding to the equation, further, does not perceptibly change the estimates of the gap coefficients, β and γ. Taken together, these results suggest that we reject the backward-looking specification in favor of our forward-looking one.

The conventional view of the Bundesbank is that it simply targets a money aggregate.[21] Clarida and Gertler (1997) challenge this view but do not provide a formal test. We do so here by letting a money aggregate also enter the reaction function. Specifically, we include a measure of the gap between the actual money stock and the official Bundesbank target. Our baseline interest rate reaction function clearly wins. The money aggregate just does not matter, while the other parameter estimates are largely unchanged.[22]

Finally, we consider whether the Bundesbank takes US monetary policy as external constraint. First we let the US Federal Funds rate in the Bundesbank

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[21] See Dornbusch (1997) for a summary of what the conventional wisdom is about the Bundesbank.

[22] These results complement Bernanke and Mihov (1997) who find that innovations in the policy indicator respond more to innovations in news about inflation than innovations in news about money growth. Clarida and Gertler (1997) also present descriptive evidence that the Bundesbank is quite willing to stray from its monetary target.

reaction function. Then we consider the level of the real DM/dollar rate. Each variable does enter significantly and with the right sign, but the quantitative effects are small. Further, once again, the estimates of the slope coefficients are virtually the same as in the baseline case. For the Funds rate: holding constant expected inflation and the output gap, a 100 basis point rise in the Funds rate generates only a 7 basis point rise in the German short rate. If we instead use the exchange rate, we find that a one percent real depreciation of the mark relative to the dollar induces a 5 basis point increase.

We now turn to the Bank of Japan. The sample is 1979:4 to 1994:12. The instrument set parallels the one used for the Bundesbank. Of course, we replace the dm/dollar rate with the real yen/dollar exchange rate.

Put simply, the Bank of Japan looks a lot like the Bundesbank over this period. The top line of Table 2 shows the results for the baseline specification. The estimate of the coefficient on the inflation gap is significantly greater than unity: β is 2.04 with a standard error of 0.19. The estimated output gap coefficient, γ, is also positive and significant, though the size is quite modest: 0.08

Table 2
Bank of Japan reaction functions

	β	γ	ρ	α	ξ
Baseline	2.04	0.08	0.93	1.21	—
	(0.19)	(0.03)	(0.01)	(0.44)	
Adding:					
Lagged inflation[a]	1.89	0.09	0.93	1.64	0.06
	(0.27)	(0.04)	(0.01)	(0.38)	(0.16)
Money growth[b]	2.01	0.07	0.94	0.74	0.07
	(0.16)	(0.03)	(0.01)	(0.47)	(0.03)
Fed funds rate	1.81	0.10	0.93	0.91	0.09
	(0.18)	(0.03)	(0.01)	(0.40)	(0.03)
Real Yen/$ rate[a,c]	1.92	0.03	0.91	1.67	0.09
	(0.11)	(0.03)	(0.01)	(0.27)	(0.01)

Test of overidentifying restrictions for basic specification $J = 14.1$, chi-squared(37) with p-value $= 0.999$.
Estimate of π^* for baseline specification $\pi^* = 2.03$.
The sample is 1979:4 – 1994:12. The instruments are $1, y_{t-1}, \ldots, y_{t-6}, y_{t-9}, y_{t-12}, \pi_{t-1}, \ldots, \pi_{t-6}, \pi_{t-9}, \pi_{t-12}, o_{t-1}, \ldots, o_{t-6}, o_{t-9}, o_{t-12}, r_{t-1}, \ldots, r_{t-6}, r_{t-9}, r_{t-12}, z_{t-1}, \ldots, z_{t-6}, z_{t-9}, z_{t-12}, q_{t-1}, \ldots, q_{t-6}, q_{t-9}, q_{t-12}$, where q is log difference of the yen/$ real exchange rate. Estimates are obtained by GMM with correction for MA(12) autocorrelation. Optimal weighting matrix obtained from first step two-stage least squares parameter estimates. Estimate of π^* assumes that long-run equilibrium real interest rate is equal to sample average of $rr = 3.32$.
[a] Deviation of yen/$ real exchange rate from linear trend included in instrument list.
[b] Annualized rate of M2 money growth over last 3 months; M2 growth over previous three months in instruments.
[c] Deviation of yen/$ real exchange rate from linear trend estimated over the sample.

with a standard error of 0.03. The estimates suggest that if anything, the Bank of Japan appears to have placed somewhat more weight on controlling inflation relative to output stabilization than the Bundesbank. Of the three G3 central banks, further, it comes the closest to being a pure inflation targeter over the sample we consider. As with the Bundesbank, the baseline specification seems to work well: the J-statistic implies that we cannot reject the overidentifying restrictions. The implied estimate of π^* is also quite plausible. The sample average real rate is 3.32, implying a value of π^* equal to 2.03, which is quite close to the number we calculated for the Bundesbank.

For the Bank of Japan, it similarly appears that the forward-looking specification outperforms the backward-looking one: Lagged inflation does not significantly matter when it is added to the reaction function, while the other coefficients remain largely unchanged. The money supply is also unimportant. Since we do not have data on the Bank of Japan money supply targets, we simply include an average of the past three months money (M2) growth in the reaction function. The variable comes in significant at the 5% level, but the effect is trivial: holding constant expected inflation and the output gap, a one percent rise in money growth over the past quarter induces only a 6 basis point rise in the call money rate. Further, the other key coefficients in the reaction function are virtually unchanged. Finally, while both the Funds rate and the real yen/$ exchange rate independently matter, the effects are quite small, in keeping with the results for the Bundesbank. Thus, overall, the baseline model seems to provide a good characterization of the Bank of Japan reaction function.[23]

Finally, we turn to the Federal Reserve. The sample is 1979:10 to 1994:12. Some preliminary analysis indicates that the second-order partial adjustment model

$$r_t = (1 - \rho_1 - \rho_2)(\alpha + \beta\pi_{t+n} + \gamma x_t) + \rho_1 r_{t-1} + \rho_2 r_{t-2} + \varepsilon_t \qquad (3.1)$$

fits the US data significantly better than the first-order model used for Germany and Japan. The instrument list is analogous to the previous cases, except it excludes exchange rates and foreign interest rates. Foreign variables are not particularly helpful for predicting US inflation or output.

The top line of Table 3 shows the results for the baseline specification. The results are similar to those for the Bundesbank and the Bank of Japan. The estimated coefficient for the inflation gap is significantly above one: 1.79 with a standard error of 0.18. Thus, the Federal Reserve appears to have lived up its reputation for this period as being aggressive about controlling inflation. The

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[23] Note that while the coefficients on the inflation forecast in both Germany and Japan are roughly more than 20 times that on the real exchange rate, the latter is substantially more volatile. On the other hand, a major depreciation of the yen of, say, ten percent relative to the dollar would only raise the Japanese short rate by seventy basis points, everything else equal.

Table 3
FED reaction functions

	β	γ	$\rho_1 + \rho_2$	α	ξ
Baseline	1.79	0.07	0.92	0.26	—
	(0.18)	(0.06)	(0.03)	(0.85)	
post 82:10	1.83	0.56	0.97	− 0.10	
	(0.45)	(0.16)	(0.03)	(1.54)	
Adding:					
Lagged inflation	2.20	0.14	0.94	− 0.45	− 0.25
	(0.75)	(0.10)	(0.05)	(1.65)	(0.40)
post 82:10	1.99	0.75	0.97	2.09	− 0.78
	(0.67)	(0.25)	(0.05)	(2.33)	(0.54)
Money growth	1.05	0.44	0.90	0.80	0.53
	(0.14)	(0.07)	(0.05)	(0.51)	(0.08)
post 82:10	1.26	0.52	0.96	1.03	0.21
	(0.24)	(0.06)	(0.04)	(0.25)	(0.04)

Test of overidentifying restrictions for baseline specification $J = 10.9$, chi-squared(28) with p-value $= 0.999$.
Estimate of π^* for baseline specification $\pi^* = 4.04$.
The sample is 1979:10–1994:12 except where noted when it is 1982:10–1994:12. The specification assumes that partial adjustment takes the ar(2) form discussed in the text. The instruments are 1, $y_{t-1}, \ldots, y_{t-6}, y_{t-9}, y_{t-12}, \pi_{t-1}, \ldots, \pi_{t-6}, \pi_{t-9}, \pi_{t-12}, o_{t-1}, \ldots, o_{t-6}, o_{t-9}, o_{t-12}, r_{t-1}, \ldots, r_{t-6}, r_{t-9}, r_{t-12}$, and lagged money growth over previous 3 months when appropriate. Estimates are obtained by GMM with correction for MA(12) autocorrelation. Optimal weighting matrix obtained from first step two-stage least squares parameter estimates. Estimate of π^* assumes that long-run equilibrium real interest rate is equal to sample average of $rr = 3.48$.

estimated output gap coefficient is 0.07 with a standard error of 0.06, indicating that the Fed looks at the output gap only as a forecaster of future inflation. It is also true that we cannot reject the overidentifying restrictions for the baseline model. Each of these results for the baseline model is consistent with those obtained by Clarida et al. (1997), with quarterly data on the GDP deflator and GDP. Finally, the implied estimated of π^* is 4.04, given a sample average real rate of 3.48. This seems a bit high, and may reflect the fact that the US began the sample period with a significantly higher inflation rate. In this respect, a longer sample period for the US might be desirable.

It is also true that lagged inflation is not significant and the point estimate for the associated coefficient has the wrong sign. Thus, as with the other central banks, we cannot reject that the Fed has been forward looking. On the other hand, lagged money growth seems to matter more so than for the other central banks. As with the Bank of Japan we add the average of the current and past two months of M2 growth. Controlling for expected inflation and output, a one percentage increase in M2 growth over the quarter induced the Federal Reserve to ultimately raise the Funds rate by 53 basis points (with a standard error of

0.08). While the coefficient on expected inflation falls, it remains above unity: β is 1.05 with a standard error of 0.14 in the alternative model.

One possible explanation for the importance of money growth is that the sample includes the brief period under Volcker where operating procedures focused on meeting non-borrowed reserve aggregate targets. (See the discussion in Bernanke and Mihov (1997).) For this reason we reestimated the model for the post-1982 sample period. The results for the baseline specification are largely unchanged. Lagged inflation, further, still does not matter. As we might expect, however, money growth is less important over this sample. The coefficient on expected inflation, β, rises to 1.26 while the coefficient on money growth drops to 0.21.[24]

To gain some feel for how well our baseline specifications explain the behavior of the three central banks, we plot the implied target rates versus the actual rates. We look not only over the sample period, but also at the roughly five-year period prior to the sample. That is, we compare the implied target rate using the post-1979 rule to the pre-1979 data as well as to the post-1979 data. By doing so, we get an impression of the magnitude of the policy shift in each country.

Fig. 2 shows the results.[25] For each central bank, the target rate implied by the estimated baseline model nicely tracks the behavior of actual rates in the post-1979 data. There are, of course, notable temporary deviations. For example, the Bundesbank pushed actual rates above the target rate at the time of the EMS breakup.[26] The Bank of Japan was somewhat easier than the model would predict during the runup of asset prices in the latter 1980s; and then it was somewhat tighter, afterwards. Around the trough of the 1982 recession, the Federal Reserve was much tighter than the implied target rate.

The comparison with the pre-1979 data is striking. In each case, the post-1979 rule implies target rates much higher than actual rates. The gap is on average roughly five hundred basis points for the Bundesbank and for the Bank of Japan. It is even higher for the US, except during the 1974–1975 recession. If our

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[24] In results that we do not report here, we find that with quarterly data, money growth has little impact on the reaction function. For the entire post-1979 sample, adding M2 growth does not materially alter the coefficient on expected inflation. For the post-1979 sample, the coefficient on expected inflation changes from 2.05 to 1.67 when money growth is added to the baseline specification. For the post-1982 sample, neither is M2 growth significant, nor does including it affect the other coefficient estimates. With quarterly data, detrended GDP measures the output gap. It is possible that for the US, this variable does a better job of proxying for the behavior of the true output gap than does detrended industrial production, the measure for the monthly data. The relatively poorer quality of the output gap in the monthly data could explain why money growth matters more in this instance than when quarterly data is employed. See Clarida et al. (1997) for an analysis of quarterly data for the US.

[25] Note that in drawing the comparison, we are using the target rate as opposed to the fitted rate (which includes the lagged interest rate). Doing so provides a sharper test of the model.

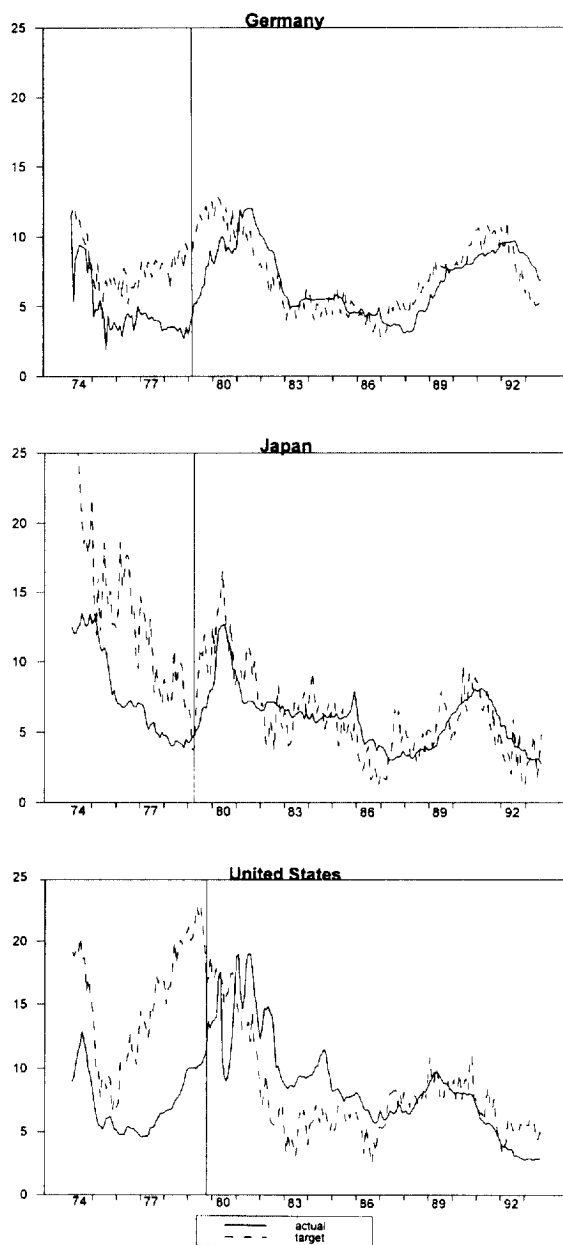[26] A similar finding is in Clarida and Gertler (1997).

Fig. 2. G3 interest rates: target vs. actual.

estimates of the post-1979 rules provide a benchmark measure of good monetary policy for each central bank, then the results quantify (what many view as) the policy mistakes of the 1970s.[27]

4. Monetary policy in the E3

We now analyze the performance of what we have termed the E3 central banks: the Banks of England, France and Italy. Interpreting the behavior of these central banks over the 1980s and 1990s requires considerable caution. In particular, it is important to take into account the evolving commitments that England, France and Italy had over this period to the ERM and to the ultimate goal of European monetary union. The collapse of the EMS in September 1992 also complicates the picture; though, as we discuss later, our analysis may shed some light on the sources of this crisis.

For at least part of the sample, it is clearly not appropriate to try to estimate the kind of reaction functions we have been working with thus far. In particular, between 1990 and 1992, all three countries belonged to the 'hard' ERM (see, e.g., Eichengreen and Wyplosz, 1993). Each of the central banks had totally sacrificed domestic monetary control. Exchange rates were fixed and capital controls were absent. The Bundesbank was effectively running monetary policy for Europe. Interest rates in England, France and Italy thus reflected the intentions of the German central bank, along with the ever-changing assessments by financial markets of the likelihood that the country in question would maintain its exchange rate peg (see, e.g., Kenen, 1996; Rose and Svensson, 1994) (Fig. 3).

Prior, to the hard ERM period, however, each central bank did have at least some leverage over domestic monetary policy. England did not join the ERM until October 1990. It is true that France and Italy's participation in the ERM began much earlier. However, as emphasized by Giavazzi and Giovannini (1989), Eichengreen and Wyplosz (1993) and others, both countries imposed strict capital controls that made feasible their ERM participation The controls provided each central bank with some leeway to pursue domestic policy objectives but maintain their commitments to intervene in support of their respective currencies. These controls were phased out and eventually abolished at the beginning of 1990, as the hard ERM emerged.

To evaluate E3 monetary policy, we take a two-step approach. First, we estimate policy reaction functions for each central bank up to the point of its

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[27] Our measure requires some qualification because it is possible that the long-run equilibrium real rate was lower in the 1970s than over the latter sample. However, given that the gaps we obtain are on the order of 500 basis points and higher it is unlikely that shifts in the long-run equilibrium real rate could account for our results.
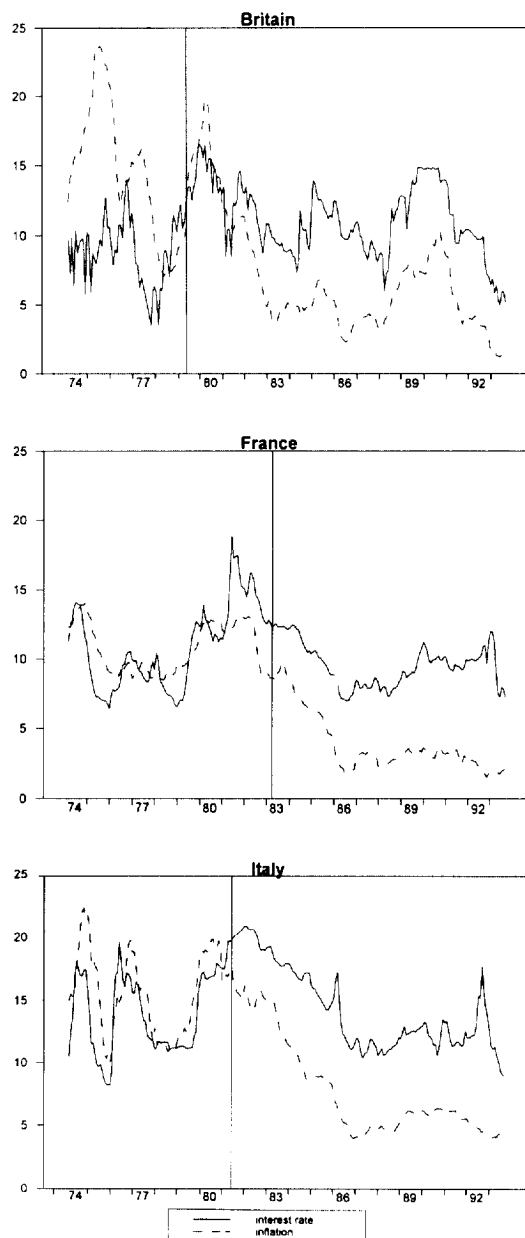
Fig. 3. E3 interest rates and inflation.

entry into the hard ERM. As with the G3 countries, we take as the starting point a date that we believe signalled the beginning of the respective policy regime. Second, to understand the period of the hard ERM, as well as its ultimate collapse, we perform the following counterfactual exercise: We ask how the actual interest rate in each E3 country would compare to an implied target rate, if the respective central bank had employed the same reaction function as the Bundesbank. As we discuss, doing so provides a benchmark to evaluate the nature of the stress in the exchange rate system that lead to the eventual collapse.

We again use monthly data, the consumer price index to measure inflation, industrial production to measure output, and an inter-bank lending rate as the instrument of monetary policy. In each case, the instrument set parallels the ones used for the Bundesbank and the Bank of Japan. Our starting point for the Bank of England is 1979:6, the date that Thatcher assumed power, and fighting inflation became a clear policy objective. For France, we choose 1983:5, the time of the 'U-turn' away from state largesse (see Artus et al., 1991). For Italy, we choose 1981:6, the time of the divorce of the bank of Italy from the Treasury (see Passacantando, 1996). The ending point in each case is the time of entry in the hard ERM.[28]

We find that for each of the E3 countries, German monetary policy proved to be a significant external constraint, even in the time prior to the hard ERM. We start with the Bank of England. The sample is 1979:6 to 1990:10. For benchmark purposes the top of Table 4 reports the estimate of the baseline model. At first glance, it does not appear that this central bank was aggressive toward inflation: The estimated coefficient on the inflation gap is just 0.98 with a standard error of 0.09. The large value of the constant α suggests that some form of misspecification may be present. Suppose, for example, that the Bank of England has the same long-run inflation target as the Bundesbank, which does not seem unreasonable in light of its behavior in recent years. Then Eq. (2.8) implies a long-run equilibrium real rate of 5.72, which is clearly too high. Fig. 4 provides some perspective. The top panel plots the British expost real rate versus the German expost real rate. For most of the sample, British real rates were high both in absolute terms and relative to German rates. Monetary policy boiled down to keep real rates steadily high over this period, even when inflation was low during the mid-1980s.[29]

Adding the German short rate to the reaction function helps clear the picture. The effect of the German rate is significant and large. Holding constant expected

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[28] From France and Italy we base the date of entry into the hard ERM on the time capital controls were completely abolished (see Eichengreen and Wyplosz, 1993).

[29] Note however that if the inflation target were higher than Germany's, the implied real interest rate at capacity would be lower.

Table 4
Bank of England reaction functions

	β	γ	ρ	α	ξ
Baseline	0.98	0.19	0.92	5.76	—
	(0.09)	(0.04)	(0.01)	(0.69)	
Adding: German DTD rate	0.48	0.28	0.87	4.89	0.60
	(0.05)	(0.02)	(0.01)	(0.40)	(0.07)
Pound/DM rate[b]	0.95	0.17	0.91	6.07	0.09
	(0.12)	(0.07)	(0.01)	(0.95)	(0.03)

[a] Implied target real interest rate at $y = 0$ and $\pi = 2$, $rr^* = 5.72$.
The sample is 1979:6 – 1990:10. The instruments are 1, $y_{t-1}, \ldots, y_{t-6}, y_{t-9}, y_{t-12}, \pi_{t-1}, \ldots, \pi_{t-6}, \pi_{t-9}, \pi_{t-12}, o_{t-1}, \ldots, o_{t-6}, o_{t-9}, o_{t-12}, r_{t-1}, \ldots, r_{t-6}, r_{t-9}, r_{t-12}, z_{t-1}, \ldots, z_{t-6}, z_{t-9}, z_{t-12}, q_{t-1}, \ldots, q_{t-6}, q_{t-9}, q_{t-12}$, where q is the log level of the pound/dm real exchange rate. Estimates are obtained by GMM with correction for MA(12) autocorrelation. Optimal weighting matrix obtained from first step two-stage least squares parameter estimates.
[b] Starting in 1986:1 and relative to the rate at which the pound entered the ERM in 1990:10.

inflation and output, a one percentage point rise in the German rate induced a 60 basis point rise in the British rate (with a standard error of 4 basis points.) Note that the coefficient on expected inflation in this case is 0.48. Thus, one could interpret the policy as setting the interest rate as a weighted average of the German short rate and a baseline policy rule that has a coefficient on expected inflation of roughly 1.20, where the weight is 0.6 on the former and 0.4 on the latter $(0.40 \times 1.20 \approx 0.48)$.

A similar story emerges for France and Italy. The sample period for France is rather short, 1983:5–1989:12.[30] The top line of Table 5 shows the estimate of the Bank of France reaction function for the baseline case. As with the Bank of England, the estimated value of the constant is large. A target of 2% long-run inflation, implies a long run real rate of 6.01, which is way too high. Again, Fig. 4 is helpful. It shows that the Bank of France simply kept ex post real rates very high over this period.

Not surprisingly perhaps, of the E3 central banks, the Bank of France followed the moves of the Bundesbank most closely. The German short rate exerts a powerful effect when added to the reaction function. Holding constant expected inflation and output, a one percentage point rise in the German rate

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[30] We emphasize that in a short sample, sampling uncertainty could seriously distort the estimation. For example, suppose we try to fit the reaction function over a short period where a central bank is trying to disinflate by pushing up real rates. In this instance the constant term rather than the slope coefficient on the inflation gap could pick up the behavior. The result would be to underestimate of the slope coefficient on the inflation gap by overestimate the constant term (and implicitly the long-run real rate of interest.)
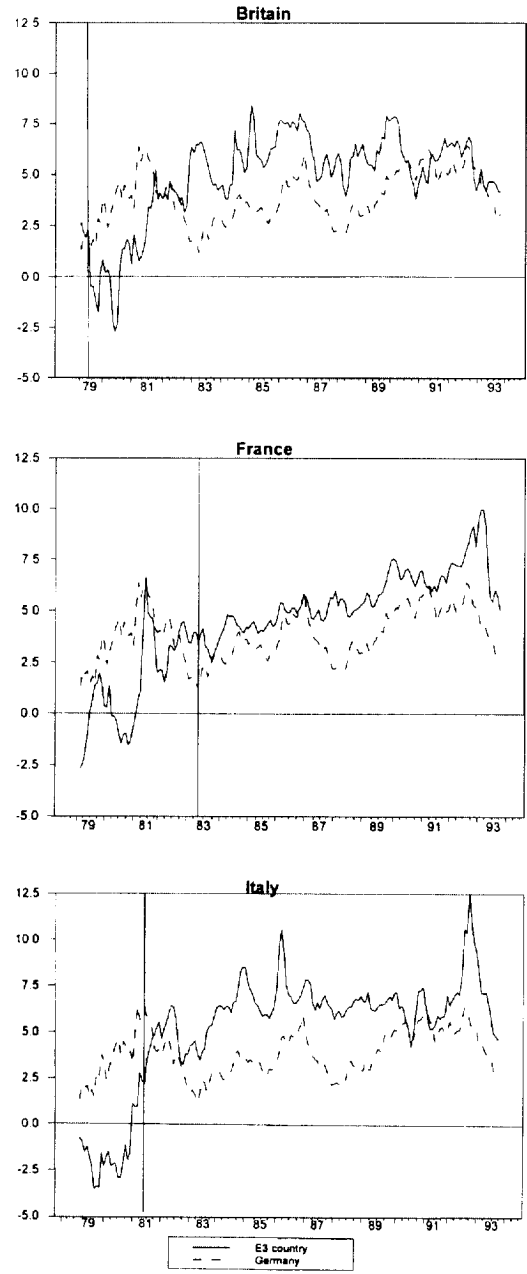
Fig. 4. E3 real interest rates.

Table 5
Bank of France reaction functions

	β	γ	ρ	α	ξ
Baseline[a]	1.13	0.88	0.95	5.75	—
	(0.07)	(0.10)	(0.01)	(0.28)	
Adding:					
German DTD rate	0.59	− 0.07	0.87	2.16	1.14
	(0.02)	(0.03)	(0.01)	(0.23)	(0.05)
France/ECU rate[b]	1.33	0.27	0.95	7.75	2.91
	(0.06)	(0.04)	(0.01)	(0.10)	(0.23)

[a] Implied target real interest rate at $y = 0$ and $\pi = 2$, $rr^* = 6.01$.
The sample is 1983:5–1989:12. The instruments are 1, $y_{t-1}, \ldots, y_{t-6}, y_{t-9}, y_{t-12}, \pi_{t-1}, \ldots, \pi_{t-6}, \pi_{t-9},$ $\pi_{t-12}, o_{t-1}, \ldots, o_{t-6}, o_{t-9}, o_{t-12}, r_{t-1}, \ldots, r_{t-6}, r_{t-9}, r_{t-12}, z_{t-1}, \ldots, z_{t-6}, z_{t-9}, z_{t-12}, q_{t-1}, \ldots, q_{t-6},$ q_{t-9}, q_{t-12}, where q is the log level of the franc/dm real exchange rate. Estimates are obtained by GMM with correction for MA(12) autocorrelation. Optimal weighting matrix obtained from first step two-stage least squares parameter estimates.
[b] Relative to central parity with a basket of other ERM currencies.

Table 6
Bank of Italy reaction functions

	β	γ	ρ	α	ξ
Baseline[a]	0.90	0.22	0.95	7.14	—
	(0.04)	(0.08)	(0.01)	(0.37)	
Adding:					
German DTD rate	0.59	− 0.03	0.93	6.03	0.59
	(0.04)	(0.05)	(0.01)	(0.28)	(0.04)
Lira/ECU rate[b]	0.91	0.10	0.94	7.17	− 0.03
	(0.02)	(0.03)	(0.01)	(0.18)	(0.04)

[a] Implied target real interest rate at $y = 0$ and $\pi = 2$, $rr^* = 6.94$.
The sample is 1981:6–1989:12. The instruments are 1, $y_{t-1}, \ldots, y_{t-6}, y_{t-9}, y_{t-12}, \pi_{t-1}, \ldots, \pi_{t-6}, \pi_{t-9},$ $\pi_{t-12}, o_{t-1}, \ldots, o_{t-6}, o_{t-9}, o_{t-12}, r_{t-1}, \ldots, r_{t-6}, r_{t-9}, r_{t-12}, z_{t-1}, \ldots, z_{t-6}, z_{t-9}, z_{t-12}, q_{t-1}, \ldots, q_{t-6},$ q_{t-9}, q_{t-12}, where q is deviation of the lira/dm real exchange from a linear trend estimated over the sample. Estimates are obtained by GMM with correction for MA(12) autocorrelation. Optimal weighting matrix obtained from first step two-stage least squares parameter estimates.
[b] Relative to central parity with a basket of other ERM currencies.

implies a 114 basis point rise in the French rate, with a standard error of 3 basis points. We emphasize that this lock-step relation between rates arises after controlling for the influence of German rates on French inflation.

The sample for the bank of Italy is 1981:6 to 1989:12. As Table 6 shows, the baseline model predicts an implausibly high long-run equilibrium real rate: 694 basis points given a long-run inflation target of 2%. Fig. 4 confirms that the Bank of Italy also maintained very high real rates over this period. Adding the

German rate to the reaction function shows that, like the other E3 central banks, the Bank of Italy tied its fortunes closely to the Bundesbank. Somewhat surprisingly, it looks a lot like the Bank of England. A one percentage point rise in the German short rate induces a 59 basis point rise in the Italian short rate, after controlling for inflation and output – virtually the same response as the Bank of England.

Overall, the simple inflation-focused policy rules that seem to characterize the G3 central banks do not describe well the behavior of the E3. Monetary policy for these countries appears to have boiled down to fighting inflation by follow-ing the Bundesbank, to varying degrees. It is true that inflation in each of these countries had dropped to tolerable levels by the mid-1980s. However, if the goal was to use the EMS to establish some sort of credibility in policy-making (see, e.g., Fischer, 1987), it is not clear the strategy was successful. Despite low inflation, financial markets forced these countries to maintain high real rates to sustain their exchange rates. And ultimately, none of these central banks could sustain their membership in the 'hard ERM': they either dropped out (Britain and Italy) or switched to a wide-band regime (France).

To explore the issue further, we consider the following experiment. Suppose that each E3 central bank had followed a policy rule of the type we estimated for the G3: Then, at each point in time, how would the actual interest rate differ from the target implied by that alternative rule. To the extent that the latter reflects good policy management, as we have been arguing, then it provides a yardstick to measure E3 performance.

Before we proceed, however, we should emphasize what we are not doing in this experiment: Specifically, we are not asking how the paths of inflation and output might have differed if an E3 central bank had followed a G3 rule. Doing so, would require specifying a complete macroeconomic framework. Rather, we are simply calculating at each point in time the target interest rate under the G3 rule, given the historical measures of the inflation and output gaps for the respective E3 country.

As a benchmark G3 policy rule, we use the estimated baseline specification for the Bundesbank. This choice makes sense for several reasons. First, the coeffi-cients of the reaction function should ultimately depend on the characteristics of the economy. Of the G3 countries, of course, the German economy bears the closest resemblance to the economies of the E3. Second, if the goal of the E3 was to trade on the credibility of the Bundesbank, it seems natural wonder what their interest rates might have looked like if they had simply followed a rule like the Bundesbank (conditional on the historical behavior of their respective economies).

Fig. 5 illustrates the outcome of this experiment. For the period 1983–1995, each panel plots the actual interest rate for an E3 country versus the implied rate under the Bundesbank policy rule, i.e., a rule that plugs in the historical values of the gap variables of the respective country, but takes the estimated coefficients
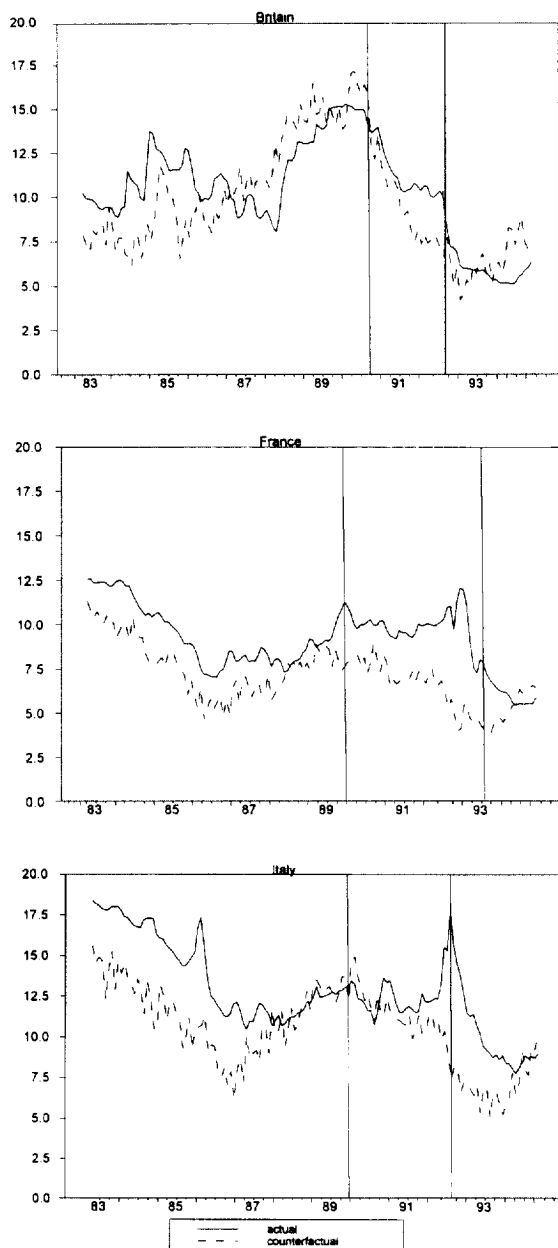
Fig. 5. E3 interest rates under Bundesbanck policy rule.

for the Bundesbank rule to calculate the E3 rule. The vertical lines denote the period of the hard ERM for each country.

A number of fascinating results emerge. Note first that the gap between the actual and the pseudo-target rate behaves varies similarly over time for each of the G3 countries. Between 1983 and roughly 1987, a period where each of these countries was continuing to disinflate, historical rates were above the pseudo-targets. Actual and target rates roughly coincide in the subsequent period, up to the beginning of the hard ERM. Put differently, with the background of relatively low inflation, each E3 country was pursuing a policy much like the Bundesbank in the several years prior to the hard ERM.[31] With the onset of the hard ERM, however, the gaps between the actual and target rates widen. Unmistakably, each country's exit from the ERM was preceded by substantial increase in the actual rate above the target.

Overall, this experiment offers a fresh perspective on the old idea that fixed exchange rates force a (follower) country to give up control of its monetary policy.[32] According to the textbook model of a small open economy with fixed exchange rates and perfect capital mobility, such a country forsakes an independent monetary policy. If the economy falls into a recession, it can be forced to tighten money and/or face reserve losses so as to keep domestic interest rates at levels in the center country. If the latter's business cycle is 'out of sync', its central bank may sometimes set interest rates higher than other countries may prefer.[33] If devaluation is ruled out – or the center country refuses to revalue – countries outside the center are faced with a painful choice: they must keep interest rates higher than they would otherwise choose, or they must abandon the fixed exchange rate and the benefits that accrue from membership.

During the period of the hard ERM, domestic considerations – specifically, inflationary pressures from German unification–induced fiscal deficits – led the Bundesbank to tighten policy. Did it make sense for the other countries to try to follow along? If we use the Bundesbank's own rule as a metric then the answer is no. At the time of the ERM break-up actual rates were much higher than would have been warranted by domestic macroeconomic conditions, given the Bundesbank policy rule. While each country eased after the breakup, it does not appear that any did so irresponsibly. Indeed, each simply adjusted rates back to the pseudo-target. In this regard, it is interesting to note the Bank of England's

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[31] These results illustrate that the finding of Stuart (1996) that the Bank of England followed a Taylor-like rule really only applies in the brief period prior to its entry into the ERM.

[32] For some interesting recent discussions of the constraints on moneatry policy that a fixed exchange rate system imposes, see Obstfeld and Rogoff (1995) and Kenen (1995).

[33] Of course, that would also happen even if business cycles are synchronized but the central bank in the center country chooses to pursue a policy tighter than domestic economic conditions would warrant.

inflation targeting policy that was adopted in the early 1990s closely resembles the Bundesbank policy rule. The actual rate at this time closely tracks the target implied by the Bundesbank rule.

It thus appears that our hypothetical interest rate gaps portrayed in Fig. 5 provide a measure of the economic stress that each E3 country incurred by operating in the hard ERM. Let us then define for each country the 'stress indicator', s_t, equal to the gap between the current rate r_t and the implied target rate r_t^* that is constructed using the parameters of the Bundesbank policy rule, i.e. $s_t = r_t - r_t^*$. Let the superscript g denote Germany. Then, since we can also compute a similar measure for Germany, $s_t^g = r_t^g - r_t^{g*}$ it is possible to decompose our stress indicator in an interesting way:

$$
\begin{aligned}
s_t &= (r_t - r_t^g) + (r_t^{g*} - r_t^*) + s_t^g \\
&= (r_t - r_t^g) + \beta^g (E[\pi_{t+n}^g \mid \Omega_t] - E[\pi_{t+n} \mid \Omega_t]) + \gamma^g (E[x_t^g \mid \Omega_t] \\
&\quad - E[x_t \mid \Omega_t]) + s_t^g.
\end{aligned}
$$

The stress indicator is the sum of three terms: (1) the interest differential, which measures the credibility of the respective E3 country's commitment to the fixed exchange rate; (2) the difference between the German and E3 target rates, and (3) the value of the stress indicator in Germany. The difference between the target rates, further, equals the sum of the differences in the inflation and output gap variables across the two countries. The virtue of this decomposition is that it permits us to unravel the sources of the increase in stress that led to collapse of the ERM.

With this index and associated decomposition we are interested in answering the following questions. How 'stressful' were the events leading up to the crisis of September 1992? We know that interest rates were rising in Germany and thus in the EMS member countries but were these rates justified by 'prudent' monetary policy given domestic conditions in each country? In particular, was the Bundesbank pursuing a specially tight policy during these years, or was the policy consistent with its estimated interest rate rule? To what extent is the asynchronization of business cycles between member countries and Germany a source of stress in those countries? To what extent, if any, did interest differentials rise in tandem with our stress indicator, or were those unresponsive to macroeconomic divergences (as argued in Rose and Svensson (1994))?

Figs. 6–8 portray the stress indicator and its components for England, France and Italy, respectively, over the period 1987–1994. As before, the parallel lines denote the time of each country's participation in the hard ERM. For England, asynchronization of the business cycle with Germany appears to be the culprit: the combination of both lower inflation and lower output in England accounts for virtually all the stress in that country at the time of its departure from the EMS; i.e., domestic macroeconomic conditions justified lowering
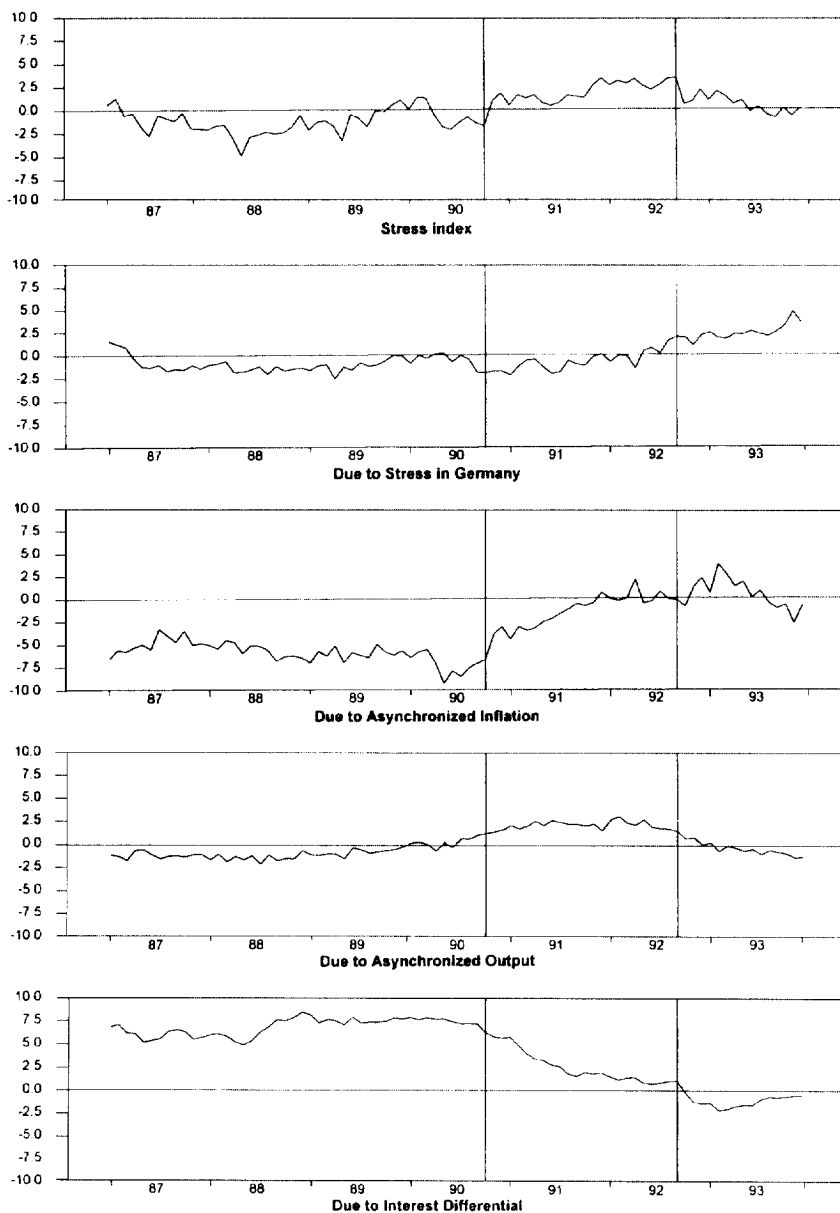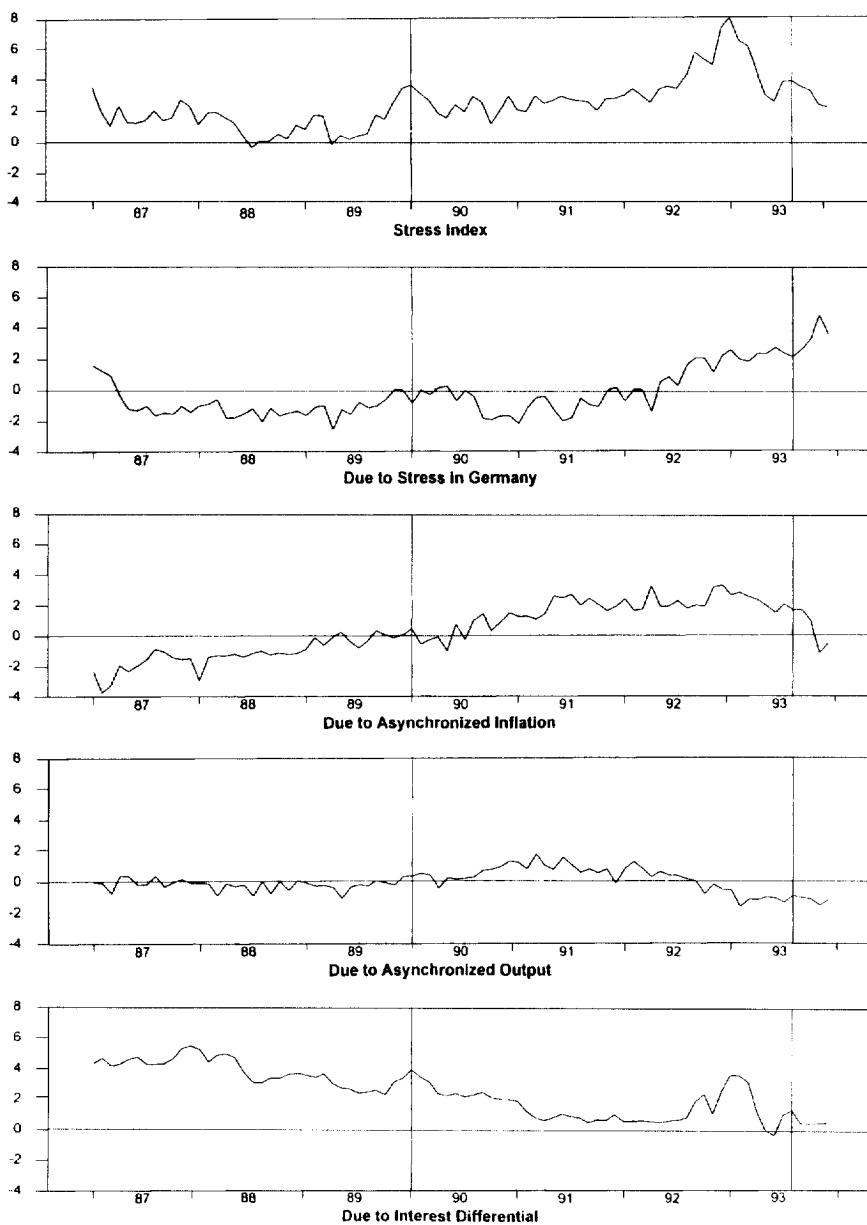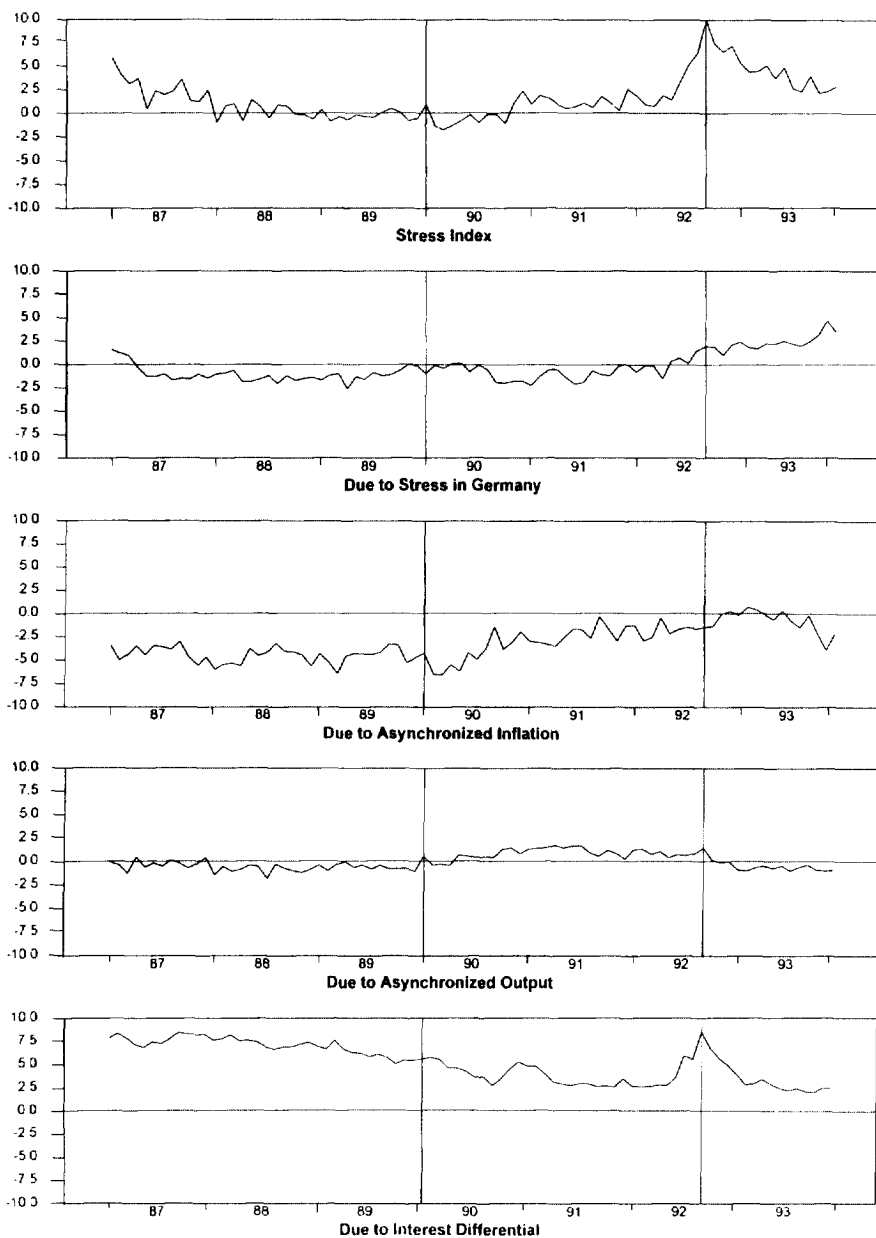
Fig. 6. Stress in Britain.

Fig. 7. Stress in France.

Fig. 8. Stress in Italy.

rates.[34] For France, two main factors stand out at the time of the breakup. First, lower inflation in France relative to Germany accounts for more than half of the measured stress (more than two hundred basis points). Second, the fact that the Bundesbank had pushed rates above their norm defined by the target policy (i.e., stress in Germany) accounts for most of the rest, slightly less than 200 basis points.

It is interesting that for France as well as England the simple interest differentials provide no clue to the breakup (Svensson and Rose, 1994). The stress measure, however, shows clear signs of trouble. Evidently financial markets believed at the time that these countries would persevere despite the strains on the domestic economy.

For Italy, the story is somewhat different. The interest differential accounts for the bulk of the stress indicator at the time of exit. Financial markets just did not believe that the Bank of Italy could maintain the peg. We note that, according to our baseline estimates for Germany reported in Table 1 and depicted in the second panels of Figs. 6–8, policy in Germany did not become 'unusually tight' until mid-1992, i.e., the run-up in interest rates following unification was in line with the estimated Bundesbank reaction function.

5. Concluding remarks

To the extent that policy-making in the G3 since 1979 provides a guideline for good monetary management, the following rule appears desirable: Inflation targeting with some allowance for output stabilization. By inflation targeting, we mean raising nominal rates sufficiently to increase real rates when expected inflation moves above its long-run target. With the benefit of hindsight, this kind of simple rule appears to have some clear advantages. It sets the economy on a course for stable long-term inflation using relatively minimal knowledge about the workings of the economy. Because the rule is relatively simple for the private sector to understand and follow, it is conducive to building and maintaining credibility.

In this vein, when judged against the kind of rules followed by the G3 countries, the monetary policies of the E3 were generally less cogent. Our results lend support to the view that it is difficult to build credibility through fixed exchange rate mechanisms due to the stress on the economy that results from loss of monetary control. It is intriguing to speculate that each of these countries may have been better off by instead pursuing the implicit inflation targeting

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[34] Indeed, the Bank of England adopts this view: 'Against a backdrop of sluggish activity and stable or falling inflation, a number of countries in Europe have experienced a growing conflict between the monetary policy required to maintain the exchange rate, and the policy that would be appropriate given domestic cyclical conditions. In a number of cases, nominal interest rates might have been lower but for the ERM. This was particularly true for those countries ... which were ... in a different cyclical position'.

rules that the G3 countries have effectively employed in recent times.[35] At least we know that the management at the Bank of England shares this belief (e.g., King, 1996).

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[35] Persson and Tabellini (1996) similarly suggest inflation targeting as an alternative to fixing exchange rates.

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