Following the Leader: Simple Estimates of the Effect of Monetary Policy on the Economy*

Julian di Giovanni† IMF

Justin McCrary‡ University of Michigan

Till von Wachter§ Columbia University

June 28, 2004

Abstract

As is widely appreciated, forward-looking behavior on the part of the monetary authority leads least squares estimates to understate the true growth consequences of monetary policy interventions. We present simple instrumental variables estimates of the impact of interest rates on real output growth for several European countries, using German interest rates as the instrument. Because of the correlation of output shocks across countries, these instrumental variables estimates are unlikely to exactly identify the effect of a monetary contraction on the real economy. However, we argue that they may approximate this effect reasonably well, since output shocks are not perfectly correlated. The least squares-instrumental variables difference bounds the degree of forward-lookingness characterizing non-German European monetary policy over the last thirty years.

*We thank Gian Maria Milesi-Ferretti, Maurice Obstfeld, David Romer and Andrew Rose for helpful comments. Any errors are our own. This paper should not be reported as representing the views of the IMF. The views expressed are those of the authors and do not necessarily reflect the views of the IMF or IMF policy.

†Address: Research Department, Economic Modeling, Rm 10-548A, International Monetary Fund, 700 19th Street, N.W., Washington, DC 20431. E-mail: `jdigiovanni@imf.org`, URL: http://socrates.berkeley.edu/~jdigio.

‡Address: University of Michigan, Ford School of Public Policy, 440 Lorch Hall, 611 Tappan St., Ann Arbor, MI 48109-1220. E-mail: `jmccrary@umich.edu`, URL: http://www.umich.edu/~jmccrary.

§Address: Department of Economics, Columbia University, 1022 International Affairs Building 420 West 118th Street New York, NY 10027. E-mail: `vw2112@columbia.edu`, URL: http://www.columbia.edu/~vw2112/.

1 Introduction

Whether monetary policy affects the real economy is one of the central questions of macroeconomics. Assessing this question empirically is a challenge: monetary interventions are thought to be highly targeted, with an eye towards keeping the economy on a stable growth path. Consequently, naïve contrasts in real output growth between episodes of contractionary and expansionary monetary policy are likely to substantially understate the true growth consequences of monetary policy interventions.

In this paper, we present instrumental variables estimates of the effect of monetary policy on real output growth for several European countries, using German interest rates as the instrument. The estimates we present are more in keeping with the approach of Friedman and Schwartz (1963) than they are with the more common vector autoregression approach.[1] However, our approach is quite similar in spirit to the block exogeneity approach to vector autoregression (see, for example, Cushman and Zha (1997)). We view our approach as strictly complementary, not supplementary, to a vector autoregression methodology. For example, a key shortcoming of our approach is that we are unable to effectively distinguish the impact of a monetary tightening of short duration from that of a tightening of long duration. As we describe below, when viewed in the context of a dynamic model, the best interpretation of our static estimates is a reduced-form parameter summarizing the stance of monetary policy over the most recent half-year.

Our estimates suggest that the effect of a 10 percentage point increase in interest rates is a contraction in quarterly real growth of 0.8 - 1.5 percentage points. This is in contrast to naïve OLS estimates, which suggest a more modest contraction of 0.3 - 0.5 percentage points. These results suggest that the monetary authorities in these countries are indeed forward-looking. However, the degree of forward-looking

[1] Another important antecedent of our work is Romer and Romer (1989).

behavior is heterogeneous; the least squares bias is stronger for countries that are less tied to Germany economically, and who have greater scope for independent and thus potentially endogenous monetary policy.

Our identification strategy takes advantage of international monetary linkages, which limit to some extent a country's ability to engage in forward-looking monetary policy. Specifically, we argue that Germany was the anchor country during our sample period, 1973-1998, in that many European countries followed Germany's lead in setting their monetary policy. This leader-follower relationship was particularly relevant during the existence of the European Monetary System (EMS) and the Exchange Rate Mechanism (ERM). Furthermore, even if a country was not part of the system, its policymakers may still have followed the Bundesbank's policy so as to import (low) inflation credibility.[2] As such, it is not surprising that German interest rates are highly predictive of interest rates for other European countries. The statistical validity of this instrumental variable approach depends on the correlation across European countries of output growth shocks. For example, if output shocks are perfectly correlated, then German monetary policy will be just as correlated with future *French* output growth as it will be with future German output growth. Strong direct links (e.g., trade) with Germany should therefore tend to decrease the difference between instrumental variable and least square estimates, since movements in the German interest rate will (presumptively) affect German output, and this may have a direct effect on the output growth of trading partners. The exchange rate and capital controls regimes during this period are also important to consider. Namely, a key component of our identification strategy relies on the fact that foreign countries adjust their interest rate when Germany moves its rates to ensure that the foreign country's exchange rate (viz. a basket of currencies) remains within its ex-

[2]See Giavazzi and Giovannini (1987) for evidence that Germany was the anchor country during the EMS period. Giavazzi and Pagano (1988) offer a theoretical model that describes why countries may submit themselves to the EMS for low-inflation discipline.

change rate bands. However, given the near-unit root properties of interest rates, one might still find a strong relationship between foreign and German rates even if capital controls are in place. We therefore relate the size of the bias to other measures of monetary dependence, following the framework of Obstfeld, Shambaugh and Taylor (2004a, 2004b).

The remainder of the paper is organized as follows. Section 2 describes the identification strategy, compares our approach to simple vector autoregression estimates, relates our static model to the results of a dynamic one, and relates the the size of the bias to potential economic fundamentals particular to the time period and country-sample that we examine. Section 3 presents the main empirical results, and Section 4 concludes.

2 Identification strategy

Consider a simple linear approximation to the relationship between real output growth (y_t)and the interest rate (i_t), from the perspective of the monetary authority in an insular economy:

$$y_t = \alpha_1 + \theta i_t + \beta_1 \hat{y}_{t|t-1} + u_{1t} \tag{1}$$

$$i_t = \alpha_2 \qquad + \beta_2 \hat{y}_{t|t-1} + u_{2t}, \tag{2}$$

where $\hat{y}_{t|t-1} = E\left[y_t|\Omega_{t-1}\right]$ denotes the monetary authority's forecast of real output growth based on information available as of date $t-1$ and assuming no change in stance, θ represents the (causal) effect of interest rates on the real economy, β_1 captures the quality of the forecast, and β_2 reflects the monetary authority's propensity to increase the interest rate in times of (expected) inflationary growth.[3] Equation

[3]Equation (1) can also be interpreted as follows. Suppose that the true model of the economy is $y_t - \hat{y}_{t|t-1} = \theta(i_t - \text{no change in stance}) + \varepsilon_{1t}$, then one arrives at (1) with an imposition that $\beta_1 = 1$. A $\beta_1 < 1$ indicates that the monetary authority's estimate of output is not perfect. The key point to remember is that if you regress X on a noisy measure of X, the regression coefficient on the noisy measure is less than one provided that the noise is idiosyncratic. The regression coefficient

(2) does not include expected inflation as a regressor; this is not important to the analysis below, but its inclusion would complicate the algebra.[4] The residuals u_{1t} and u_{2t} are assumed to be orthogonal to the forecast and to each other, which in turn implies that the interest rate is exogenous. Thus, if the forecast were observed by the researcher, consistent estimates of θ be obtained from a ordinary least squares (OLS) regression of y_t on i_t and the control variable $\hat{y}_{t|t-1}$.

However, because the information set is not known or not measured, the researcher typically only observes a set of variables, w_{t-1}, believed to be used by the monetary authority to predict y_t. These may be a strict subset of Ω_{t-1} or merely correlated with some elements of Ω_{t-1}. A simple control variable approach to the simultaneity problem is to run a regression of output growth on interest rates and the variables w_{t-1}. This is quite similar in spirit to the traditional vector autoregression approach, in which lagged values of output and interest rates (and typically a commodity price index as well) are included as control variables. That this procedure generally results in biased[5] estimates is easy to see. Let $\xi_t \equiv \hat{y}_{t|t-1} - \delta' w_{t-1}$ denote the residual from a (population) linear projection of $\hat{y}_{t|t-1}$ on w_{t-1}, where δ are the projection coefficients.[6] Then the system (1) and (2) becomes

$$y_t = \alpha_1 + \theta i_t + \beta_1 \delta' w_{t-1} + \beta_1 \xi_t + u_{1t} \tag{3}$$

$$i_t = \alpha_2 \qquad\quad + \beta_2 \delta' w_{t-1} + \beta_2 \xi_t + u_{2t}, \tag{4}$$

the main difference now being the presence in both error terms of the component ξ_t, the researcher's error in estimating the monetary authority's beliefs regarding

estimates the ratio of the signal (the variance in X) to the total variance (i.e. the variance of X plus the variance of the noise).

[4]Expected inflation could be thought of as an additional control variable to appear on the right-hand side of equations (1) and (2), and the control variables w_{t-1} would then be chosen to predict both anticipated growth and anticipated inflation. The only substantive conclusion affected is that it becomes more tedious to state the assumptions under which one may sign the bias of a least squares estimate of θ.

[5]For brevity, we frequently refer to an estimator's asymptotic bias simply as its "bias".

[6]Note that because this residual is a linear combination of the elements of Ω_{t-1}, it is orthogonal to u_{1t} and u_{2t}.

the path of output growth. Aside from the degenerate and unusual case in which $V\left[i_t|w_{t-1}\right] = 0$,[7] this will lead the interest rate to be correlated with the residual term in the output equation (3), which in turn will cause least squares estimates to be biased. The bias can easily be shown to be $\beta_1\beta_2 V\left[i_t, w_{t-1}\right]^{-1} V\left[\xi_{t|t-1}|w_{t-1}\right]$, so that the sign is determined by the signs of β_1 and β_2; both are expected to be positive, leading to positively biased least squares estimates.

However, if the monetary authority has goals that do not relate to inflation or output targeting, then we may be able to break the simultaneity between monetary policy and the economy. For example, the authority may need to shadow a foreign interest rates to keep its exchange rate within a band. Suppose that there exists a variable z_t which captures alternative factors correlated with movements in interest rates. Augmenting (3) and (4) to accommodate the factor z_t, we have the estimation equations

$$y_t = \alpha_1 + \theta i_t + \beta_1 \delta' w_{t-1} + \varepsilon_t \tag{5}$$

$$i_t = \alpha_2 + \gamma z_t + \beta_2 \delta' w_{t-1} + \nu_t, \tag{6}$$

where, following the discussion above, $E\left[\varepsilon_t|w_{t-1}\right] = E\left[\nu_t|w_{t-1}\right] = 0$, but the error terms ε_t and ν_t may be correlated. The system (5) and (6) is the canonical simultaneous equations model. Although OLS will be inconsistent for θ, instrumental variables (IV) estimation[8] will be consistent if $C\left[z_t, \varepsilon_t|w_{t-1}\right] = 0$. We believe that this style of identification strategy has not been fully explored in the empirical monetary policy literature, perhaps because credible instruments are hard to come by — most variables that predict interest rates also predict output.

In this paper, we estimate the impact of monetary policy on the real economy for

[7] For ease of notation, throughout the paper we write $E\left[A_t|B_t\right]$ for the population linear projection of A_t onto B_t; $V\left[A_t|B_t\right]$ for the variance of the residual from such a projection; and $C\left[A_t, B_t|C_t\right]$ for the covariance between the residual from the population linear projection of A_t onto C_t, on the one hand, and the residual from the population linear projection of B_t onto C_t, on the other.

[8] Using as instruments z_t and the control variables w_{t-1}.

several European countries and model the relationship between output and interest rates by the system (5)and (6), with z_t a foreign interest rate such as the German interest rate.

With such a choice of instrument, the claim that $C[z_t, \varepsilon_t | w_{t-1}] = 0$ is probably overly strong, because output shocks are likely to be correlated between countries. When the Bundesbank tightens, it is because they believe output growth exceeds potential growth. If this is likely to be occurring simultaneously in both the home country and Germany, then we might expect $C[z_t, \varepsilon_t | w_{t-1}] = a$, where a is perhaps a small number compared to $C[\nu_t, \varepsilon_t | w_{t-1}]$, but is not zero. We next consider the estimands of the OLS and IV estimators for θ when the instrument is not purely exogenous:

$$\hat{\theta}_{OLS} \stackrel{p}{=} \theta + \frac{\gamma a + C[\nu_t, \varepsilon_t | w_{t-1}]}{V[i_t | w_{t-1}]} \tag{7}$$

$$\hat{\theta}_{IV} \stackrel{p}{=} \theta + \frac{a}{C[z_t, i_t | w_{t-1}]}. \tag{8}$$

Because the parameter a is involved in both expressions, (7) and (8) imply a relationship between the bias of the OLS and IV estimators, notated B_{OLS} and B_{IV}, respectively. Specifically,

$$\begin{aligned} B_{OLS} &= \frac{C[z_t, i_t | w_{t-1}]}{V[i_t | w_{t-1}]} \frac{C[z_t, i_t | w_{t-1}]}{V[z_t | w_{t-1}]} B_{IV} + \frac{C[\nu_t, \varepsilon_t | w_{t-1}]}{V[i_t | w_{t-1}]} \\ &\equiv \rho^2 B_{IV} + b, \end{aligned} \tag{9}$$

where ρ denotes the correlation between z_t and i_t conditional on w_{t-1}. Under what conditions will least squares do worse than instrumental variables? Using equation (9), we see that

$$B_{OLS} > B_{IV} \qquad \Longleftrightarrow \qquad B_{IV} < b/\left(1 - \rho^2\right). \tag{10}$$

By the Schwartz inequality, $1 - \rho^2 > 0$. The key term in the inequality in (10) is thus b, which cannot be measured directly in the data, but should be approximately equal to the bias in a least squares estimate of the impact of monetary policy on the real economy using data on Germany, denoted by B^*_{OLS} (we presume that the relationship between German interest rates and output may be modeled by equations (3) and (4), above). To further explore the bias, consider the (fictional) auxiliary population regression

$$\varepsilon_t = \eta \varepsilon^*_t + \omega_t, \tag{11}$$

where ε^*_t are German output shocks in the German analogue to equation (5). Equation (11) allows us to characterize the bias of the IV estimator as

$$B_{IV} = \eta \frac{C\left[z_t, \varepsilon^*_t | w_{t-1}\right]}{C\left[w_t, i_t | w_{t-1}\right]} = \frac{\eta}{\gamma} \frac{C\left[z_t, \varepsilon^*_t | w_{t-1}\right]}{V\left[z_t | w_{t-1}\right]} \approx \frac{\eta}{\gamma} B^*_{OLS} \approx \frac{\eta}{\gamma} c, \tag{12}$$

where η is the correlation of domestic and German output shocks, and γ is the response of the domestic interest rate to the German interest rate. This equation leads to an approximate version of the inequality in (10):

$$B_{IV} < c / \left(1 - \rho^2\right) \qquad \overset{A}{\Longleftrightarrow} \qquad \eta < \gamma / \left(1 - \rho^2\right), \tag{13}$$

where the superscript above the logical operator emphasizes that the relationship is approximate. The derivation of this inequality again follows from the use of equations (7)-(9), where we now must approximate the relationships using German data. The sources of the approximation in equation (12) are twofold. First, the OLS bias for Germany involves conditioning on German control variables, not home country control variables (as in (9)). Second, Germany's OLS bias is only a rough guide to what b will be.

As we show below, γ is close to 0.8 and ρ is close to 0.4, leading the right hand side of (13) to be over 0.95.[9] Because output shocks are unlikely to be correlated more than moderately, this leads to the firm expectation that IV estimates will be less biased than OLS.

[9]Clearly both γ and ρ will vary by country; we refer to pooled estimates of their magnitudes.

2.1 Dynamic specification

The estimation equations (5) and (6) are fundamentally static representations of a complex, dynamic system. To relate our static specification to the more conventional ones from the literature, suppose that in place of (5) the data-generating process is

$$y_t = \alpha_1 + \theta_0 i_t + \theta_1 i_{t-1} + \ldots + \theta_p i_{t-p} + \beta_1 \delta' w_{t-1} + \varepsilon_t.$$

Then a straightforward omitted variable calculation shows that the probability limits are no longer as they were in (7) and (8), but instead

$$\hat{\theta}_{OLS} \overset{p}{=} \theta_0 + \theta_1 \phi_1 + \theta_2 \phi_2 + \ldots + \theta_p \phi_p + \frac{\gamma a + C\left[\nu_t, \varepsilon_t | w_{t-1}\right]}{V\left[i_t | w_{t-1}\right]} \tag{14}$$

$$\hat{\theta}_{IV} \overset{p}{=} \theta_0 + \theta_1 \phi_1^{IV} + \theta_2 \phi_2^{IV} + \ldots + \theta_p \phi_p^{IV} + \frac{a}{C\left[z_t, i_t | w_{t-1}\right]}, \tag{15}$$

where $\phi_j = C\left[i_t, i_{t-j} | w_{t-1}\right] / V\left[i_t, w_{t-1}\right]$, $j = 1, 2, \ldots, p$ are the autocovariances of interest rates, and $\phi_j^{IV} = C\left[z_t, i_{t-j} | w_{t-1}\right] / C\left[z_t, i_t | w_{t-1}\right]$ are the instrumental variable analogues. Thus, in an environment where monetary policy affects the economy with a lag, estimation of a static model such as ours combines the current effect of monetary policy with a weighted sum of the effects of past policy. Consequently, we believe the best interpretation of our static estimates is a reduced form parameter summarizing the stance of the monetary authority over the most recent half year. Most estimates of the effect of monetary policy aim to obtain the effect of unexpected changes in monetary policy on real output. For example, Bernanke and Mihov (1998) and Bernanke and Blinder (1992) view unpredicted shocks to the funds rate as exogenous variation in monetary policy. As noted above, however, equations (5) and (6) are a static model. To see the relation of our approach to theirs, it is useful to rewrite Bernanke and Mihov's model with a single lag:

$$y_t = a_0 + a_1 i_t + a_2 y_{t-1} + a_3 i_{t-1} + \nu_{1t}$$

$$i_t = b_0 + b_1 y_t + b_2 y_{t-1} + b_3 i_{t-1} + \nu_{2t}.$$

Bernanke and Mihov focus on the case where ν_{2t} is uncorrelated with future output realizations and $b_1 = 0$.[10] This corresponds to assuming that conditional on the recent history of the system, monetary policy is not forward looking, and that there is no current effect of output on interest rates. Adapting our framework to their dynamic model suggests the estimation equations

$$y_t = \alpha_1 \qquad + \quad \theta_0 i_t + \theta_1 i_{t-1} + \beta_1 \delta' w_{t-1} + \varepsilon_t \tag{16}$$

$$i_t = \alpha_2 + \gamma_0 z_t + \gamma_1 z_{t-1} + \lambda i_{t-1} + \beta_2 \delta' w_{t-1} + \nu_t. \tag{17}$$

Since w_{t-1} will typically contain lagged values of output, the main difference between the two models is the inclusion of current and lagged foreign interest rates in the policy equation. In other respects, the approaches are very similar.

If we treat the lag of interest rates as predetermined, the dynamic specification of our IV approach amounts to using z_{t-1} as an additional instrument for i_t. An alternative would be to treat both i_t and i_{t-1} as endogenous and to instrument them by z_t and z_{t-1}. However, interest rates tend to be highly persistent. While this is also a problem for identification in standard vector autoregression models that include multiple lags of the interest rate, it is a particular problem for IV estimation. Essentially, current and lagged foreign interest rates do not provide enough distinct variation to function as two separate instruments. Thus, we limit ourselves to providing some estimates for the case in which i_{t-1} is treated as predetermined in the sensitivity analysis.

2.2 Relationship between OLS-IV difference and economic fundamentals

As discussed above, the use of the German interest rate as an instrument for domestic monetary policy is not perfect given the potential correlation between the Bundes-

[10] In fact, Bernanke and Mihov (1998) assume that there is no contemporaneous effect of interest rates on output. Both assumptions identify the model; we choose the one in the text to focus on the key similarities and differences between the two approaches.

bank's forward-looking behaviour and that of the domestic monetary authority, as well as the correlation of shocks hitting both economies. Therefore, it is of interest to relate the size of the difference between the OLS and IV estimates to a country's relationship with Germany. Furthermore, given that the sample period we examine is one where Germany and many of the countries in the sample were operating in an exchange rate band, the link between domestic and German interest rate first differences may provide us with useful information.[11] This subsection addresses these issues.

In trying to relate the relative "success" of the identification strategy, a natural question to ask is "how similar are some countries to Germany than others?" One potential natural measure of this similarity is bilateral distance. For example, it is a stylized fact in the international macroeconomics literature that countries, which are farther apart also experience less correlated business cycles due to links such as trade (Frankel and Rose 1998). Though Europe is geographically dense, one might still expect that Austria exhibits more similar patterns to Germany than Spain does, for example. Thus, one would expect that the size of the IV estimator and of the OLS-IV difference to be increasing with distance. Conversely, the greater the direct ties between a country and Germany should yield weaker results for the IV estimation. For example, if a country is heavily dependent on trade with Germany (relative to its GDP), then shocks that hit Germany will be directly transmitted to the domestic economy as German supply and demand for goods adjust. Therefore, German monetary shocks will have a direct effect on a country's GDP, and this direct effect will make it more difficult to differentiate between the OLS and IV estimates.

Another issue that must be addressed is the interpretation of the first-stage interest rate regression given that many countries were fixed (at least within a band) to the Germany Deutschmark during our sample period. The recent work of Obstfeld,

[11] Note that an interest rate first difference is defined as $\Delta i_t = i_t - i_{t-1}$.

Shambaugh and Taylor (2004a, 2004b) is of particular relevance to this discussion. Specifically, Obstfeld, Shambaugh and Taylor test for differences in monetary independence across flexible and fixed exchange rate regimes by examining the relationship between domestic and base country interest rates.[12] In doing so, they advocate testing the relationship between interest rate *first differences* rather than interest rate *levels*, because testing the latter relationship will not yield useful information under certain conditions.

In particular, Obstfeld, Shambaugh and Taylor show that (conditional on interest rate parity holding) if interest rates exhibit unit roots, a levels regression will yield a base country interest rate coefficient that approaches one in the probability limit. Furthermore, if the interest rates are not cointegrated, these level-regressions will yield no useful information — Shambaugh (2004) emphasizes the importance of this spurious regression problem. Obstfeld, Shambaugh and Taylor therefore argue that a better test for monetary independence is to regress the domestic country's interest rate first differences on the base country's first differences. For the most part, the interest rate data we use tend to exhibit unit roots and are not cointegrated with the German rate.[13] Therefore, it is also important to consider the relationship between interest rate first differences in examining the relative size of the bias across countries. In particular, a higher coefficient on interest rate first differences regressions implies more similar behaviour by domestic and Germany policy makers, which in turn should imply a smaller absolute difference between OLS and IV estimates.

Simulations run by Obstfeld, Shambaugh and Taylor provide additional insight into this problem. The authors examine the properties of the interest rate regressions

[12] For our purposes, Germany is the base country.

[13] Table A.1 presents general Dickey-Fuller statistics (DF-GLS) based on the work of Elliott, Rothenberg and Stock (1996), where the null hypothesis is unit root. We cannot reject the unit root for most countries, though it can just be rejected for Germany at the 5% level, but not at the 1% level. Table A.2 presents evidence that most interest rate series are actually cointegrated with Germany's rates (the exceptions are Great Britain, Portugal and Switzerland).

by employing simulations of a target zone based on the model of Krugman (1991), with the term structure of interest rates based on the work of Svensson (1991). The two stochastic processes driving the simulations are (i) a process for domestic fundamentals, and (ii) a process for the base country interest rate. These two processes may be correlated, where Obstfeld, Shambaugh and Taylor interpret a higher correlation as higher interest rate smoothing by the domestic policy maker. For our purposes, a larger (smaller) correlation implies a smaller (larger) difference between the OLS and IV estimates. That is, a larger (smaller) coefficient implies that domestic monetary policy makers follow German monetary policy more (less) closely. The simulations provide evidence that the coefficient from the interest rate first differences regressions will be smaller if either (1) the exchange rate bands of the target zone model are wider, or (2) the correlation between fundamentals is higher. We may use this information to relate the relative size of the OLS-IV difference (and IV estimates) to observables across countries. First, if larger "effective" exchange rate bands imply higher exchange rate volatility, we expect that the size of the OLS-IV difference (IV estimate) is positively related to volatility. Second, though the correlation between fundamentals is not observable, we may calculate the coefficient from interest rate first differences regressions, where we expect that the size of OLS-IV difference (IV estimate) is negatively related to this coefficient.[14]

[14]Ideally, we would also like to simulate the target zone model à la Obstfeld, Shambaugh and Taylor. We would then be able to treat the German interest rate as the base rate and simulate a country's interest rate, where we would vary the size of the target zone and/or correlation between the innovations to the country's fundamentals and the German interest rate process. We would then run our output-growth OLS and IV regressions, where we would substitute the actual interest rates with the simulated ones. This work will be pursued in the future.

3 Data and empirical results

3.1 Data and empirical implementation

We estimate OLS and IV regressions of the impact of nominal short term interest rates on real output growth for eleven European countries using quarterly data from 1973 to 1998. These countries are chosen given data availability and include but are not limited to most participants in the European Monetary System (EMS): The countries are Austria, Belgium, France, Great Britain, France, Italy, Netherlands, Norway, Portugal, Spain, Sweden, and Switzerland.[15] Nominal GDP data are taken from the International Monetary Funds International Financial Statistics (IFS) database and are deflated by each country's real GDP deflator (1995=100, also from the IFS database). To control for seasonal components we deseasonalize real GDP growth (log-difference of real GDP), by regressing it on quarterly dummies, and using the residuals from these regressions as our main dependent variable. We lack complete data for quarterly GDP for Belgium, Italy, the Netherlands, Portugal, and Sweden in the 1970s.[16] The short-term interest rate by which we measure monetary policy is the overnight lending/call money rate from Global Financial Database. We average end-of-month rates quarterly.[17] We also have tried using the central bank's discount rate, and the three month T-bill rate (annualized). Our results are generally robust to the choice of interest rates used.

Our main estimation equations are (5) and (6), where the level of the quarterly German overnight rate is used as an instrument for the level of the call money rate in the other European countries. It is widely accepted in the literature that the German

[15] Notable exceptions due to data limitations on quarterly nominal interest rates are Denmark and Ireland.

[16] Data are missing from 1973Q1-1980Q2 (Belgium), 1973Q1-1977Q1 (Netherlands), 1973Q1-1977Q1 (Portugal), and 1973Q1-1980Q1 (Sweden). For Portugal we are also missing interest rate data from 1973Q1-1975Q3.

[17] Overnight/call money rates are missing for two countries: 1973Q1-1978Q2 (Italy) and 1973Q1-1975Q3 (Portugal).

central bank became the effective trend-setter in the stance of monetary policy for other European countries since the break down of the Bretton-Woods system. This role of leadership was strengthened within the EMS founded in 1979,[18] and a large literature grew out of the attempt to quantify and explain the degree of the ensuing asymmetry.[19] Some have argued that Germany effectively ran monetary policy for the entire EMS (e.g., Giavazzi and Giovannini 1987); others have argued that German dominance left room for own monetary policy action as intended by the founders of the EMS (e.g., von Hagen and Fratianni 1990). Thus, while German monetary policy seems to have been a strong influence on countries' interest rates, this did not negate forward-looking behavior on the part of the monetary policy, particularly for larger countries within the EMS, and those who joined late/had wider exchange rate bands. For the smaller, open countries on the other hand, pegged exchange rates and flexible capital markets may have left little scope for independent monetary policy.[20] Thus, we would expect the differences between IV and OLS to be strongest for countries that were not only subject to less similar shocks as Germany, but also had greater scope for independent monetary policy and behaved as such in the EMS — Great Britain is one late-joiner who naturally comes to mind. Moreover, some countries, such as Austria, were not part of the EMS, but effectively pegged their exchange rate to Germany and surrendered all independent monetary control.[21]

[18] This system was precluded by an informal joint float against the dollar knows as the "snake". Members of this system were Belgium, Germany, Luxembourg, and the Netherlands. France, Great Britain and Italy participated briefly and sporadically in the snake during the 1970s.

[19] The original members of the EMS (and their initial exchange rate bands) in 1979Q1 were Belgium (±2.25%, Denmark (±2.25%), France (±2.25%), Germany (±2.25%), Ireland (±2.25%), Italy (±6%), Luxembourg (1979Q2, ±2.25%), the Netherlands (±2.25%). Late joiners included Great Britain (1990Q1, ±6%), Portugal (1992Q1, ±6%), and Spain (1990Q1, ±6%). Note that the exchange rate band expanded, for all countries remaining in the EMS, to ±15% in 1993Q3. See Table A.3 for more details on the realignments over time.

[20] The existence of flexible capital markets was not always the case during the EMS-period. As Giavazzi and Giovannini (1989) point out, the use of capital controls were predominant in many of the "weaker" currency countries. Paradoxically, Giavazzi and Giovannini find that though these controls had a tendency to break the link between interest rates (as measured by the differential in movements of on-shore and off-shore rates), that they could not reject France and Italy's monetary policy from being different from Germany's during the period.

[21] Indeed, a common joke during the period was that the head of the Austrian central bank was

3.2 Empirical results

We first present results for a simple baseline model with no additional covariates included. The baseline specification is only correct under the stylized case in which the central bank controls the interest rate directly, and has as its only objective the smoothing of output. In this special case, the interest rate is only a function of the central bank's projection of shocks that are unexpected by the market. Thus, interest rates should be orthogonal to any market information. Clearly, the interest rate is in effect also determined by market forces as well as by other policy goals of the central bank. In particular, if the central bank uses the interest rate to manage inflation, and inflation correlates positively with lagged output growth, then the coefficient on nominal interest rates in a growth regression might overstate the effects of monetary policy. Therefore, we will successively add lags of real output growth to our specification. In addition, as explained above, we also estimate a dynamic version of our static model that includes lags of interest rates.

Table 1 shows results for a regression of real quarterly output growth on nominal interest rates for all countries, sorted by GDP. This table corresponds to the following regression system, which is analogous to estimating (5) and (6):

$$y_t = \alpha_1 + \theta i_t + \varepsilon_t \tag{18}$$

$$i_t = \alpha_2 + \gamma i_t^{DEU} + \nu_t, \tag{19}$$

where OLS estimation only uses (18), and the first-stage of the IV estimation uses (19).[22] The second column of the table gives simple OLS estimates of the effect of monetary policy. Taken at face value, these estimates imply that a one percentage point increase in the interest rate lowers quarterly real growth only moderately: 0.093 percentage points in Sweden and only 0.01 percentage points in France. Given the

paid more than the head of the Bundesbank, and that all his pay was to compensate him for waiting for faxes from Germany to let Austria know when to move interest rates.

[22] The other estimations we present include lags of output growth, y_t, to (18).

discussion in Section 2.2, we also pool our results using the four variables of interest. Specfically, pooled estimates are presented in which countries are weighted by (i) their distance to Germany [Pooled 1], (ii) the (inverse) of their trade with Germany to GDP ratio [Pooled 2], (iii) their Deutchmark exchange rate volatility [Pooled 3], and (iv) one minus the coefficients from the interest rate first differences regressions [Pooled 4].[23,24] The average effect for all the pooled OLS results is -0.038 percentage points, where weighting by exchange rate volatility [Pooled 3] yields the most negative OLS estimate.

The corresponding estimates using the German interest rate as an instrument for the national interest rate are shown in the third column. For all countries (except Austria), the IV estimates are more negative than the OLS estimates. This suggests that some degree of endogeneity with respect to real output growth affects most countries' interest rates. A simple interpretation of this endogeneity is that it is capturing the extent to which the monetary authority is forward-looking. The pooled estimates summarize this result: the IV estimate suggests that a one percentage point increase in interest rates (on average) causes a reduction in real output growth of 0.103 percentage points, which exceeds the OLS estimate by a factor of three.

However, the magnitude and significance of the IV estimates is different between countries. A simple way to examine the relationship between these estimates and the fundamentals by which we pool the results are presented in Figure 1, which is based on results from Table 1. Figure 1(a) shows that the IV estimates becomes more negative with distance from Germany, as expected. This relationship is not very strong, however. The relationship between the IV estimates and trade ratio is plotted in Figure 1(b). As expected, the IV estimates become less negative the more important a country's trade with Germany is relative to its total output. Figures 1(c) and 1(d)

[23]Note that subtracting the coefficient from one implies that the higher the coefficient the lower the weight, while keeping all weights positive.

[24]See Table A.4 for the weights used for these regressions as well as other summary statistics.

present some more striking results. In particular, the IV estimates are more negative for countries whose currencies were more volatile viz. the Deutchmark [Fig. 1(c)]. This result confirms the intuition that a more flexible exchange rate regime allowed countries more monetary independence, and hence the use of the German rate as an instrument picked up more exogenous domestic country monetary shocks. Finally, Figure 1(d) provides evidence that IV results are stronger for countries with lower interest rate first differences regression coefficients, which imply lower correlation between domestic and German shocks.

These differences across countries carry over to differences between OLS and IV estimates. The OLS-IV difference, shown in the third column is generally large and positive for countries that are farther from Germany, less dependent on trade with Germany, have a more volatile exchange rate, and have smaller interest rate first differences regression coefficients. The cross-country heterogeneity in the OLS-IV difference is greater than that of the IV estimates, as witnessed in Figure 2. As expected, the difference is (i) increasing with distance [Fig. 2(a)], (ii) decreasing with the trade to GDP ratio [Fig. 2(b)], (iii) increasing with exchange rate volatility [Fig. 2(c)], and (iv) decreasing with the interest rate first differences regression coefficients [Fig. 2(d)]. Again, the relationship with distance is not overwhelmingly strong in Figure 2(a), though this is in part driven by Great Britain (GBR), which is quite close to Germany as measured. However, in as much that distance is picking up direct economic ties, the fact that Great Britain is off the "continent" is also relevant. Therefore, the trade with Germany/GDP ratio is most probably a better proxy for economic closeness. Indeed, the OLS-IV difference exhibits a strong negative relationship with respect to this variable in Figure 2(b), and note the position of Great Britain. Finally, Figures 2(c) and 2(d) bear out the fact that the IV estimation produces greater differences from OLS for countries with larger exchange rate bands and smaller coefficients from interest rate first differences regressions.

The first stage underlying the IV estimates is very significant and strong for all countries. The strength of the coefficients, shown in Table 2, again varies considerably across countries. In contrast to the results in Table 1, there does not appear to be systematic differences between countries in the covariance of home country interest rates with the German interest rate viz. the four fundamentals that we have discussed thus far.[25] Note that we would not have expected any systematic difference, since countries who had the option for more independence may still have an incentive to tie themselves to the German rate and countries fixing tightly to the Deutchmark may face no choice. All countries but Great Britain, Spain, Switzerland, and Norway have first stage coefficients on the German interest rate of at least 0.8, each one significantly and all below unity. Not surprisingly, these four countries either were never part of the EMS or joined late. The lowest first-stage coefficient is Spain's 0.34. Thus, overall, German monetary policy seems to be a strong determinant of interest rates for those countries included in our sample.

To the extent that the central bank pursues other policies, the results of the baseline model in Table 1 might be affected by a bias from confounders affecting both nominal interest rates and real output growth. As discussed in Section 2, above, natural control variables are lags of growth itself: if it negatively affects current growth rates and is positively correlated with current interest rates, then the baseline results may overstate the effect of monetary policy.

The results including a single lag of real output growth are shown in Table 3. Compared to Table 1, the table shows small differences in OLS estimates, indicating that past output growth and current interest rates are not strongly correlated. The differences between the OLS results in Table 3 and Table 1 are never significant, nor do they appear follow a particular pattern across countries.[26] However, there are

[25]The one exception is that the size of the first-stage coefficient is strongly positively associated with the coefficient from the interest-rate differences regressions.

[26]The pooled estimates at the bottom of Table 3 suggest they should be slightly negative, at odds

some minor differences in the IV estimates; in particular, it appears that inclusion of one lag of output growth strengthens moderately the estimated IV effect. For example, the results of Table 1 indicated that for Great Britain, a one percentage point increase in the interest rate would lead to a reduction in real growth of 0.18 percentage points. The estimate in Table 3 suggests a reduction of 0.27 percentage points is to be expected, exceeding the baseline model effect size by about 50%. The pooled estimates indicate that this is a general pattern: overall, the effects in Table 1 indicated a reduction in real growth (averaged over the four pooled estimates) of 0.10 percentage points, but the effects in Table 3 indicate a reduction of 0.12 percentage points would be expected.

We draw two main conclusions from the results presented in Tables 1 and 3. First, the differences between the OLS and IV estimates are both economically important and statistically distinct, indicating that there may be a substantial component of monetary policy that is forward looking. Second, this difference is dependent on how economically close a country is to Germany viz. direct links (e.g., trade) as well as the exchange rate regime it is following. A corollary to these findings is that larger countries (as measured by GDP) were generally less dependent on Germany economically and also were exercised discretion viz. their exchange rate regime. Therefore, taking the difference between our OLS and IV estimates as a rough estimate of the extent to which the monetary authority is forward-looking, it would seem that large countries are better able than small countries to tighten the reins of a growing economy in anticipation of inflationary growth. This conclusion is consistent with the belief that smaller open countries may have less scope to conduct independent monetary policy. Larger countries on the other hand have a greater potential for endogenous monetary policy.

Estimates containing four lags of real output growth are shown in Table 4. These

with the simple omitted variable explanation.

estimates are quite similar to those in Table 3. The OLS estimates, shown in the second column, are very similar to corresponding estimates in Table 1 or 3. The IV estimates, shown in the third column, are generally similar to those in Tables 1 and 3, but the precision is affected somewhat by the inclusion of the additional controls. This imprecision may be traced back to a weakening of the first stage relationship between home country and German interest rates, reported in the sixth column of Table 2. Turning to the pooled estimates in Table 4, we see that they are remarkably similar to those reported in Tables 1 and 3. Taking home country interest rates as exogenous conditional on four lags of output growth, a one percentage point increase in the interest rate would appear to result in a quite modest contraction (averaged over the four pooled estimates) of 0.04 percentage points. In contrast, the pooled IV estimates suggest that the contraction is likely to be more on the order of 0.14 percentage points.

The European Monetary System came into effect in 1979 and committed countries to keep their exchange rates within bands of the German rate. Thus, this should have strengthened the role of leadership of the Bundesbank, and further constrained the monetary policy actions of member countries. This change in institutions may well have affected the relationships we have documented here. On the one hand, the EMS should lead to more negative OLS estimates of the effect of interest rates on growth. On the other hand, von Hagen and Fratianni (1990) speculate that the Bundesbank itself may have become more lenient on inflation, since inflation's negative consequences for the German economy would be partially exported to the other countries under fixed exchange rates. This would imply lower IV estimates, since German monetary policy may have become more endogenous.

Table 5 shows the baseline regression for the EMS era (that is, 1979 to the present).[27] Overall, OLS estimates tend to be slightly more negative although the

[27] The results if more lags are included are qualitatively similar to what is shown in Tables 3 and

pooled estimates show hardly any effect (none of the differences are statistically significant). The IV estimates also show very little difference, except for Switzerland, where the coefficient is now almost twice as large as before.[28] This is also reflected in the results for the relative bias of IV and OLS in Column 4 —comparing them to those in Table 1, only Switzerland shows a sizeable difference. The first stage coefficients shown in the last Column of Table 2 reveals the effect of the EMS, where there has been a considerable increase in the effect of German monetary policy for countries within the system. Furthermore, Austria's coefficient is no longer significantly different from one, which is not surprising given that Austria effectively surrendered its monetary policy making decisions to Germany during the EMS. Note also that those countries with increases in the interest rate first differences regression coefficients also saw an increase in the first-stage coefficient.[29] Thus, part of the increase in first stages is a genuine policy change; part is likely to be related to the convergence of economies during the EMS. As will be discussed below, these developments have opposite effects on the relative bias of IV vs. OLS. For example, the interest rate first differences coefficient for Great Britain increased from 0.072 to 0.246, while its IV estimate decreased (in absolute value) from -0.238 to -0.218. By way of this increase in common output shocks (i.e., decrease in interest rate first differences coefficients) German monetary policy may thus have become more endogenous with respect to Great Britain's policy during the EMS despite an increase in the Great Britain's first stage – reflected in a decline of the IV estimate.

Overall, these estimates are not inconsistent with the hypothesis that monetary policy has become less endogenous in the follower countries and more endogenous in

4.

[28]Note that Austria the difference between IV and OLS is now positive. However, the large standard error indicates this may simply be due to sampling variation.

[29]The coefficients for the interest rate first differences regressions are for the years 1973-1998 (1979-1998) Austria 0.181 (0.220), Belgium 0.121 (0.128), France 0.155 (0.185), Great Britain 0.072 (0.246), Italy 0.620 (0.620), Netherlands 0.174 (0.238), Norway 0.127 (0.677), Portugal 0.228 (0.238), Spain -0.109 (-0.165), Sweden 0.066 (0.442), Switzerland -0.025 (0.229).

Germany since 1979. Consistent with this hypothesis a separate OLS regression for Germany reveals that the coefficient on the nominal interest rate drops from -0.02 to zero (although standard errors are again large).

As noted in Section 2, above, estimates for the static model of equations (5) and (6) are a reduced-form parameter for the stance of monetary policy over the recent past. Specifically, if there are lagged effects of nominal interest rates on output growth, the results in Tables 1, 3, and 4 can be interpreted as the weighted sum of the impact of current and lagged interest rates (see equations (14) and (15)). The differences in the point estimates across countries could thus be partly explained by the accumulation of differential effects over time and differences in the persistence of interest rates.

As a check on our results, we also ran the dynamic specification suggested in equations (16) and (17), assuming that lagged home country interest rates are predetermined. This assumption is tenuous, and would be violated if the central bank were able to accurately estimate output growth more than one period ahead. However, if the assumption were true and if past interest rates had a negative effect on output growth and a positive effect on current interest rates, we would expect inclusion of lagged interest rates to lower the coefficient on current interest rates both in OLS and IV regressions.

The data cannot identify effects for single countries with any degree of precision. For the pooled specifications, we find that inclusion of lagged interest rates (one or four lags) leads to differences in OLS estimates of unclear sign — all countries are included OLS is more negative, but if only countries with complete data are included, it is less negative. In the first stage, inclusion of lagged own interest rates reduces the coefficient on the instrument considerably, consistent with a positive correlation of current and lagged interest rates within and across countries. However, IV estimates turn these results upside down – including lagged interest rates leads to significantly positive effects of past interest rates on output growth with *stronger* negative effects of current rates. This suggests that lagged interest rates may be endogenous as well, consistent with monetary policy actions with a horizon of several quarters. Unfortunately, as suggested in Section 2, the lags of German interest rates are too persistent to provide separate instruments for lags of followers interest rates, and thus we cannot move beyond this point.

We also conduct some robustness checks. Figures A.1 and A.2 present leverage plots for each country for regressions with no output growth lags. The leverage is calculated as follows. We run the OLS and IV regressions, where we drop an observation each period. We record the estimated interest rate coefficient, and then subtract the estimated interest rate coefficient from regressions using the whole sample (in this case, the estimates from Table 1). This is done for each period, so a point on the figure corresponds to the period where the data point has been dropped. The smaller the leverage the better. In examining the plots, the leverage coefficients are generally close to zero for most countries. Austria, the Netherlands and Sweden are particular exceptions, and these countries are indeed some where the OLS-IV difference is not significantly different from zero. This fact is particularly interesting for Sweden, since the estimated bias is actually quite large (0.078), but the standard errors are also large.

4 Conclusion

We have presented a sequence of simple estimates of the effect of monetary policy on real output growth, ranging from least squares contrasts to instrumental variables estimates. We believe that the transparency of the identifying assumptions underlying these types of simple contrasts generate substantial insight into the relationship between monetary policy and the real economy. However, it is also clear that such an approach is not without drawbacks — for example, it does not appear practicable to tailor our approach to estimation of the dynamic impacts of policy. Consequently, we view our approach as a complement to, not a substitute for, the more common approaches in the monetary policy literature.

The identification strategy we have pursued attempts to exploit the fact that monetary policymakers may sometimes have competing goals. In particular, since the breakdown of the Bretton-Woods system, many European central banks have followed the leadership of the Bundesbank in setting monetary policy to stabilize their exchange and inflation rates. Using quarterly German nominal interest rates as an instrument for other European countries' nominal interest rates, we estimate that the causal effect of a one percentage point increase in interest rates is a contraction in quarterly real growth of 0.08 - 0.15 percentage points. This is in contrast to naïve OLS estimates, which suggest a more modest contraction of 0.03 - 0.05 percentage points.

The OLS-IV difference may be interpreted as a measure of the extent to which the monetary authority is forward-looking. This size of this difference can be related to economic fundamentals. First, we show that the difference is decreasing with respect to the economic closeness between a country and Germany, as measured by physical distance and trade with Germany. Second, we show that the difference is increasing with Deutchmark exchange rate volatility, and decreasing with how dependent a country's monetary policy is on Germany's (as measured by the interest rate first differences regression coefficients). These latter results are expected given the work of Obstfeld, Shambaugh and Taylor (2004a, 2004b), and nicely confirms the expected behaviour within a target zone model, which the EMS was.

Finally, we find that during the period of pegged exchange rates under the European Monetary System, IV estimates of the effect of monetary policy, as well as the OLS-IV difference, are smaller than during the post-1973 period as a whole. This may have been due partly to higher correlation of (reaction to) shocks across countries as European economies converged.

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Table 1. The effect of interest rates on real output growth

Country	OLS	IV	OLS-IV	Hausman-Wu Test
Austria	-0.085	-0.071	-0.014	0.05
	(0.083)	(0.104)	(0.062)	p=0.82
Belgium	-0.075	-0.091	0.016	0.51
	(0.031)	(0.039)	(0.023)	p=0.48
France	-0.010	-0.062	0.052	4.42
	(0.020)	(0.033)	(0.026)	p=0.04
Great Britain	-0.054	-0.238	0.183	6.01
	(0.027)	(0.097)	(0.094)	p=0.01
Italy	-0.024	-0.076	0.052	7.27
	(0.017)	(0.028)	(0.022)	p=0.01
Netherlands	-0.093	-0.138	0.045	3.09
	(0.035)	(0.044)	(0.027)	p=0.08
Norway	-0.045	-0.056	0.011	0.00
	(0.075)	(0.265)	(0.256)	p=0.96
Portugal	-0.021	-0.070	0.049	0.82
	(0.031)	(0.064)	(0.056)	p=0.37
Spain	-0.026	-0.171	0.145	3.86
	(0.012)	(0.116)	(0.116)	p=0.05
Sweden	-0.076	-0.153	0.078	0.65
	(0.080)	(0.127)	(0.099)	p=0.42
Switzerland	-0.010	-0.075	0.065	0.63
	(0.046)	(0.095)	(0.083)	p=0.43
Pooled 1	-0.034	-0.101	0.068	6.74
	(0.012)	(0.029)	(0.027)	p=0.01
Pooled 2	-0.033	-0.110	0.077	9.81
	(0.011)	(0.028)	(0.026)	p=0.00
Pooled 3	-0.047	-0.094	0.047	4.95
	(0.015)	(0.026)	(0.022)	p=0.03
Pooled 4	-0.038	-0.105	0.067	7.35
	(0.013)	(0.029)	(0.026)	p=0.01

Notes: The entries in the table are coefficients of OLS (IV) regressions of quarterly growth rates of real deseasonalized GDP on nominal overnight/call money rates without other regressors for the period from 1973 to 1998. The IV regressions use the German overnight rate as instrument. The first stage coefficients are shown in Table 2. The Hausman-Wu test statistics are for the hypothesis of no difference between OLS and IV coefficients and have a Chi-Squared distribution with one degree of freedom. See text for definition of pooled regressions. Standard errors are in parentheses.

Table 2. First stage of nominal interest rates using German rate as instrument

	No Lags		One Lag		Four Lags		Post-1978	
Country	First stage	t-stat β=1	First stage	t-stat β=1	First stage	t-stat β=1	First stage	t-stat β=1
Austria	0.763	4.21	0.765	4.12	0.833	2.96	0.985	0.32
	(0.056)		(0.057)		(0.056)		(0.048)	
Belgium	0.966	0.41	0.917	0.96	0.967	0.35	0.966	0.41
	(0.084)		(0.086)		(0.092)		(0.084)	
France	1.129	0.92	1.160	1.12	1.294	1.92	1.499	3.06
	(0.140)		(0.143)		(0.153)		(0.163)	
Great Britain	0.544	2.98	0.550	2.78	0.955	0.23	0.731	1.90
	(0.153)		(0.162)		(0.198)		(0.142)	
Italy	1.263	1.65	1.323	1.94	1.373	2.21	1.329	2.04
	(0.160)		(0.167)		(0.169)		(0.161)	
Netherlands	0.882	1.68	0.866	1.87	0.877	1.60	0.939	0.98
	(0.070)		(0.071)		(0.077)		(0.062)	
Norway	0.476	3.28	0.479	3.24	0.487	2.93	0.627	1.90
	(0.160)		(0.161)		(0.175)		(0.197)	
Portugal	1.107	0.50	1.079	0.36	1.096	0.43	1.284	1.27
	(0.215)		(0.218)		(0.225)		(0.224)	
Spain	0.338	3.26	0.308	3.35	0.441	2.48	0.894	0.62
	(0.203)		(0.206)		(0.225)		(0.171)	
Sweden	1.029	0.20	1.021	0.14	1.013	0.07	1.029	0.20
	(0.147)		(0.150)		(0.192)		(0.147)	
Switzerland	0.513	5.41	0.514	5.32	0.553	4.48	0.504	4.33
	(0.090)		(0.091)		(0.100)		(0.115)	
Pooled 1	0.778	4.33	0.777	4.33	0.838	2.97	1.014	0.28
	(0.051)		(0.052)		(0.055)		(0.052)	
Pooled 2	0.739	5.13	0.741	5.04	0.827	3.17	0.997	0.05
	(0.051)		(0.051)		(0.054)		(0.050)	
Pooled 3	0.810	5.32	0.807	5.38	0.871	3.45	0.978	0.60
	(0.036)		(0.036)		(0.037)		(0.037)	
Pooled 4	0.746	5.65	0.745	5.64	0.816	3.88	0.946	1.19
	(0.045)		(0.045)		(0.047)		(0.045)	

Notes: The table shows coefficients of a regression of a countries' quarterly overnight/call money rate on the German overnight rate for different specifications. The columns next to the coefficients show t-test statistics for the hypothesis that the first stage coefficient is equal to one. See text for definition of pooled regressions. Standard errors are in parentheses.

Table 3. Real effects of monetary policy: One lag of growth

Country	OLS	IV	OLS-IV	Hausman-Wu Test
Austria	-0.069	-0.032	-0.037	0.40
	(0.079)	(0.098)	(0.059)	p=0.52
Belgium	-0.074	-0.094	0.020	0.57
	(0.034)	(0.044)	(0.038)	p=0.45
France	-0.011	-0.076	0.066	7.49
	(0.020)	(0.033)	(0.044)	p=0.01
Great Britain	-0.040	-0.312	0.272	14.08
	(0.025)	(0.115)	(0.162)	p=0.00
Italy	-0.021	-0.065	0.043	5.27
	(0.017)	(0.027)	(0.039)	p=0.02
Netherlands	-0.105	-0.157	0.053	3.77
	(0.037)	(0.047)	(0.037)	p=0.05
Norway	-0.086	-0.134	0.048	0.04
	(0.072)	(0.254)	(0.249)	p=0.84
Portugal	-0.036	-0.090	0.054	1.05
	(0.029)	(0.063)	(0.066)	p=0.31
Spain	-0.015	-0.155	0.140	3.45
	(0.011)	(0.123)	(0.234)	p=0.06
Sweden	-0.118	-0.164	0.046	0.28
	(0.072)	(0.115)	(0.093)	p=0.60
Switzerland	-0.014	-0.081	0.067	0.67
	(0.047)	(0.096)	(0.086)	p=0.41
Pooled 1	-0.044	-0.128	0.083	11.14
	(0.012)	(0.029)	(0.028)	p=0.00
Pooled 2	-0.040	-0.141	0.101	18.43
	(0.011)	(0.027)	(0.028)	p=0.00
Pooled 3	-0.051	-0.096	0.045	4.87
	(0.015)	(0.025)	(0.022)	p=0.03
Pooled 4	-0.045	-0.126	0.081	11.41
	(0.013)	(0.028)	(0.027)	p=0.00

Notes: The entries in the table are coefficients of OLS (IV) regressions of quarterly growth rates of real deseasonalized GDP on nominal overnight/call money rates without other regressors for the period from 1973 to 1998. The IV regressions use the German overnight rate as instrument. The first stage coefficients are shown in Table 2. The Hausman-Wu test statistics are for the hypothesis of no difference between OLS and IV coefficients and have a Chi-Squared distribution with one degree of freedom. See text for definition of pooled regressions. Standard errors are in parentheses.

Table 4. Real effects of monetary policy: Four lags of growth

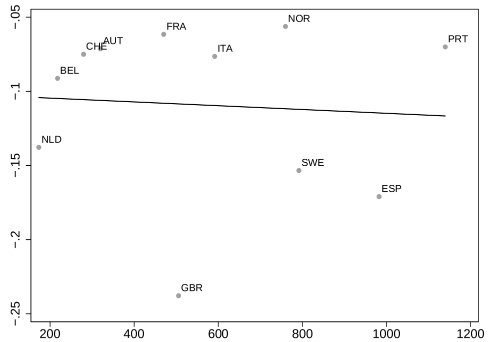
Country	OLS	IV	OLS-IV	Hausman-Wu Test
Austria	-0.105	-0.087	-0.019	0.22
	(0.062)	(0.074)	(0.042)	p=0.64
Belgium	-0.061	-0.060	-0.001	0.00
	(0.036)	(0.046)	(0.047)	p=0.96
France	-0.005	-0.070	0.064	9.44
	(0.019)	(0.030)	(0.077)	p=0.00
Great Britain	-0.051	-0.168	0.117	5.46
	(0.026)	(0.064)	(0.114)	p=0.02
Italy	-0.020	-0.058	0.038	4.62
	(0.017)	(0.026)	(0.064)	p=0.03
Netherlands	-0.097	-0.155	0.057	4.01
	(0.038)	(0.049)	(0.054)	p=0.05
Norway	-0.094	-0.424	0.330	1.80
	(0.073)	(0.291)	(0.339)	p=0.18
Portugal	-0.027	-0.088	0.061	1.36
	(0.030)	(0.063)	(0.106)	p=0.24
Spain	-0.006	-0.089	0.083	5.61
	(0.007)	(0.057)	(0.235)	p=0.02
Sweden	-0.130	-0.178	0.048	0.31
	(0.059)	(0.108)	(0.144)	p=0.58
Switzerland	-0.023	-0.148	0.125	2.48
	(0.047)	(0.098)	(0.105)	p=0.12
Pooled 1	-0.039	-0.143	0.103	19.75
	(0.012)	(0.027)	(0.035)	p=0.00
Pooled 2	-0.034	-0.145	0.111	26.7
	(0.011)	(0.025)	(0.035)	p=0.00
Pooled 3	-0.054	-0.122	0.068	14.47
	(0.014)	(0.023)	(0.023)	p=0.00
Pooled 4	-0.041	-0.138	0.096	19.58
	(0.012)	(0.026)	(0.031)	p=0.00

Notes: The entries in the table are coefficients of OLS (IV) regressions of quarterly growth rates of real deseasonalized GDP on nominal overnight/call money rates without other regressors for the period from 1973 to 1998. The IV regressions use the German overnight rate as instrument. The first stage coefficients are shown in Table 2. The Hausman-Wu test statistics are for the hypothesis of no difference between OLS and IV coefficients and have a Chi-Squared distribution with one degree of freedom. See text for definition of pooled regressions. Standard errors are in parentheses.

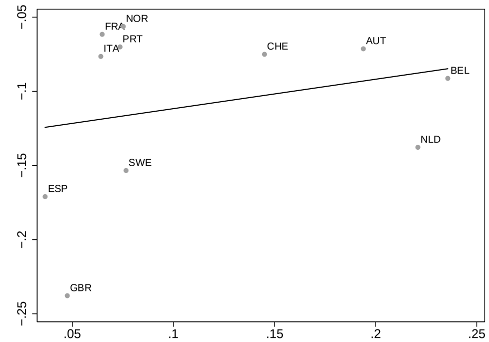
Table 5. Real effects of monetary policy: Post-1978 and no lags

Country	OLS	IV	OLS-IV	Hausman-Wu Test
Austria	-0.026	-0.035	0.009	0.09
	(0.070)	(0.076)	(0.030)	p=0.76
Belgium	-0.075	-0.091	0.016	0.51
	(0.031)	(0.039)	(0.023)	p=0.48
France	-0.005	-0.050	0.045	6.41
	(0.019)	(0.027)	(0.019)	p=0.01
Great Britain	-0.108	-0.218	0.111	5.49
	(0.028)	(0.061)	(0.054)	p=0.02
Italy	-0.026	-0.064	0.038	4.63
	(0.017)	(0.025)	(0.019)	p=0.03
Netherlands	-0.103	-0.137	0.035	2.40
	(0.039)	(0.045)	(0.023)	p=0.12
Norway	-0.066	-0.072	0.006	0.00
	(0.061)	(0.179)	(0.169)	p=0.97
Portugal	-0.025	-0.058	0.033	0.50
	(0.030)	(0.056)	(0.048)	p=0.48
Spain	-0.033	-0.140	0.107	16.39
	(0.016)	(0.039)	(0.036)	p=0.00
Sweden	-0.076	-0.153	0.078	0.65
	(0.080)	(0.127)	(0.099)	p=0.42
Switzerland	-0.042	-0.131	0.089	2.13
	(0.031)	(0.073)	(0.066)	p=0.14
Pooled 1	-0.041	-0.095	0.055	9.28
	(0.012)	(0.022)	(0.019)	p=0.00
Pooled 2	-0.042	-0.104	0.062	14.67
	(0.011)	(0.020)	(0.017)	p=0.00
Pooled 3	-0.046	-0.084	0.038	6.78
	(0.013)	(0.020)	(0.015)	p=0.01
Pooled 4	-0.046	-0.102	0.056	10.41
	(0.012)	(0.022)	(0.019)	p=0.00

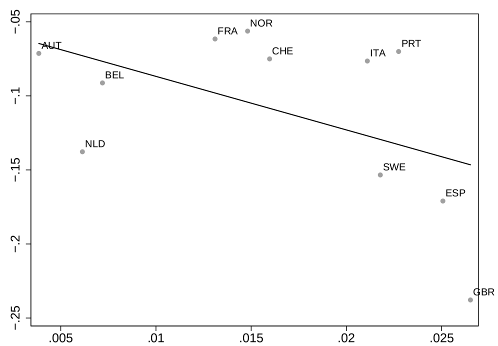
Notes: The entries in the table are coefficients of OLS (IV) regressions of quarterly growth rates of real deseasonalized GDP on nominal call money rates without other regressors for the period from 1973 to 1998. The IV regressions use the German overnight rate as instrument. The first stage coefficients are shown in Table 2. The Hausman-Wu test statistics are for the hypothesis of no difference between OLS and IV coefficients and have a Chi-Squared distribution with one degree of freedom. See text for definition of pooled regressions. Standard errors are in parentheses.



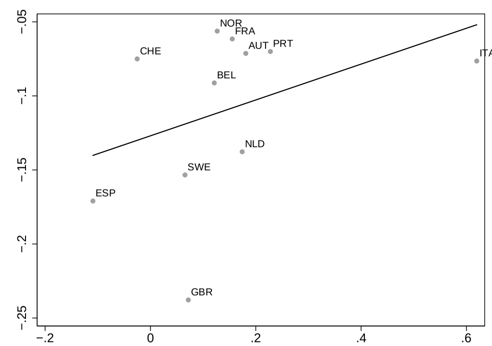
(a) IV vs. distance to Germany (miles)



(b) IV vs. trade with Germany/GDP

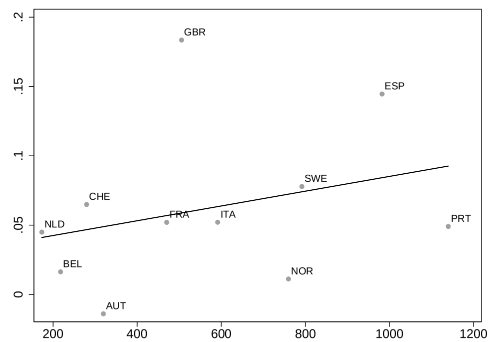


(c) IV vs. bilateral exchange rate volatility (σ(NER))

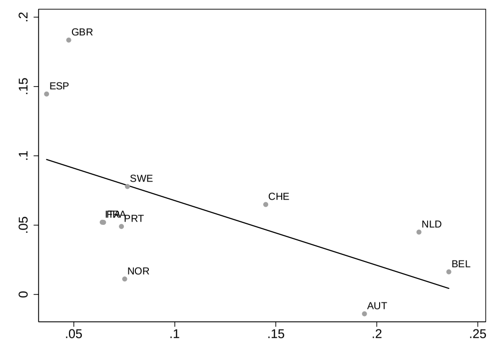


(d) IV vs. interest rate first differences regression coefficient ($\beta(\Delta i, \Delta i^{DEU})$)

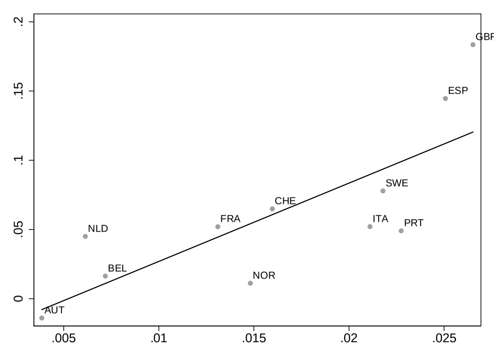
Figure 1. Relationship between instrumental variable estimates (IV) and economic fundamentals (no lags)



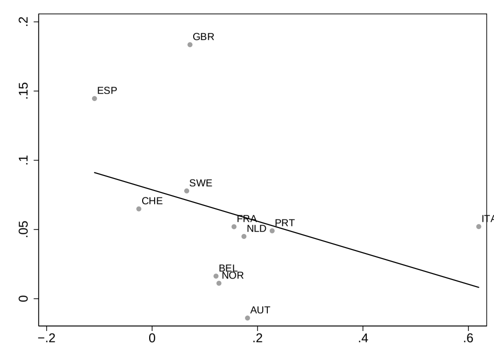
(a) OLS-IV vs. distance to Germany (miles)



(b) OLS-IV vs. trade with Germany/GDP



(c) OLS-IV vs. bilateral exchange rate volatility (σ(NER))



(d) OLS-IV vs. interest rate first differences regression coefficient ($\beta(\Delta i, \Delta i^{DEU})$)

Figure 2. Relationship between OLS-IV difference and economic fundamentals (no lags)

Appendix A Additional tables and figures: Time-series statistics for interest rates and country summary statistics

Table A.1. DF-GLS test for unit roots

Country	DFGLS	LAGS	MAIC
Austria	-1.93	6	-9.34
Belgium	-1.59	12	-8.45
France	-1.31	11	-7.11
Great Britain	-0.83	12	-8.45
Italy	-0.89	6	-7.62
Netherlands	-0.93	8	-7.98
Norway	-1.30	6	-7.10
Portugal	-1.14	9	-7.89
Spain	-0.81	8	-6.70
Sweden	-0.72	11	-7.23
Switzerland	-2.57	12	-9.44
Germany	-2.03	12	-9.09

Notes: Note: critical values for all DFGLS statistics are: -2.599 (1%), -1.950 (5%), -1.610 (10%). Modified Akaike Information Criterion (MAIC) used to choose lag length.

Table A.2. Cointegration rank test (using Johansen method) of foreign and German interest rates

Country	Max-λ	Trace
Austria	40.18	42.20
Belgium	35.32	39.40
France	30.63	36.12
Great Britain	12.11	15.96
Italy	20.41	22.90
Netherlands	49.08	54.84
Norway	19.14	27.30
Portugal	7.19	8.71
Spain	17.95	27.59
Sweden	24.42	31.75
Switzerland	13.77	16.31

Notes: The null hypothesis is that there are zero cointegrating vectors. The Osterwald-Lenum critical values at the 95% level for the cointegration equation (with intercept) is 15.67 for the Max-λ statistic and 19.96 for the Trace statistic.

Table A.3. Entry and realignment dates into EMS

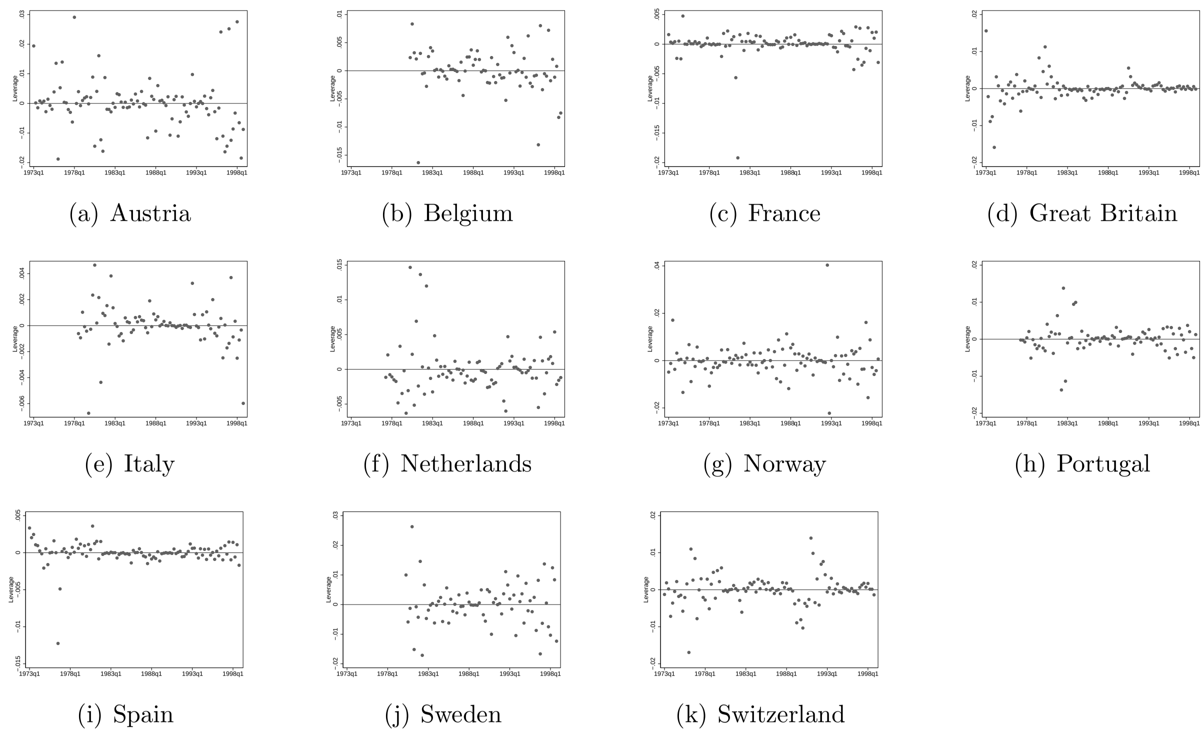
Date	Germany	Belgium	Denmark	France	Ireland	Netherlands	Italy	Spain	Great Britain	Portugal
1979Q3	+2.00		-2.86					NM	NM	NM
1979Q4			-4.76					NM	NM	NM
1981Q1							-6.00	NM	NM	NM
1981Q4	+5.50			-3.00		+5.50	-3.00	NM	NM	NM
1982Q1		-8.50	-3.00					NM	NM	NM
1982Q2	+4.25			-5.75		+4.25	-2.75	NM	NM	NM
1983Q1	+5.50	+1.50	+2.50	-2.50	-3.50	+3.50	-2.50	NM	NM	NM
1985Q3	+2.00	+2.00	+2.00	+2.00	+2.00	+2.00	-6.00	NM	NM	NM
1986Q2	+3.00	+1.00	+1.00	-3.00		+3.00		NM	NM	NM
1986Q3					-8.00			NM	NM	NM
1987Q1	+3.00	+2.00				+3.00		NM	NM	NM
1990Q1							-3.86		NM	NM
1992Q3	+3.50	+3.50	+3.50	+3.50	+3.50	+3.50	-3.50	+3.50	+3.50	+3.50
1992Q3								-5.00	NM	
1993Q1					-10.00				NM	
1993Q2								-8.00	NM	-6.50
1995Q1								-7.00		-3.50
Entry										
Date	1979Q1	1979Q1	1979Q1	1979Q1	1979Q1	1979Q1	1979Q1	1989Q1	1990Q1	1992Q1
Band	±2.25	± 2.25	±2.25	±2.25	±2.25	±2.25	±6.00	±6.00	±6.00	±6.00

Notes: All realignment values are percentage changes of the currency's bilateral central rate against those currencies who bilateral parities were not realigned. Th entry exchange rate band is in percentages. "NM" stands for non-member. Source: Bofinger (2000).

Table A.4. Country summary statistics

Country	GDP (billions PPP \$)	$\rho(\Delta y, \Delta y^{DEU})$	Distance	Trade/ GDP	$\sigma(\Delta \text{NER})$	$\beta(\Delta i, \Delta i^{DEU})$
Austria	130.00	0.17	319.62	0.19	0.0038	0.181
Belgium	171.00	0.24	217.77	0.24	0.0072	0.121
France	971.00	0.19	470.18	0.06	0.0131	0.155
Great Britain	918.00	0.22	505.60	0.05	0.0265	0.072
Italy	921.00	0.29	591.54	0.06	0.0211	0.620
Netherlands	253.00	0.23	173.14	0.22	0.0061	0.174
Norway	76.80	-0.08	759.93	0.08	0.0148	0.127
Portugal	98.20	0.05	1140.08	0.07	0.0227	0.228
Spain	479.00	0.13	982.60	0.04	0.0251	-0.109
Sweden	154.00	-0.05	791.83	0.08	0.0218	0.066
Switzerland	152.00	0.08	279.68	0.15	0.0160	-0.025

Notes: The GDP and Trade/GDP values are calculated by averaging annual series over 1973Q1-1998Q4. The trade variable is the total value of bilateral trade between the country and Germany. The output growth correlation measure, $\rho(\Delta y, \Delta y^{DEU})$, is calculated by first deseasonalizing output growth for each country and Germany (DEU), and then calculating the correlation over 1973Q1-1998Q4. The exchange rate volatility measure, σ(NER), is calculated by taking the standard deviation of the change of end-of-month log nominal exchange rate viz. Germany over 1974Q1-1998Q4. Note that the last four columns are the variables used for the four pooled specifications of regressions in Tables 1, 3-5.

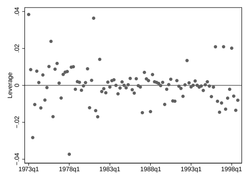


(a) Austria (b) Belgium (c) France (d) Great Britain

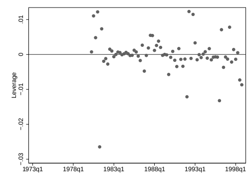
(e) Italy (f) Netherlands (g) Norway (h) Portugal

(i) Spain (j) Sweden (k) Switzerland

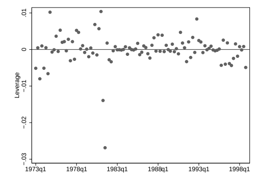
Figure A.1. Leverage plots for OLS estimates (no lags)



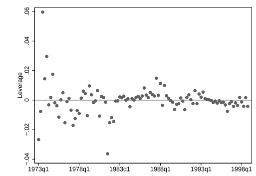
(a) Austria



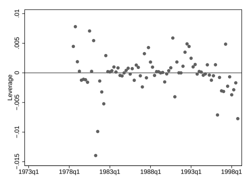
(b) Belgium



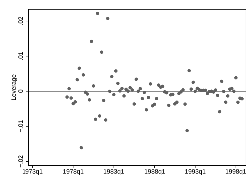
(c) France



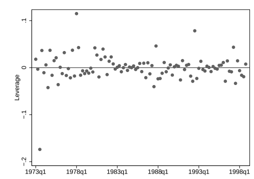
(d) Great Britain



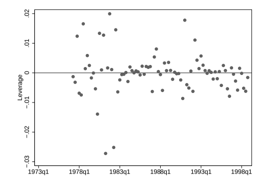
(e) Italy



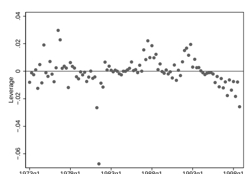
(f) Netherlands



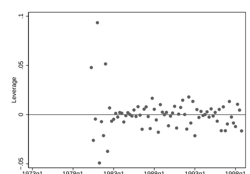
(g) Norway



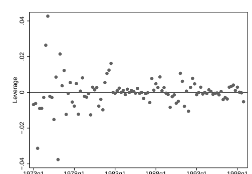
(h) Portugal



(i) Spain



(j) Sweden



(k) Switzerland

Figure A.2. Leverage plots for IV estimates (no lags)