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Comparing Monetary Policy Reaction Functions: ECB versus Bundesbank

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Abstract

This paper compares the ECB's conduct of monetary policy with that of the Bundesbank. Estimated monetary policy reaction functions for the Bundesbank (1979:4-1998:12) and the European Central Bank (1999:1-2004:5) show that, while the ECB and the Bundesbank react similarly to expected inflation, the ECB reacts significantly stronger to the output gap. Theoretical considerations suggest that this stronger response to the output gap may rather be due to a higher interest rate sensitivity of the German output gap than to a higher weight given to output stabilisation by the ECB. Counterfactual simulations based on the estimated interest rate reaction functions suggest that German interest rates would not have been lower under a hypothetical Bundesbank regime after 1999. However, this conclusion crucially depends on the assumption of an unchanged long-run real interest rate for the EMU period. Adjusting the Bundesbank reaction function for the lower long-run real interest rate estimated for the ECB regime reverses this conclusion.

JEL: E5
Keywords: Taylor rule, monetary policy, ECB, Bundesbank

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I. Introduction

In January 1999, the European Central Bank (ECB) took over control of monetary policy in Europe from the Deutsche Bundesbank, the de-facto leading monetary authority in the European Monetary System. In the Maastricht Treaty, the ECB was given an institutional design which was very similar to that of the Bundesbank, with institutional independence and the overriding objective of price stability as central characteristics. Since the Bundesbank had one of the best track records among European central banks in achieving low and stable inflation rates, trying to transfer the Bundesbank's anti-inflation reputation to the ECB by using a similar institutional framework was regarded a necessary precondition to ensure price stability oriented monetary policy in the new euro area. However, after five years of operation, the evaluation of the ECB's inflation record by external observers is not unanimously positive. For instance, Gali et al. (2004) show that under Wim Duisenberg's term of office the annual rate of change in the euro area harmonised index of consumer prices (HICP) has been more often above the 2 % upper bound of the ECB's inflation objective than below. They conclude that the ECB has not managed to meet its inflation objective and that euro area headline inflation "…appears to be adrift due to inattentive policy."

On the other hand, the first years of EMU were accompanied by a pronounced weakness in economic activity in the euro area as a whole and in Germany in particular. In the first four years of EMU, annual real GDP growth was on average around 1.8 % in the euro area, compared to a mere 1.1 % in Germany, which was the lowest real growth rate of all euro area countries. At the same time, annual harmonised consumer price inflation averaged 2.0 % in the euro area and, again bottom-of-the-table in the euro area, 1.3 % in Germany. Since all countries face the same short-term nominal interest rate set by the ECB, this implies that, despite its weaker growth performance, Germany experienced higher real interest rates than the euro area average. This observation has lead some observers to argue that the ECB's monetary policy is inadequate for the needs of the German economy and contributes to the German economic slump by delivering interest rates which are too high for Germany under the current circumstances.[1]

Whether the ECB's monetary policy is sufficiently anti-inflationary in order to preserve the anti-inflation reputation inherited from the Bundesbank and whether the new monetary regime contributes to the German economic malaise by delivering inappropriate real interest rate levels are questions of major economic and political importance. In order to address both

[1] See, for instance, "The Neglected Economy", *The Economist*, 16 September 2002 or Steve Liesman, *Wall Street Journal*, 17 November 2002.

questions a benchmark is needed against which to compare the ECB's conduct of monetary policy. A natural benchmark is the monetary policy regime represented by the Bundesbank's conduct of monetary policy prior to EMU. One could hardly argue that the ECB responds too soft to euro area inflation if a comparison would show that the reaction of the Bundesbank to German inflation was not significantly stronger. By the same token, one could hardly make the case that the ECB contributes to the weakness of the German economy if the Bundesbank would not have delivered lower interest rates.

In the present study, we attempt to answer these questions by estimating and comparing the monetary policy reaction functions of the ECB and the Bundesbank. Based on the estimated Taylor rules we test whether the ECB's interest rate setting differs from that of the Bundesbank in the past. In particular, we assess whether the ECB's monetary policy reaction to inflation is sufficient to stabilise the inflation rate in the euro area and whether the ECB's reaction to inflation and output differs significantly from the former Bundesbank interest rate rule. We then try to interpret our findings based on a simple theoretical framework. Employing counterfactual out-of sample simulations, we subsequently compare the interest rate path the Bundesbank would have delivered if it had still been in control of German monetary policy with the one actually set by the ECB. This allows us to address the second question, namely whether nominal interest rates in Germany would have been lower under a hypothetical continuation of the Bundesbank regime.

The plan of the paper is as follows. Section 2 discusses the empirical set up, the econometric methodology, and the data base. Section 3 presents the empirical results and discusses the economic implications of the empirical findings. In section 4 we compare interest rate setting by the ECB with that under a hypothetical Bundesbank regime over the EMU period and section 5 concludes.

2. Empirical Set up, Econometric Methodology and Data Base

In recent years, virtually all central banks in the industrialised countries have conducted monetary policy through market-orientated instruments designed to influence short-term interest rates (Borio 1997). Since the seminal contribution of Taylor (1993), it has become common to describe interest rate setting in terms of a monetary policy reaction function, where the short-term nominal interest rate, representing the central bank's monetary policy instrument, responds to deviations of inflation and output from their targets. There are now quite a number of studies which estimate such a reaction function for the euro area (Gerlach and Schnabel 2000, Mihov 2001, Doménech et al. 2002, Gerdesmeier and Roffia 2003, Clausen and Hayo 2005). All of these studies utilise synthetic aggregate data on macroeconomic variables and span a sample period going back at least to the mid-1980s. This approach could be defended by pointing out that there is not much evidence that the national aggregate demand and supply functions in the euro area member countries did exhibit a pronounced structural break as a result of forming EMU (Mihov 2001, Clausen and Hayo 2005). This does not imply, however, that averaging the behaviour of national central banks in the past gives a good account of how interest rates under the new monetary regime react to output and inflation. Before EMU, monetary policy was effectively conducted by the Deutsche Bundesbank and the ECB is, after all, a new institution with new rules and responsibilities. Now that five years have passed since the start of EMU, enough observations on the actual performance of the euro area have become available to perform a first assessment of the ECB's conduct of monetary policy using an empirically estimated Taylor rule.

In order to address the two questions raised above we estimate Taylor rules for the ECB and the Bundesbank. For Germany, we use monthly data from the formation of the EMS onwards (1979:4 – 1998:12), explicitly taking into account potential changes in the Bundesbank's conduct of monetary policy after German unification (1990:8 – 1998:12). For the ECB, data from 1999:1 to 2004:5 is employed. This is a rather short-sample period, so that the estimation results should not be over-interpreted. But the sample period covers 65 observations, which is sufficient for time series analyses. It is also important to note that the sample period includes an economic upswing (1999-mid 2001) and an economic downturn (end 2001-2003), so that the estimation results should not be extremely affected by potential asymmetries in monetary reaction with regard to e.g. the state of the business cycle.[2]

In the estimations of the Taylor rules, we adopt the industry standard specification first proposed by Clarida et al. (1998), which has been commonly applied in subsequent research on Taylor rules. The central bank's target level for short-term nominal interest rates is modelled as a function of the deviation of current output from its trend (y_t) and of the expected deviation of one year ahead inflation (π_{t+12}) from its (constant) target (π^*): $i^T_t = r^*+\pi^*+ \beta (\pi_{t+12} -\pi^*)+\gamma y_t$, where r* is the long-run real interest rate level.[3] $r^*+\pi^*$ constitute the long-run level of the nominal interest rate, when inflation is equal to its long-run target level and the output gap is zero. Finally, we allow for interest rate smoothing by including a

[2] The sample period is, however, too short to test for the significance of such potential asymmetries.

[3] As we will show in our discussion further below, such a Taylor rule is the optimal interest rate rule in a simple backward looking model of the economy proposed by Svensson (1997) and Ball (1999).

lagged interest rate term in the Taylor rule specification.[4] The path of actual short-term nominal interest rates is then modelled as a weighted average of the lagged interest rate and the target interest rate: $i_t = \rho\ i_{t-1} + (1-\rho)\ i^T_t$. Given these considerations, we estimate the following Taylor rule:

(1) $i_t = \rho\ i_{t-1} + (1-\rho)\ \alpha + (1-\rho)\ \beta\ \pi_{t+12} + (1-\rho)\ \gamma\ y_t + \varepsilon_t$,

with: i = nominal short-term interest rate, π = inflation rate, y = output gap, ρ = degree of interest rates smoothing, α = constant of the target interest rate, β = inflation weight in the target interest rate, γ = output weight in the target interest rate, ε = error term.

Thus, the presence of interest rate smoothing implies that there is partial adjustment of nominal interest rates to their target level, with a fraction of $1-\rho$ of the difference between the target rate and last period's rate being eliminated each period. The constant of the target interest rate is given by $\alpha = r^* + (1-\beta)\ \pi^*$.

The data utilised in the estimation are: Day-to-day money market rate for the interest rate, seasonally adjusted industrial production for output and annualised rate of change in the seasonally adjusted CPI for inflation. Data sources are IFS for Germany and the ECB web site for the euro area. Following Clarida et al. (1998) the output gap has been constructed by taking the residuals of a regression of the industrial production series on a constant, a linear trend and a quadratic trend. [5]

A major problem when working with forward-looking and contemporaneous variables is that they may be correlated with the error term, leading to biased estimates of the coefficients of interest. Therefore, these variables must be instrumented. In addition, the error term may experience non-normality, autocorrelation and heteroscedasticity, causing problems with respect to statistical inference. It is now common to use the General Method of Moments (GMM) estimator, as it accounts for endogeneity biases as well as non-spherical errors. The GMM estimator possesses excellent asymptotic properties, but may perform poorly in small samples (see the special issue of the *Journal of Economics and Business Statistics* 1996). Traditional instrumental variable methods, such as two-stage least squares and variants, are also problematic in the case of finite samples (Nelson and Startz 1990); they are special cases

[4] Recent evidence shows that the explicit modelling of a lagged interest rate term is preferable to an autoregressive errors specification (Castelnuovo 2003).

of the GMM estimator (Hayashi 2000). However, as restricted estimators the traditional instrumental variable methods are more efficient and it appears likely that they outperform unrestricted GMM as long as their assumptions are fulfilled. In small samples like the present ones, efficiency is of particular importance, and it seems to be advisable to rely on a traditional instrumental variable estimator whenever possible.

Another general estimation problem is the choice of instruments. In time-series econometrics, it is easy to find instruments that fulfil the orthogonality conditions between regressors and error term. Typically, this assumption is investigated using a test of the validity of over-identifying restrictions when there are more instruments than estimated coefficients (Davidson and McKinnon 1993). [6] Recent research shows that the use of weak instruments, i.e. instruments that do not contribute much to explaining the instrumented variable, can lead to substantial biases in both estimators and test statistics even in large samples (Hahn and Hausman 2003, Stock et al. 2002). Stock and Yogo (2003) propose a test of weak instruments based on the F-test value of the first stage regression in a two-stage least squares procedure. This test does not, however, solve the question of how to choose *specific* instruments, for example, which lags of a variable.

We address the instrument selection problem in a novel way by applying a recently developed automatic model selection algorithm called GETS (see Hendry and Krolzig 1999). GETS starts from a general model and removes redundant instruments. While doing so, it searches all possible paths of the testing-down process and reports the most parsimonious model that does not violate a reduction test. Thus, the strongest instruments will be selected from a given choice of variables and their lags. This does not remove all arbitrariness, as, for instance, the researcher still needs to choose the potential instrumental variables and their maximum lag length, but it appears to be superior to the ad hoc methods typically employed in empirical research.

3. Empirical Estimation of ECB and Bundesbank Monetary Reaction Functions

Starting with the *Bundesbank*, instruments are being selected using the GETS reduction algorithm at a nominal 5% significance level based on a general model containing six lags of the potential instruments interest rate, inflation rate, rate of change of the effective real exchange rate, output gap, rate of change of the world oil price in DM, and monthly growth

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[5] Alternative detrending methods such as a Hodrick-Prescott or a bandpass filter yield qualitatively similar results.

[6] It should be noted that the test of over-identifying restrictions in fact tests the joint hypotheses that the instruments are orthogonal to the error term *and* the estimated model is correctly specified.

rate of the money aggregate M3.[7] The Stock and Yogo (2003) test shows no indication of problems with regard to biases in the estimators. It is possible to reject the null hypothesis that the nominally sized test statistics at 5% significance level exceed an actual level of 15%.[8] Employing these instruments in Two-Stage least squares (2SLS) estimation leads to residuals that exhibit severe problems of non-normality, autocorrelation and heteroscedasticity. Since at least the non-normality problems are not easily corrected, we choose GMM as the more robust estimation technique. The hypothesis that the instruments are orthogonal to the error terms cannot be rejected at a level of 5%.

An important event in recent German history is reunification, with German Monetary Union (GMU) on 1 July 1990. We split our sample at that date in order to see whether it has had a noticeable impact on the Bundesbank's reaction function (see Table 1).[9] The fit of both equations is high and all variables are significantly different from zero at a 1 % level. However, the explanatory power of the equation is primarily due to the lagged interest rate variable, and thus does not provide much evidence regarding the adequacy of the estimated Taylor rules. A comparison of the two columns referring to the Bundesbank shows that the estimates are very similar. The lagged interest rate has exactly the same coefficient and the inflation coefficients are very close. Some differences are found for the output gap coefficients, which are not statistically significant when taking into account the estimation uncertainty surrounding both coefficients.

A general result of the theoretical literature on policy rules (e.g. Clarida et al. 2000) is that stabilising inflation around its target level requires that real interest rates rise in response to a rise in expected inflation. In other words, the inflation coefficient in the Taylor rule must be larger than one. [10] For the post-GMU sample, the inflation coefficient is above one, but only significantly so at the 10 % level. This implies that - in view of the extent of estimation uncertainty - the requirement for a policy that stabilises the inflation rate is met only marginally. Testing for the equality of the weights on output and inflation we find that the

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[7] The resulting instrument set is: interest rate (lags: 1, 2, 3), inflation (lags: 6), growth rate of the effective real exchange rate (lags: 1, 4), output gap (lags: 1, 2, 3, 6), the growth rate of the oil price index in DM (lags: 1, 6), and the monthly growth rate of the money aggregate M3 (lags: 2).

[8] In contrast, there is evidence that the Clarida et al (1998) specification suffers from problems with weak instruments. In their basic specification, Clarida et al. (1998) use 48 instruments (p. 1045, Table 1). In the first-stage regression for the inflation rate the Stock and Yogo-test can barely reject the hypothesis of a bias of 10% of the OLS bias and cannot reject the Null that the nominally sized test statistics of a 5% level does not exceed a level of 15%.

[9] One could estimate a Taylor rule from 1979:4 to 2003:7 using German data and then test for a break in 1999:1. This would not take into account, however, that the ECB uses aggregate European variables in its rule.

[10] The requirement of a more than proportional response of the nominal interest rate to the inflation rate in order to deliver an increase in the real interest rate that ultimately stabilises the rise in inflation is referred to as the Taylor principle.

interest rate response to the output gap is significantly smaller than the response to expected inflation. Comparing our reaction coefficients to the ones Clarida et al. (1998) obtained for the period 1979:4 to 1993:12 shows only slight differences (β =1.31, γ = 0.25). However, estimating the Clarida et al. baseline model for the post-GMU period gives a coefficient of 0.74 for the inflation weight and 0.48 for the output gap. The drop of the coefficient on inflation below one may be an indication of a weak instrument problem in their specification.

Table 1: Estimates of reaction functions for the Bundesbank and the ECB

Variables	Bundesbank 79:4-90:6	Bundesbank 90:8-98:12	ECB 99:1-03:5
Interest rate$_{t-1}$ (ρ)	0.92**	0.92**	0.85**
	(0.018)	(0.015)	(0.047)
Inflation$_{t+12}$ (β)	1.21**	1.25**	1.48(*)
	(0.244)	(0.162)	(0.786)
Output gap$_t$ (γ)	0.43**	0.32**	0.60**
	(0.137)	(0.045)	(0.098)
Constant (α)	3.64**	2.56**	0.32
	(0.670)	(0.353)	(1.772)
No. of observations	135	101	53
σ	0.372	0.154	0.157
R^2	0.976	0.996	0.964
Over-identifying restrictions test	$Chi^2(13) = 8.53$	$Chi^2(13) = 8.25$	$Chi^2(14) = 23.3$

Notes: (*), *, and ** indicate significance at a 10%, 5%, and 1% level, respectively. Bundesbank estimates based on GMM. ECB estimates based on the two-stage least squares procedure. Standard errors for coefficient estimates are computed using the procedure by Newey and West (1987). The R^2 is based on the short-run dynamic model. Diagnostic tests for the instrumental variable estimation of the ECB reaction function: Jarque-Bera normality test: $Chi^2(2) = 0.11$, LM autocorrelation test: $Chi^2(2) = 0.97$, ARCH test: $Chi^2(1) = 0.62$, White-heteroscedasticity test with cross-products: $Chi^2(9) = 24.4$**, RESET(1) test: F(1, 47) = 0.92.

For the *ECB reaction function*, the sample period is January 1999 till May 2004.[11] Again we select instruments based on the GETS algorithm, starting with six lags of the interest rate, the inflation rate, the rate of change of the effective real exchange rate, the output gap, the rate of change in the world oil price in euro, and the monthly growth rate of the money aggregate M3MA.[12] Applying the Stock and Yogo (2003) test, we can reject the hypotheses that the

[11] Given that we employ a one-year ahead inflation rate, the actual estimation period ends in May 2003.

[12] The resulting instrument set is: interest rate (lags: 1,3), inflation (lags: 3,6), rate of change of the effective real exchange rate (lags: 1), output gap (lags: 4,5), the growth rate of the oil price index in EUR (lags: 1,3,6), and the monthly growth rate of the money aggregate M3MA (lags: 1,2,4,5,6).

biases in the estimators are larger than 10% and that the nominally sized test statistics at 5% exceed an actual level of 20%. As before, the hypothesis that the instruments are orthogonal to the error terms cannot be rejected. This time we find there are few problems with employing 2SLS . In the notes below Table 1, a battery of diagnostic tests are listed that show no violation of model assumptions except for evidence of heteroscedasticity. To avoid invalid inference, we employ, as in our estimates for Germany, robust standard errors.[13]

Regarding the actual estimates, we find that all estimates in the dynamic model, except for the constant term, are significantly different from zero at a 5 % level. This also applies to the long-run coefficients displayed in Table 1, except for the inflation rate, which is only significant at the 10% level (p-value: 0.066). The point estimate of the inflation coefficient in the ECB Taylor rule is 1.48 and therefore above one. However, statistically we cannot reject the hypothesis that it is equal to one ($F(1,49) = 0.55$). On the other hand, the inflation coefficient in the ECB Taylor rule is also not significantly different from the inflation coefficient in the Bundesbank Taylor rule. Thus, the evidence neither supports the view that the ECB responds sufficiently aggressive to expected inflation in order to stabilise the inflation rate around its target value, nor that it responds less forceful than the Bundesbank did. Regarding the monetary policy reaction to the output gap, it is noteworthy that the output reaction coefficient estimated for the ECB is more than twice as large as the one found for the Bundesbank. Even when taking the estimation uncertainty of both estimates into account, the difference between the two output gap reaction coefficients has a t-statistic of 2.62 and is thus significant at the 1% level.

As a robustness test of the results obtained from the industry standard specification of the Taylor rule with a forecast horizon for the inflation rate of one year we additionally estimate Taylor rules with forecast horizons of 9, 6, and 3 months, respectively. We derive new instrument sets along the lines described above and re-estimate equation (1). To economise on space, Table 2 contains the coefficient estimates for the inflation rate and the output gap only (all omitted information is available upon request).

For the pre-unification period, the point estimates for the Bundesbank's weight on the inflation rate are always significantly different from zero but below unity. Testing against the inflation coefficient taken for the one-year horizon in Table 1 neglecting that it is an estimated parameter, we can reject that the estimates in Table 2 are equal. However, none of these differences are significant when taking the estimation uncertainty of the model with the one-year-ahead inflation rate into account. Regarding the output gap estimates in Table 2 for the

[13] Normal standard errors are: ρ (0.038), β (0.782), γ (0.127), and α (1.72).

different inflation rate forecast horizons, we get again results that are significantly different from zero. Except for the three months inflation forecast horizon, these estimates are also significantly different from the estimates in Table 1. As before, after taking estimation uncertainty of the estimates from Table 1 into account, we can no longer reject equality.

Table 2: Varying inflation forecast horizons (β = inflation weight, γ = output gap weight)

	β^{G79-90}	β^{G90-98}	β^{ECB}	γ^{G79-90}	γ^{G90-98}	γ^{ECB}
9 months ahead	0.90**◊	1.22**	0.90	0.23**◊	0.37**	0.56**
6 months ahead	0.99**◊	1.11**	-0.05◊	0.25**◊	0.66**	0.71**
3 months ahead	0.84**◊	3.59	-0.65◊	0.36**	0.01	0.87**

Notes: * (**) indicates significance at a 5% (1%) level. ◊ indicates a significant difference to the point estimate for the model with the one-year-ahead inflation rate at a 5% level of lower.
Instrument sets for *ECB estimates: 9 months ahead*: interest rate (lags: 1), inflation (lag: 1,3,4,6), growth rate of the effective real exchange rate (lags: 4), output gap (lags: 1,2,4,5,6), the growth rate of the oil price index in EUR (lags: 3,4,6), and the monthly growth rate of the money aggregate M3MA (lag: 2,3,4,5,6); *6 months ahead*: interest rate (lags: 1), inflation (lag: 3,5), growth rate of the effective real exchange rate (lags: 1,3), output gap (lags: 1,4,5), the growth rate of the oil price index in EUR (lags: 3,6), and the monthly growth rate of the money aggregate M3MA (lag: 2,3,4,5,6)*; 3 months ahead*: interest rate (lags: 1), inflation (lag: 3,6), output gap (lags: 2,4,5), the growth rate of the oil price index in EUR (lags: 6), and the monthly growth rate of the money aggregate M3MA (lag: 2,4,5,6).
Instrument sets for the *Bundesbank estimates*: *9 months ahead*: interest rate (lags: 1,2,3), inflation (lag: 1,3,6), growth rate of the effective real exchange rate (lags: 1,2,4), output gap (lags: 1,2,3,6), the growth rate of the oil price index in EUR (lags: 1,2,3), and the monthly growth rate of the money aggregate M3MA (lag: 1,2,3,4); *6 months ahead*: interest rate (lags: 1,2,3,5), inflation (lag: 1,3), growth rate of the effective real exchange rate (lags: 1,3,4), output gap (lags: 1,2,3,6), the growth rate of the oil price index in EUR (lags: 1,3,5), and the monthly growth rate of the money aggregate M3MA (lag: 1,2,3,4,5)*; 3 months ahead*: interest rate (lags: 1,2,3,6), inflation (lag: 1,6), growth rate of the effective real exchange rate (lags: 1,4), output gap (lags: 1,2,3), the growth rate of the oil price index in EUR (lags: 1,6), and the monthly growth rate of the money aggregate M3MA (lag: 3,4,5,6).

Looking at the post-unification period, even when ignoring estimation uncertainty in the baseline estimation, the inflation reaction coefficient estimates in Table 2 are no longer significantly different from the ones for the one-year horizon. The same conclusion holds true for the output gap reaction coefficients.

For the ECB, none of the estimates for the inflation coefficients are significantly different from zero. The decrease of the inflation weight in the Taylor rule when reducing the forecast horizon is accompanied by an increase in the estimated output gap weight. None of the estimates for the ECB in Table 2 are significantly different from the point estimates in Table 1.

Thus, as in most alternative specifications the Taylor principle is violated, we conclude that the original specification is preferred by the data as it yields more plausible results from an economic point of view. Especially the results for the three and six months horizon obtained for the ECB Taylor rule are rather implausible. In our view, these results suggest that both, the ECB and the Bundesbank have been aware that it would make no sense to target inflation three or six months ahead if the empirical transmission lag of monetary policy is longer. The empirical evidence on monetary transmission suggests that the transmission lag of monetary policy is about one year for output and about two years for prices.[14] As we will show in the following, the industry standard specification of the Taylor rule with an inflation forecasting horizon of one year is the optimal Taylor rule for a simple structural model which assumes exactly this transmission lag for monetary policy.

Concentrating on the estimates from Table 1, the main findings are 1) that the ECB and the Bundesbank appear to respond in a very similar way to expected inflation and 2) that the ECB appears to respond significantly stronger to the output gap than the Bundesbank did. As we have already pointed out below, an inevitable caveat to our analysis is that the estimate of the ECB reaction function is based on a rather short-sample period covering only five years of data. Nevertheless, the difference between the two output gap reaction coefficients is significant at the 1% level. Does this finding imply that the ECB gives a significantly higher weight to output stabilisation than the Bundesbank did? In order to address this question, we need to know how the Taylor rule reaction coefficients depend on the preference parameters of the central bank and on the structural parameters of the economy. Favero and Rovelli (2003) and Castelnuovo and Surico (2003) identify the preference parameters of the US Federal Reserve Bank by estimating jointly a small structural model of the US economy and a Taylor rule using quarterly data. Prior to the empirical estimation, they determine the functional form of the Taylor rule by calculating the optimal rule based on the estimated dynamic structure of the economy. By using the model-specific optimal rule, they impose theoretically motivated restrictions on the Taylor rule coefficients which enables them to identify the preference parameters of the central bank.

Instead of considering an optimising Taylor rule in connection with a structural model, we have estimated a standard, but ad hoc formulation of the monetary policy reaction function.[15] Since we do not identify the structure of the economy, we can not know in general how the Taylor rule parameters depend on preference and structural parameters. It turns out, however, that our monetary policy reaction function represents the optimal specification of the Taylor rule for a fairly standard and commonly used small structural model of the economy

[14] See Peersman and Smets (2003), Peersman (2004), Hofmann (2004), and Clausen and Hayo (2005).

[15] While it would in principle be possible to follow the approach by Favero and Rovelli (2003) and Castelnuovo and Surico (2003) by estimating a structural model of the euro area economy and a Taylor rule corresponding to the estimated structural model, the ECB regime is still too young to estimate these equations with quarterly data. Such an exercise would only be feasible by extending the sample size through the use of synthetic euro area data. However, drawing inferences about the ECB's preferences based on pre-EMU observations, a period where monetary policy in Europe was largely shaped by the Bundesbank, would not be appropriate.

proposed by Svensson (1997).[16] In this model, the economy is described by two equations, an aggregate supply and an aggregate demand function:

$$(2)\quad \pi_{t+1} = \pi_t + \alpha_1 y_t + \varepsilon_{t+1}$$

$$(3)\quad y_{t+1} = \beta_1 y_t - \beta_2 (i_t - \pi_{t+1|t}) + \eta_{t+1},$$

where $\pi_{t+1|t}$ denotes the expectation of π_{t+1} in period t. The dynamic structure of the model applies to annual data (Svensson, 1997). The intertemporal loss function of the central bank is given by

$$(4)\quad L = E_t \sum_{\tau=t}^{\infty} \delta^{\tau-t} \frac{1}{2}\left[(\pi_t - \pi^*)^2 + \lambda y_t^2\right],$$

where δ is the central banks' discount factor, π^* is its inflation target and λ is the relative weight the central bank puts on output stabilisation. The central bank minimises its loss function by optimally adjusting its monetary policy instrument, the short-term nominal interest rate. The resulting optimal Taylor rule is given by[17]

$$(5)\quad \begin{aligned} i_t &= \pi_{t+1|t} + \frac{1}{\beta_2}\left[1 - \frac{\delta\alpha_1^2 k}{\lambda + \delta\alpha_1^2 k}\right](\pi_{t+1|t} - \pi^*) + \frac{\alpha_1\beta_1}{\beta_2} y_t, \\ k &= \frac{1}{2}\left(1 - \frac{\lambda(1-\delta)}{\delta\alpha_1^2} + \sqrt{\left(1 + \frac{\lambda(1-\delta)}{\delta\alpha_1^2}\right)^2 + \frac{4\lambda}{\alpha_1^2}}\right) \end{aligned}$$

Equation (5) suggests that the optimal Taylor rule for the simple structural model proposed by Svensson (1997) has the same functional form as the ad hoc Taylor rule presented in equation (1). As we cannot rule out a situation of observational equivalence, this does not mean that the ad hoc Taylor rule directly implies a structural model of this form. It shows, however, that the ad hoc specification of the Taylor rule appears to be based on similar assumptions about the time lags of monetary transmission as the Svensson model. The output gap coefficient in equation (5) solely depends on the structural parameters of the economy and

[16] A very similar model has been proposed by Ball (1999).

not on the preference parameters of the central bank. The relative weight of the output gap in the central banks loss function only affects the inflation reaction coefficient. The bigger the weight on the output gap, the less aggressive the central bank responds to an increase in expected inflation.[18] Thus, the ECB's significantly stronger response to output deviations compared to the Bundesbank's may rather be a reflection of the dissimilarities between the euro area economy and the German economy than of different preferences about price stability and output stabilisation.

The output gap coefficient in equation (5) depends positively on the responsiveness of the inflation rate to the output gap (α_1), positively on the persistence of the output gap (β_1) and negatively on the responsiveness of the output gap to the interest rate (β_2). In this framework, the stronger reaction of the ECB to the output gap may be due to more flexible prices (higher α_1), higher persistence in the output gap (higher β_1) or weaker transmission of monetary policy (lower β_2) in the euro area compared to Germany. Let us consider these possibilities in turn. Evidence from empirical Phillips Curves reported in Benigno and Lopez-Salido (2002) and Clausen and Hayo (2002) suggests that prices react more strongly to capacity utilisation in Germany than in many other euro area countries. Hence, this channel does not provide an explanation for the ECB's relatively stronger response to the output gap.

Next, we analyse the possibility that the persistence of the output gap differs between Germany and the euro area. We estimate the persistence of the output gap for Germany after reunification as an AR(1) model. The resulting coefficient is 0.94. Estimating the same type of model for the euro area using the sample period in Table 1, we obtain a coefficient of 0.83. Thus, the persistence of the output gap in Germany seems to be higher. Testing the difference in the AR(1) parameters assuming independent samples yields a t-statistic of 1.39. Thus, at a 10% level of significance, these estimates are statistically indistinguishable. Note that the lagged output gap coefficient in equation (3) is conditional on the interest rate effect and estimating within an AR-model may lead to biased estimates. However, including the real interest rate in the equation does not change the outcome in a noteworthy way. To conclude, the persistence of the output gap is equal or higher in Germany than it is for the euro area. It therefore cannot explain the stronger output reaction of the ECB.

Finally, let us consider the possibility of differences in monetary policy transmission as an explanation. The available empirical evidence indicates that German output reacts rather

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[17] A detailed derivation of the equation can be found in Svensson (1997).

more strongly to monetary policy changes than the euro area average (Clausen and Hayo 2002, Peersman 2004, Hofmann, 2004). Thus, from the perspective of the Svensson model, the significant differences in output gap coefficients between the ECB and the Bundesbank monetary policy reaction functions can only be explained by a relatively higher interest rate elasticity of the German economy.

4. Comparing Counterfactual Interest Rate Paths

This section addresses the second question raised above, namely whether interest rates in Germany would have been lower since the start of EMU if the Bundesbank regime had still been in place. As a first step, we compare the ECB target interest rates for the euro area with hypothetical target rates for the Bundesbank based on German inflation and output gap values. There is, however, a problem with computing the counterfactual interest rate series for the Bundesbank. The estimate of the constant of the constant of the target interest rate α is substantially higher for the Bundesbank Taylor rule than for the ECB Taylor rule. As we have already shown below, the constant in the target Taylor rule is defined as $\alpha = r^* + (1-\beta)\,\pi^*$. Thus, the implied long-run real interest rate r^* can be recovered by taking the estimate of the constant α and of the inflation reaction coefficient β and by making an assumption about the central bank's target inflation rate π^*. Assuming an inflation goal of 2%, the implied long-run real interest rate recovered from the Bundesbank Taylor rule (post-GMU) is 3.06%. If we assume the same inflation goal for the ECB, we obtain an implied long-run real interest of only 1.28%. Because of the large standard error of α in the ECB Taylor rule, this implied real interest rate is also very imprecisely measured.

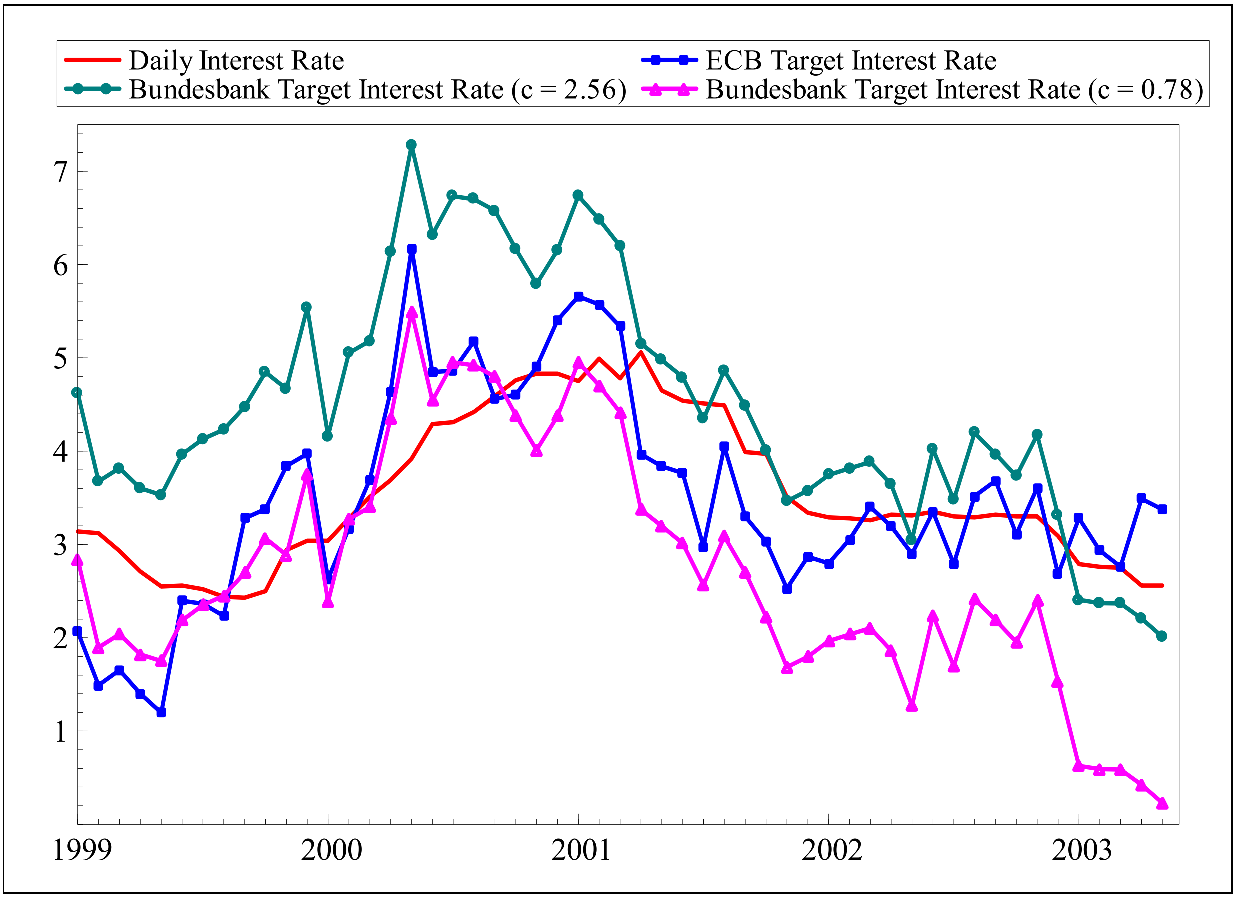
This difference in implied real interest rates between the two regimes may reflect lower real interest rates under the EMU regime due to the process of fiscal consolidation in the 1990s, but probably also due to lower levels of potential real growth, especially in Germany. Thus, the constant α may also have been lower under a hypothetical post-1999 Bundesbank regime. On the other hand, the implied real interest rate in the ECB Taylor rule is very imprecisely measured and it is well known that in general estimates of the regression constant should not be over-interpreted as their main purpose is to anchor the regression line. For these reasons it seems advisable to do two types of simulation exercises for the Bundesbank. The first is based on the actually estimated target interest rate. The second one uses an adjusted

[18] The intuition for this result is that a more gradual adjustment of inflation to its target level involves less output fluctuations. The higher the weight on output stabilisation, the more gradual inflation is therefore adjusted to its target level.

constant derived by taking the lower estimate of the long-run real interest rate from the ECB Taylor rule. The adjusted constant α is then given by $\alpha^{adj} = r^*_{ECB} + (1 - \beta_{BUBA})\pi^* = 0.78$.

Figure 1 plots the simulated target rates over the period 1999:1 to 2003:5, adding the monthly average of the euro area day-to-day interest rate as an indicator of the actual monetary policy stance.

Figure 1: Comparing target interest rates for Germany under a counterfactual Bundesbank regime and the actual ECB regime (in %)



Notes: The *ECB* target rates are based on actual inflation (t+12) and actual output gap (t) for the euro area. Weights: Inflation rate 1.48, output gap 0.60, constant: 0.32. The *Bundesbank* target rates are based on actual inflation (t+12) and actual output gap (t) for *Germany*. There are two series that that use the same weights: inflation rate 1.25, output gap 0.32, but different constant terms: 2.56 and 0.78.

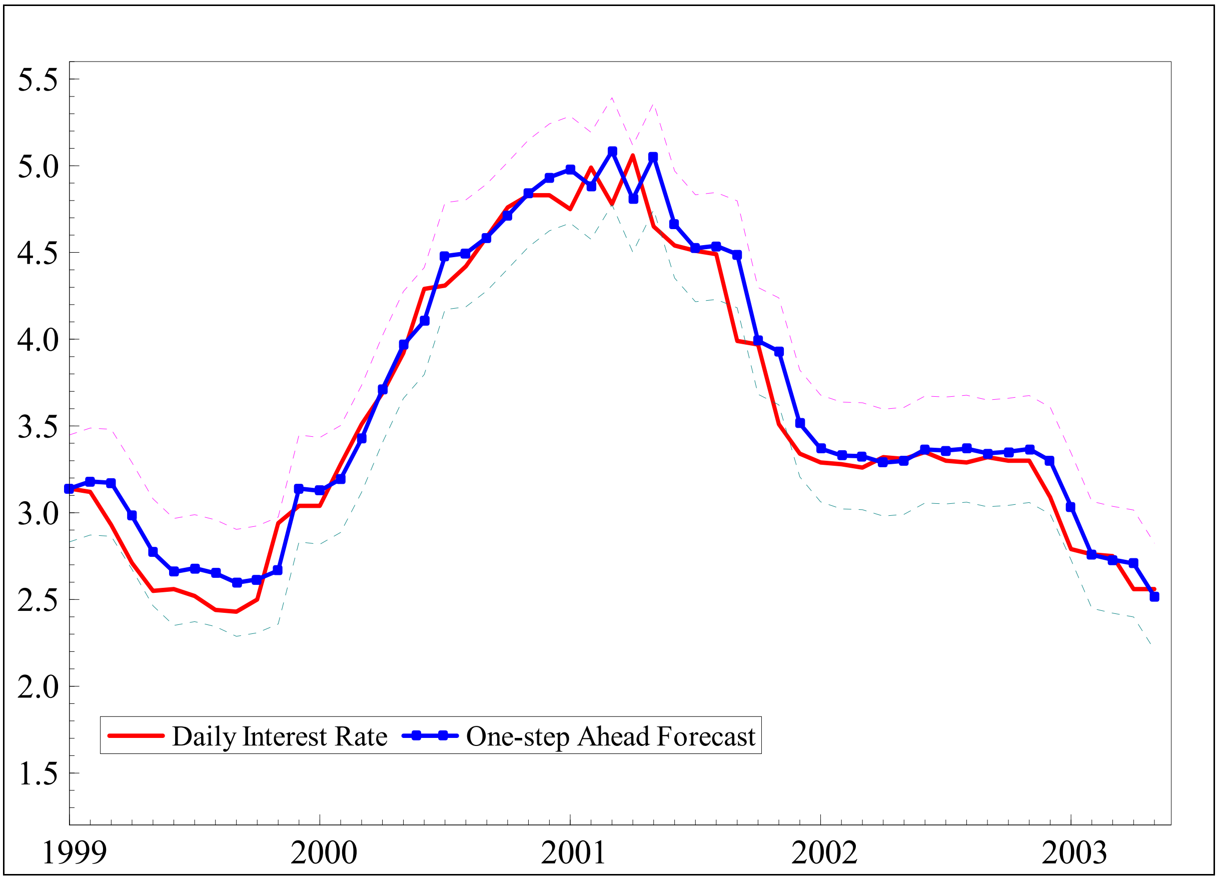
The graph shows that the counterfactual Bundesbank target rates calculated based on the actual estimates in Table 1 were about two percentage points higher than the ECB target rates in 1999/2000. From 2001 till early 2002 the Bundesbank's target rates remained above those of the ECB, but the gap between the two narrowed to about 0.5 percentage points on average. In 2002, the gap between the Bundesbank and the ECB target rates further narrowed, and in

2003 the Bundesbank target is lower than the ECB's target rate. Looking at the Bundesbank target rate calculated by assuming the same value of r* that has been estimated for the ECB, we get a completely different picture. Until late 2000 the two target rates are very similar. Since then the gap between the two constantly widens, with the ECB target rates lying about 3 percentage points above the hypothetical Bundesbank target rates in 2003.

Analysing the target rates yields interesting conclusions about the long-run implications of the central banks Taylor rules. In the short-run, however, the dynamics of short-term nominal interest rates are to a significant extent governed by interest rate smoothing, reflected by the large and highly significant estimate of the smoothing parameter for both the Bundesbank and the ECB Taylor rules in Table 1. We therefore compare the path of actual nominal interest rates in the euro area with the projected level of nominal interest rates obtained from the Bundesbank Taylor rule. The simulated rates are obtained by calculating forecasts from the Bundesbank Taylor rule as given by equation (1) based on German data. There are various forecasting exercises one can think of, such as one-step ahead forecasts or six or twelve months ahead forecasts, or a full dynamic out-of sample projection over the full forecasting period. All these forecasting exercises differ in the extent to which the forecasting errors of the past are corrected. The one-step ahead forecast takes into account only the current period's forecast error, as the actual lagged interest rate is used to calculate the forecast in each period. Forecasts over varying time horizons, such as six or twelve months ahead forecasts, reflect at each point of time the accumulated forecast errors over the given forecasting window. The dynamic out of sample projection over the full sample period indicate at each point in time the accumulated forecast errors up to that period as the forecast interest rate from the last period is used to calculate the forecast for the current period. Thus, the one-step ahead forecast and the dynamic projection represent respectively a kind of lower and upper bound for the various possible forecasting exercises with regard to the extent to which the forecast errors are accumulated. For this reason we focus on these two methods to simulate a hypothetical Bundesbank interest rate path.

Figure 2 shows the actual euro zone daily money market rate and the one-step ahead forecasts for the hypothetical Bundesbank regime. It is apparent that the two series never stray very much from one another and the 95% confidence bands are rarely crossed. Thus, based on these estimates we can conclude that it would not have made much difference whether the Bundesbank or the ECB were setting interest rates for Germany. However, for at least two reasons this conclusion may be premature. First, the exercise is biased towards finding similar series, as we use actual ECB rates as lagged interest rates. Here it may be considered more realistic to use the predicted value from last period, or, in other words, dynamic forecasts. Second, according to our Taylor rule estimates the implied real interest rate differs between the two time periods. It may therefore be appropriate to adjust the projections so that the German Taylor rule is based on the same long-run real interest rate that was estimated for the ECB regime.

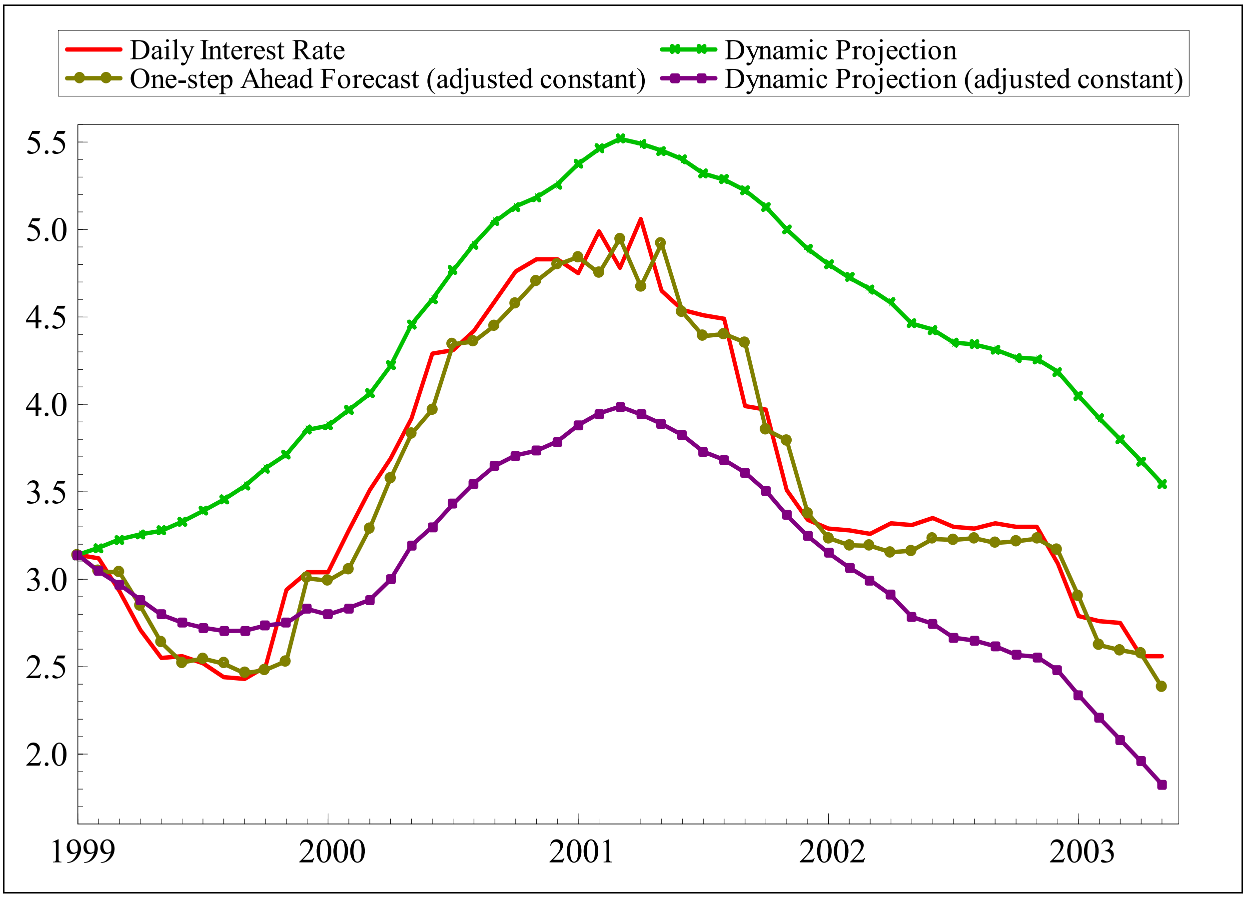
Figure 2: Comparing predicted German interest rates (one-step ahead) based on the Bundesbank Taylor-rule with actual interest rates in the Euro Area (in %)



Notes: The light dotted lines are confidence bands based on +/- 2 standard errors of the estimated dynamic reaction function for the Bundesbank over the period 1990:8-1998:12.

Reflecting these considerations, we compute the one-step ahead forecast calculated with adjusted constant, i.e. imposing the long-run implied real interest rate from the ECB Taylor rule, and the dynamic projection calculated with and without adjusted constant. Figure 3 shows that the actual euro area interest rates and the one-step ahead forecast of the Bundesbank's interest rate with adjusted constant are still very similar. Thus, the correction of the one-step ahead forecast has little effect on the results. This is not entirely surprising, as the two series differ only by the current period's forecast error. Perhaps more informative are the dynamic projections, which accumulate the forecast errors over the entire sample. The graphs reveal that the results and the implied conclusions crucially depend on whether the constant is adjusted or not. The dynamic projection constructed using the actual constant from the estimated Bundesbank Taylor rule suggests that the hypothetical interest rates set by the Bundesbank would have been clearly above the actual interest rate delivered by the ECB over the entire sample period. In contrast to this, the dynamic projection with adjusted constant suggests that the Bundesbank rates would have been below the actual ECB rates since 2000. In 2003, the counterfactual Bundesbank rates would have been about 1 percentage point lower than the actual interest rate.

Figure 3: Comparing simulated German interest rates based on the Bundesbank Taylor-rule with actual interest rates in the Euro Area (in %)



Hence, the simulation exercise does not deliver clear-cut results. If we take the estimated Bundesbank Taylor rule at face value we conclude that interest rates in Germany were not higher but probably even lower under the ECB regime than they would have been under a continuation of the former Bundesbank regime. This result appears to be mainly due to the higher estimated long-run real interest rate for the Bundesbank Taylor rule. If we impose the estimated long-run real interest rate from the ECB Taylor rule in a simulation with the Bundesbank Taylor rule the results are completely reversed. Under this scenario, we conclude that the Bundesbank rates would probably have been up to one percentage point lower than the money market rates delivered by the ECB.

5. Conclusions

This study compares monetary policy reaction functions for the Bundesbank and the ECB by estimating Taylor rules for both the Bundesbank (1979:4 – 1998:12) and the ECB (1999:1 – 2004:5) following the forward-looking specification suggested by Clarida et al. (1998). Particular care is spent on the selection of instruments and adequate estimation techniques. In particular, we put forward a novel way of instrument choice, combining the test for weak instruments suggested by Stock and Yogo (2003) with the model-selection algorithm GETS developed by Hendry and Krolzig (1999).

We find that the Bundesbank interest rate reaction function can be characterised by an inflation reaction coefficient of about 1.25 and an output gap reaction coefficient of about 0.3 before and after German reunification. For the ECB we obtain an inflation reaction coefficient of about 1.5, which is not significantly different from the Bundesbank's inflation response, and an output gap reaction coefficient of about 0.6, which is significantly higher than the corresponding coefficient for the Bundesbank. Thus, while the ECB and the Bundesbank react similarly to expected inflation, the ECB reacts much stronger to the current output gap. It is noteworthy that our estimates of the ECB Taylor rule differ somewhat from euro area Taylor rules estimated based on synthetic historical euro area data. For instance, Gerlach and Schnabel (2001) get an inflation weight of 1.51 and an output weight of 0.28, while Gerdesmeier and Roffia (2003) find an inflation weight of about 2 and an output weight of below 0.5. These differences in results may be explained by the fact that our estimates are based on observations entirely drawn from the ECB regime, while the latter studies use observations from a time when the ECB as an institution did not yet exist.

Based on our estimates, we can address two important economic policy questions: First, there are concerns that the ECB has not reacted strongly enough to deviations of the inflation rate from its target (Gali et al. 2004) and places too much weight on output stabilisation instead (Neumann 2002). Although the point estimate of the inflation coefficient in the Taylor rule is above unity, it is not statistically different from one. Taking this finding on its own implies that in response to a hike in prices real interest rates in the Euro zone may not rise sufficiently to stabilise the inflation rate. However, the ECB's reaction to inflation is also not significantly different from that of the Bundesbank, one of the most successful central banks in terms of fighting inflation.

On the other hand, we show that the ECB reacts significantly stronger to the output gap than the Bundesbank did. A stronger response of the ECB to the output gap may reflect different preferences about inflation and output stabilisation of the ECB compared to the Bundesbank, or differences in economic structure between the euro zone and Germany. Based on widely used models proposed by Svensson (1997) and Ball (1999), which imply an optimal Taylor rule of similar functional form as the specification we have followed, we show that the relatively stronger reaction of the ECB to deviations of output from trend may be attributed to a lower interest rate sensitivity of output in the euro area compared to Germany, but not to differences in the preference parameters of the ECB and the Bundesbank.

The second important policy question we address is whether the handing-over of monetary policy from the Bundesbank to the ECB led to higher interest rates for Germany and contributed to the particularly weak economic performance of Germany after the start of EMU. Based on counterfactual simulations, we assess whether the German economy would have experienced a different, perhaps less restrictive interest rate path if, instead of the ECB, the Bundesbank had still been in charge of monetary policy in Germany. The simulations do not deliver clear-cut results. If we take the estimated Bundesbank Taylor rule at face value we conclude that interest rates in Germany were rather lower under the ECB regime than they would have been under a hypothetical continuation of the former Bundesbank regime. However, this result is reversed when we eliminate the effect of the differences in the estimated long-run real interest rate levels. The estimated long-run real interest rate in the ECB Taylor rule is less than half as large as that in the Bundesbank Taylor rule. This difference in implied real interest rates between the two regimes may reflect lower real interest rates under the EMU regime due to the process of fiscal consolidation in the 1990s, but probably also due to lower levels of potential real growth, especially in Germany. Thus, the long-run German real interest rate is probably also lower post-1999, which would in turn lead to a lower constant term in a hypothetical post-1999 Bundesbank rule compared to the rule estimated for the pre-1999 period. To control for this effect we also perform the simulations imposing the estimated long-run real interest rate from the ECB Taylor rule on the Bundesbank Taylor rule. The resulting counterfactual suggests that the German interest rates could have been up to one percentage point lower under a hypothetical Bundesbank regime after 1999. However, since the long-term real interest rate is very imprecisely estimated under the ECB regime, this finding should be taken with considerable caution.

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