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Eastern Enlargement, EMU and Monetary Policy under Fixed Exchange Rates: Lessons from the Experience of West Germany in the Bretton Woods Era

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In diesem Aufsatz wird die Geldpolitik der Deutschen Bundesbank in der Ära Bretton Woods empirisch untersucht. Basierend auf den theoretischen Aussagen des Lehrbuchmodells einer kleinen offenen Volkswirtschaft bei festen Wechselkursen wird mit Hilfe der Kointegrationsanalyse zunächst eine Gleichgewichtsbeziehung auf dem Geldmarkt zwischen der abhängigen Variable Geldmenge und den erklärenden Variablen Einkommen, Preise und Zinsen geschätzt. Dabei erweist sich die Geldmenge als langfristig endogene Variable bzw. als «Granger non-causal in the long-run». Darüber hinaus wird die Gültigkeit der Zinsparität zwischen dem deutschen und amerikanischen Zinsniveau empirisch überprüft. Es zeigt sich, dass langfristig die amerikanische Geldpolitik im Bretton Woods-System für die deutsche Zentralbank eine bindende Restriktion darstellte. Aus den Ergebnissen werden Schlussfolgerungen für die zukünftige Ausgestaltung eines geeigneten Wechselkurssystems für die neuen mittel- und osteuropäischen Mitgliedsländer der EU gezogen.

Keywords: Bretton Woods, Bundesbank, monetary policy, fixed exchange rate system, cointegration, Granger non-causality in the long-run

JEL-Codes: C32, E42, E52, F33

1 Introduction

On May 1st, 2004 the EU family has grown by eight Central and Eastern European Countries (the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, the Slovak Republic and Slovenia, henceforth CEECs). Naturally, after the process of real economic integration between the EU and the CEECs has been completed the question about further progress with regard to monetary economic integration ranks high on the political agenda. According to the present legislation, with their accession to the EU the CEECs will also become full members of the European Monetary Union (EMU). However, they will be granted a derogation under Art. 122 of the treaty according to which they will not

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have the obligation to adopt the euro until they satisfy the conditions of the so-called “Maastricht criteria”.¹

Actually, even after an entry to the EU the choice of a suitable exchange rate regime is open for the CEECs and, hence, it comes as no surprise that there is a lively debate about this issue among economists, with proposals ranging from pure flexible exchange rates to an immediate one-sided introduction of the euro as a legal tender by the CEECs.² However, it comes as a surprise that, contrary to issues of real economic integration where many authors stressed the historical analogy between the situation of the CEECs after the end of the Cold War and that of Western Europe after the end of World War II,³ in the present debate about monetary economic integration of the CEECs this part of economic history does not play a significant role. Instead, the recent discussion is centered around the experiences with Southern Enlargement of the European Union or more generally the functioning of the EMS from 1973 onwards, although with regard to the productivity differentials between Western European countries and the U.S. after WWII, the gradual liberalisation of capital movements, the dominance of the Dollar as international reserve currency and the Federal Reserve System as “lender of last resort” in the Bretton Woods system of fixed exchange rates, there are several historical parallels to the current situation which might potentially prove fruitful to investigate.

Ultimately, suggestions for the choice of the future exchange rate regime should take into account which contribution it could make or, at least, how conducive it is for the further growth process of the CEECs and for a rapid adjustment of per capita real income to the level of the EU. It is a very similar kind of question which has found renewed interest among economic historians by asking which role the Bretton Woods system has played in Western Europe’s growth process from 1945–1973 (“the golden age of capitalism”) and, in particular, the monetary policy of the German

1 For details see ECOFIN (2000) and BELKE and HEBLER (2002). The Maastricht Criteria stipulate that monetary policy satisfy certain criteria on inflation and interest rates and fiscal policy on budget deficits and public debts. In addition, it is expected that the CEECs join the European Exchange Rate Mechanism II (ERMII) and that their currencies participated for a period of at least two years without devaluations in the ERMII before the final adoption of the euro.

2 See, *inter alia*, SACHS (1996), KOPITS (1999) and BOFINGER and WOLLMERSHÄUSER (2000).

3 See, *inter alia*, EICHENGREEN and UZAN (1992), DORNBUSCH ET AL. (1993) and FEINSTEIN ET AL. (1994).

Bundesbank⁴ in the economic upswing in post-war Germany (“das Wirtschaftswunder”).⁵ Although the (*de jure*) independence of the German central bank and its proverbial aversion to inflation are seen as a characteristic of the West German economic system in all contributions, the judgement of its monetary policy has nevertheless remained ambiguous. Supply-side oriented authors (GIERSCH ET AL. 1994; KLUMP 1996; DICKHAUS 1996) stress the beneficial effects of price stability on investment and exports, whereas demand-side oriented authors (ABELSHAUSER 1983; SCHEIDE 1987; DORNBUSCH 1993) emphasize the destabilizing effects on the business cycle and the resulting output losses from a monetary policy geared solely around price stability. Yet, despite the traditional belief in Germany that the stability of the D-Mark and the independence of the Bundesbank are inseparable, the autonomy of the Bundesbank and its restrictive stance under the Bretton Woods system of fixed exchange rates are also controversial. LINDLAR (1997) und HOLTFRERICH (1998) doubt the ability of central bankers to provide for West Germany’s long-run independence from monetary developments abroad. They argue that the Bundesbank was forced – albeit reluctantly – to follow an expansionary monetary policy. BERGER (1997), however, highlights the Bundesbank’s substantial manoeuvring room to follow its main goal of internal price stability for the first decade of the Bretton Woods system, while ESCHWEILER and BORDO (1994) do the same for the second decade.

Interestingly, the recent debate about the extent to which the Bundesbank could attain control of the money supply continues an econometric discussion which was on the agenda twenty years earlier by international economists. Here attention is focused on the estimation of the so-called offset coefficient, i.e. the fraction of a given increase in domestic credit that is offset by losses in foreign exchange reserves in the same quarter. While KOURI and PORTER (1974) (see also KOURI 1975) suggest that the scope for a domestically-oriented monetary policy in the nonreserve countries of the Bretton Woods fixed exchange rate system was negligible, some authors argue that the Bundesbank enjoyed a considerable degree of monetary independence (NEUMANN 1978; HERRING and MARSTON 1978; OBSTFELD 1982; LASKAR 1983). In the most recent contribution,

4 On August 1st, 1957, the Deutsche Bundesbank legally replaced the Bank deutscher Länder (BdL) as the West German central bank. Since the institutional form of the new central bank was virtually identical to the old one, this legal change did not have any consequences for monetary policy. In the following, the term Bundesbank is also used for the West German central bank before 1957, i.e. for the BdL.

5 See BORDO and EICHENGREEN (1993) and EICHENGREEN (1996).

PASULA (1994) provides evidence that there was little or no monetary autonomy during the Bretton Woods era. However, as noted already by OBSTFELD (1982, p. 48), the conclusions derived from the estimation of the offset coefficient “relate exclusively to the feasibility of sterilization as a short-run or *temporary* policy.”

The aim of this paper is to provide further empirical evidence on how the Bundesbank conducted monetary policy in the Bretton Woods era. What economic goals did the Bundesbank have and, equally important, to what extent could they be achieved? To answer these questions we will apply recent advances in the econometric analysis of time series which seem ideal for analysing the monetary policy of a small open economy under a fixed exchange rate system. Starting with the estimation of a conventional vector autoregressive (VAR) model of money, output, prices, and interest rates, we will derive a long-run money demand function by cointegration analysis. Since it appears reasonable to assume that in the long run, money is endogenous in a fixed exchange rate system, we will test for the possibility of the so-called “Granger non-causality in the long run”. Furthermore, in order to evaluate the extent to which the Bundesbank could control its money supply, we will seek a second cointegrating relationship between German and U.S. interest rates and will attempt to establish that the latter served as the “long-run forcing” variable in the Bretton Woods system. The structure of the paper is as follows: in the next section, we will outline the methodology. In *Section 3*, we will report on the results for money demand, followed by *Section 4* on money supply. The last section gives the conclusion and draws some policy implications with regard to the appropriate exchange rate policy of the CEECs after accession to the EU.

2 Methodology

The objective of this section is to make use of the recently developed concepts of cointegration and long-run Granger non-causality in modelling the behaviour of money, output, prices, and interest rates in a fixed exchange rate system. Since monetary theory suggests that there should be a long-run equilibrium relationship between the money stock and output, prices, and interest rates as long as these variables could be regarded as integrated time series, a cointegration analysis should reveal at least one cointegrating relationship among these variables. Moreover, according to the model of a small open economy under a fixed exchange rate system,

interest rates and prices are determined on the world markets and, if wages and prices are flexible, output will be at its full employment level. Since the levels of output, prices, and interest rates determine money demand, in the long run departures from money equilibrium under fixed exchange rates could only be removed if the money stock reacts. In other words, money is endogenous and should prove to be neutral for the development of output, prices, and interest rates in the long run.

Monetary theory predicts that there should be a long-run equilibrium relationship between the money stock and output, prices, and interest rates. Hence, it seems natural to test this proposition by estimating a regression model with money on the left hand side and output, prices, and interest rates on the right hand side of the regression equation. This simple estimation strategy is based, among other things, on the assumption that the means and variances of the respective time series are well-defined constants and independent of time. Yet as time series analysts have always pointed out, these assumptions are not satisfied by most macroeconomic time series. Instead, exchange rate or interest rate series, for example, seem to meander with no particular tendency toward decreasing or increasing over time, whereas money or output series show a clear tendency to grow but not to follow a simple linear time path. This 'random walk' behaviour (with or without drift) is typical of so-called integrated series and gives rise to several econometric problems. In particular, ordinary least squares (OLS) estimations of relationships involving integrated time series lead to mistaken inferences. This is known as the 'spurious regression' problem (GRANGER and NEWBOLD 1974). Yet one important exception to the rule exists: if in fact the integrated time series are tied together by a long-run equilibrium relationship, they are said to be cointegrated (ENGLE and GRANGER 1987). Although individually each series appears to behave like a random walk, the existence of long-run equilibrium and thus of a cointegrating relationship ensures that they cannot move 'too far' from each other. The reason for this behaviour lies in the 'error correction mechanism': at least one of the variables of a cointegrating relationship takes past equilibrium deviations (the so-called error correction term) into account and reacts accordingly to close the gap. Thus, the existence of a cointegrating relationship among variables implies the existence of an error correction model (ECM). This is, in fact, the essence of the Granger representation theorem which states that if two or more variables are integrated of order one and at least one linear combination of these variables which is stationary exists, it is always possible to switch

from a vector autoregressive to a vector error-correction (VEC) representation of the variables involved.⁶

Basically, there are two approaches to cointegration analysis (for recent surveys see MILLS 1998; CARPORALE and PITTIS 1999). The first approach begins with the estimation of an unrestricted VAR without any *a priori* assumptions on the number of cointegrating relationships or on weak exogeneity. JOHANSEN's (1988) maximum likelihood estimation procedure could then be employed to test for the presence of cointegration. After the number of cointegrating relationships is specified, restrictions suggested by economic theory on the cointegrating vectors and feedback coefficients could be imposed. The second approach stipulates the number of cointegrating relationships and the existence of exogenous variables at the outset and thus starts with the estimation of the conditional model.⁷ The cointegrating vector could be estimated by means of single equation estimation methods, such as the autoregressive distributed lag (ARDL) estimator advocated by PESARAN and SHIN (1999) or the fully-modified ordinary least squares (FMOLS) estimator attributed to PHILLIPS and HANSEN (1990). The cointegrating vector is in turn used to compute the error correction term. The test for weak exogeneity could then be obtained from the variable addition test of the error correction term in the marginal model. Clearly, the first strategy is preferable on theoretical grounds since it is much more convincing to test rather than to assume the validity of restrictions implied by economic theory. From a practical point of view, however, the second strategy has its advantages due to the limitations on the length of time-series data typically available in macroeconomic studies. Since the estimation of VARs is wasteful with degrees of freedom, one advantage is that there are fewer constraints in terms of the number of variables which could be considered in the analysis. Another advantage is that the single equation error correction model could be seen as a structural relationship, which remains constant even if the data generating process of the exogenous variables changes.

6 For a detailed treatment of cointegration analysis see BANERJEE ET AL. (1993), HAMILTON (1994), HARRIS (1995), and HATANAKA (1996).

7 As argued by PESARAN and SMITH (1998), for most countries world foreign variables are largely exogenous so there should always exist a natural set of exogenous variables such as foreign prices, output or interest rates.

3.1 Multiple Equation Cointegration Analysis

The empirical analysis starts with the estimation of an unrestricted VAR for the four-variable system in levels of money (m), output (y), prices (p), and interest rates (i).⁸ Logarithms of quarterly, seasonally unadjusted data are used, covering the period from 1949:1 until 1973:1.⁹ The VAR includes a constant term and seasonal dummies.¹⁰ Since the maximum lag order is set at 8 quarters, the effective estimation period is reduced to 1951:1–1973:1. Owing to problems of autocorrelation and parameter instability, irrespective of the chosen lag length, we restrict the estimation period further to 1952:3–1973:1.¹¹ After so doing, the Akaike Information Criterion (AIC), the Hannan-Quinn Criterion (HQC), and sequential reduction tests based on the F-form of the LR test indicate an appropriate lag length of 5 quarters, while the Schwarz Bayesian Criterion (SBC) suggests a VAR of order 1 (see *Table 1*). Because a VAR of order 1 does not pass the various mis-specification tests and especially reveals significant autocorrelation problems, a lag order of 5 is chosen.

8 For a description of the data and preliminary ADF-tests for testing of order of integration see *Appendix*.

9 Since the literature on money demand functions treats both semi-log and double-log specifications (RÜDEL 1989; OTTO 1994), we estimate the VAR with the absolute level and the natural logarithm of interest rates, respectively. Results changed only marginally between the two specifications. In the following the results of the log-log model are presented because a final encompassing test based on the single equation money demand function reveals that the double-log specification encompasses the semi-log specification. ALECKE (2001) obtains similar findings for German money demand in the post Bretton Woods period (1973:2–1998:4). As argued by HOFFMAN and RASCHE (1996, p. 102), one possible disadvantage of the semi-log specification is that it imposes a higher long-run elasticity at higher interest rates. They recommend using a double-log specification for the case of the U.S. money demand in the postwar period.

10 Preliminary ADF-tests reveal that money, output, and prices could be seen as integrated series of order one, while the result for the interest rate variable points to a stationary series. Nonetheless, due to the widely acknowledged problematic features of unit root tests, we decide to include the interest rate series into the VAR model; see LÜTKEPOHL (2001).

11 It might be noted – although it is probably no more than a historical accident – that West Germany officially joined the Bretton Woods system right now in July 1952. In fact, the significant autocorrelation problems which result when the periods before 1952:3 are included in the VAR may be caused by the volatile behaviour of output and prices in the first three years after the currency reform. West Germany experienced a sharp economic downturn from 1949:1 until 1950:2 with decreasing output and falling prices, which suddenly was replaced by the so-called Korea boom leading to a sharp balance of payments crisis.

Table 1 Testing for the Appropriate Lag Length

Lag Order	AIC	SBC	HQC	adj. LR test
8	-31.679	-27.012	-29.523	[0.064]
7	-31.132	-27.318	-29.549	[0.328]
6	-31.726	-27.992	-29.945	[0.710]
5	-31.955	-28.615	-30.288	[0.000]
4	-31.919	-28.660	-30.054	[0.015]
3	-31.427	-29.020	-30.136	[0.000]
2	-30.621	-29.066	-29.902	[0.000]
1	-30.955	-29.252	-29.810	[0.000]

Source: Own calculations.

Table 2 reports various diagnostic test statistics for both the individual equations and the full system because i.i.d. disturbance terms are a crucial requirement for the application of the Johansen ML estimation procedure. The diagnostic tests include tests to determine the absence of serial correlation (AR), autoregressive conditional heteroskedasticity (ARCH), heteroskedasticity (HK) as well as a test for normality (NORM).¹² As can be seen from the rejection probabilities given in Table 2, the null hypotheses cannot be rejected in all cases, so the residuals seem to be well-behaved. In the next step, we therefore turn to cointegration analysis of the estimated VAR(5).

Table 2 Diagnostic Tests of the Estimated VAR(5)

Diagnostic tests Equation	AR	ARCH Rejection probabilities	HK	NORM
Money	[0.416]	[0.576]	[0.994]	[0.697]
Output	[0.420]	[0.928]	[0.997]	[0.553]
Prices	[0.143]	[0.792]	[0.999]	[0.649]
Interest Rates	[0.306]	[0.232]	[0.782]	[0.593]
System	[0.144]	-	[0.999]	[0.803]

Source: Own calculations.

The cointegration analysis based on Johansen's ML method leads to the results given in Table 3. In sum, the Johansen LR test statistics strongly reject the null hypothesis of no cointegration between the variables. The maximum eigenvalue and trace statistics adjusted for the degrees of free-

¹² For details on the computation of these test statistics, see DOORNIK and HENDRY (1994).

dom, as recommended by REIMERS (1992), select one cointegrating relationship, whereas in the unadjusted case, they point to the presence of one or two cointegrating relationships, depending on the set of critical values used.

Table 3 Johansen ML Estimates of the Cointegration Rank

LR test statistic	' λ -max'	'adj. λ -max'	' λ -trace'	'adj. λ -trace'
Null hypothesis				
rank ≤ 0	39.25**	29.79*	73.63**	55.89**
rank ≤ 1	24.31*	18.45	34.39*	26.1

Notes: The critical value for the ' λ -max' LR statistic (' λ -trace' LR statistic) for testing the null hypothesis rank ≤ 0 is 27.1 (47.2) at a 5% significance level; the critical value for the ' λ -max' LR statistic (' λ -trace' LR statistic) for testing the null hypothesis rank ≤ 1 is 21.0 (29.7) at a 5% significance level; 'adj. λ -max' ('adj. λ -trace') denotes the ' λ -max' statistic (' λ -trace' statistic) when adjusted for degrees of freedom as recommended by REIMERS (1992).

* denotes rejection at the 5% significance level.

** denotes rejection at the 1% significance level.

Source: Own calculations.

It appears that the above estimates do not indicate the appropriate cointegration rank. However, as noted by PESARAN and SMITH (1998, p. 501), complete agreement between the various methods is very rare in practical applications and thus, the decision on the number of cointegrating relations has to account for *a priori* information implied by economic theory.¹³ Because macroeconomic theory suggests only one long-run relationship between the variables, we choose a cointegrating rank of one. However, the obtained cointegration vector reveals long-run elasticities of money demand with respect to output, prices, and interest rates which are not very consistent with conventional economic theory. In particular, the price and interest rate coefficients are wrongly signed. Even if we test overidentifying restrictions on the cointegrating vector and factor loadings such as long-run price and output homogeneity or weak exogeneity of output, prices, and interest rates, the implied cointegrating vector remains inconsistent from an economic point of view. Only if the long-run

13 It may be noted that mistakenly including an I(0) variable in the Johansen VAR, which treats all variables as I(1) variables, would lead to an overestimation of the cointegration rank by one since an I(0) variable seems to be cointegrated with itself. As mentioned above, preliminary ADF-tests suggest that the interest rate variable may be indeed an I(0) variable. Thus, an estimated cointegrating rank of two does not have to be inconsistent with the assertion of just one long-run equilibrium relationship within the system. As suggested by an anonymous referee, we re-estimated the system with 2 cointegrating vectors restricting the cointegrating vector on the interest rate variable accordingly to $\beta = 0, 0, 0, 1$. However, this does not lead to an improvement with regard to the theoretical plausibility of the coefficients in the money demand equation. Also, the results of the restricted cointegration analysis remain nearly unaffected.

price elasticity of money demand is constrained to be unity, the cointegrating vector will display reasonable and significant coefficients of output and interest rates. With the imposition of long-run price homogeneity, the null hypothesis of output, prices, and interest rates being weakly exogenous can not be rejected at the 5% significance level. Hence, in order not to abandon the complete analysis and dismiss the conventional economic wisdom of no money illusion (at least in the long run), we choose to incorporate this non-statistical *a priori* information into the subsequent modelling stage.

3.2 Single Equation Estimation

Under conditions of weak exogeneity, it is justified to condition upon output, prices, and interest rates for the estimation of the long-run coefficients of the money demand equation and to move to a single equation estimation procedure. Hence, in the next step, we will apply the ARDL single equation estimator recently proposed by PESARAN and SHIN (1999) which estimates the following ARDL (m,n,k) equation by OLS:¹⁴

$$(m - p)_t = \alpha_0 + \sum_{i=1}^m \alpha_{1,i} (m - p)_{t-i} + \sum_{i=0}^n \alpha_{2,i} y_{j,t-i} + \sum_{i=0}^k \alpha_{3,i} i_{j,t-i} + u_t$$

The benefit of this approach is that one can allow for different lag orders and contemporaneous influences of the weakly exogenous variables. Thus, it is possible to economise on the degrees of freedom and to improve the precision of the estimates.¹⁵ Based on the AIC and HQC selection criteria¹⁶, an ARDL (5,2,3) model is selected which yields the following long-run solution (with *t*-values in brackets):¹⁷

14 Note that PESARAN and SHIN (1999) choose a slightly different parameterization of the ARDL model as a starting point for their analysis than given in the above formula. See PESARAN and PESARAN (1997, p. 393) for a detailed description of how to obtain the error correction model and to estimate the long-run coefficients and their asymptotic standard errors from the selected ARDL model.

15 Furthermore, another advantage of the ARDL procedure as stressed by these authors lies in the fact that it can be applied irrespective of whether the regressors are stationary or contain a unit root. It thereby avoids the usual pretesting problems in cointegration analysis.

16 The estimated dynamic equation in the levels of real money, output, and interest rates seems to be well-behaved. None of the diagnostic tests indicates serious problems concerning autocorrelation (AR), non-normality of the residuals (BJ), heteroskedasticity (HK), autoregressive conditional heteroskedasticity (ARCH), or functional form mis-specification (RESET). The probabilities of falsely rejecting the null hypotheses are AR [0.366], BJ [0.964], HK [0.965], ARCH [0.701], and RESET [0.540], respectively.

17 The SBC and R² criteria select an ARDL (5,0,3) and an ARDL (5,3,3) specification, respectively. The long-run coefficients based on these models ($(m-p) = 1.003 \cdot y - 0.115 \cdot i$ and $(m-p) = 1.012 \cdot y - 0.125 \cdot i$), however, differ only slightly from those of the ARDL (5,2,3) model.

$$m - p = -3.84 + 1.014 \cdot y - 0.132 \cdot i$$

$$(17.16) \quad (27.75) \quad (3.42)$$

$$\chi^2 = 826.49 \quad [0.000]$$

which shows plausible and significant values of both sign and order. The individual *t*-tests of the long-run coefficients of output and interest rates as well as the Wald-test of their joint significance provide strong evidence in favour of cointegration. However, as argued by KREMERS ET AL. (1992) and BANERJEE ET AL. (1993), the critical test for the presence of cointegration among the variables (and thereby implicitly for the error correction term being stationary) is provided by the empirical *t*-value of the error correction term in the conditional ECM. This amounts to a direct test of the hypothesis that the adjustment process to equilibrium is non-degenerating. The error correction coefficient, based on the conditional ECM version of the ARDL (5,2,3) equation, is estimated as -0.105 with a *t*-value of -4.79 . Thus, the error correction term is not only statistically highly significant and correctly signed, but it also suggests a moderate speed of convergence toward equilibrium.¹⁸

Up to this point, the statistical inference based on single equation estimation has relied on the weak exogeneity of the right hand side variables of output, prices, and interest rates for the long-run coefficients of the money demand equation. As mentioned above, this condition can be tested by adding the error correction term to the marginal model and proving its significance (BOSWIJK 1995). Since all the variables are stationary in the marginal model, the usual *t*-statistics and *F*-statistics can be applied. The following individual *t*-statistics (rejection probabilities in square brackets) are obtained in the equations for the first differences of output, prices, and interest rates, respectively: 0.16 [0.874], 1.25 [0.215] and -0.32 [0.752]. The *F*-test for the joint significance of the EC-term produces an empirical value of 0.59 [0.622]. Hence, the results show that the null hypothesis of weak exogeneity of output, price, and interest rates can not be rejected. None of the three variables is error correcting in response to deviations from long-run monetary equilibrium, or in other words, money is “Granger non-causal in the long run” (GRANGER and LIN 1995). Instead, the output, price, and interest rate series can be referred to as the long-run forcing variables of the system (PESARAN, SHIN and SMITH 2000).

¹⁸ According to the critical values tabulated by BANERJEE ET AL. (1993, Table 4), for a sample size of 100 and two exogenous variables, the relevant critical value for the 5% significance level is -3.56 .

4.1 Interest Rate Parity

The existence of a long-run relationship between money, output, prices, and interest rates, and the endogeneity of money can be seen as one cornerstone of the theoretical model of a small open economy under fixed exchange rates. Yet, this leaves the question unanswered as to whether German interest rates were actually determined on world markets. In this section, we will attempt to establish the existence of interest rate parity between German and U.S. short-term interest rates (i^*). We choose U.S. interest rates because the Bretton Woods system was effectively a gold-dollar standard, in which U.S. monetary policy was of overriding importance for the rest of the world.¹⁹ Additionally, it can be expected that U.S. interest rates were not influenced by German monetary conditions and should thus prove to be weakly exogenous.²⁰ One criticism of this line of reasoning is that full convertibility for the Western European currencies was not established in the Bretton Woods system before 1958, since under the institutional shield of the European Payments Union (EPU), Western Europe applied foreign exchange controls and quantitative restrictions toward the dollar area. In fact, however, West Germany gradually lifted most of the restrictions for both current and capital account transactions long before the dissolution of the EPU.

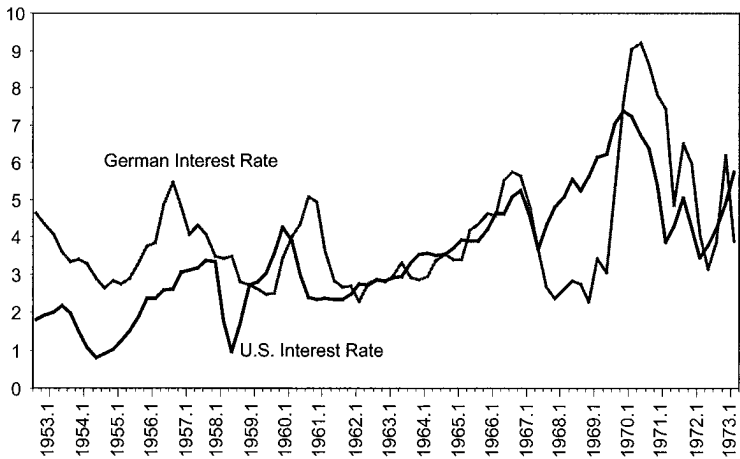
Figure 1 shows the German and U.S. short-term interest rates between 1952:3 and 1973:1. It can be seen that considerable deviation still existed between the interest rates in the early 1950s, which became increasing smaller over time and with the actual conversion to the Bretton Woods system.²¹

19 See GENBERG and SWOBODA (1993) for a theoretical analysis of the importance of U.S. monetary policy within the Bretton Woods system, which can also be characterized as a Gold-Dollar Standard. In addition, one might ask if purchasing power parity (PPP) holds in the long-run between German and U.S. prices. As shown in ALECKE (1999), however, cointegration analysis does not reveal evidence for PPP. As noted by GIERSCHE ET AL. (1994), the failure of PPP to hold comes as no surprise with regard to the post-war growth performance of West-Germany and could be explained by the so-called Balassa-Samuelson theorem. According to this, international variations in the prices of nontradables are the source of price level discrepancies between rich and poor nations. Hence, as West Germany managed to close the income gap *vis-à-vis* the U.S. in the Bretton Woods era, the prices of German nontradables had to increase relative to those in the U.S., which in turn implies a real revaluation of the D-Mark (i.e. a non-stationary real exchange rate).

20 For a cointegration analysis between German and U.S. interest rates for the period after 1973, see HANSEN (1996).

21 For a brief historical account see ALECKE (1999). Throughout the Bretton Woods era the Bundesbank constantly expressed complaints about imported inflation. As early as June 1953, one year after the Bundesbank officially joined the Bretton Woods system, the Bundesbank explained its reduction of the discount rate with the unwanted inflow of foreign exchange.

Figure 1 German and U.S. Short-Term Interest Rates



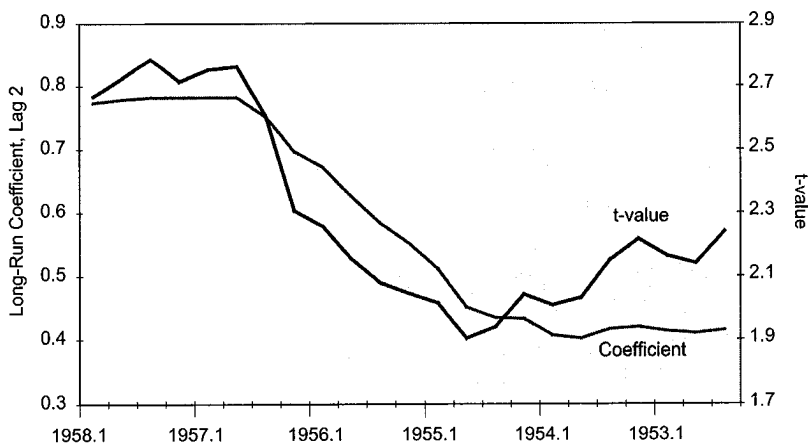
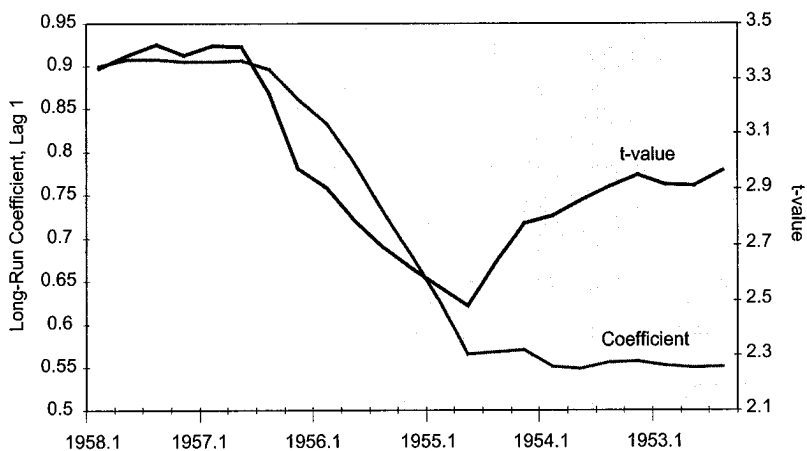
Source: See Appendix.

The graphical analysis leads to the expectation of a structural break in the cointegration relationship between the two interest rates. Because the assumption of weak exogeneity for U.S. interest rates appears plausible based on theoretical considerations, and because one might suppose that the Johansen estimation procedure would react less robustly to structural breaks, in the first step a preliminary cointegration analysis is undertaken with the help of a bivariate single equation estimation. In order to detect a possible structural break, “reverse recursive” long-run solutions are calculated beginning with the period 1958:1–1973:1, adding the previous quarters up to 1952:3 successively.

Figure 2 presents the coefficient paths and the t-statistics for the long-run solutions of bivariate ARDL models with a lag length of 1 and 2 quarters, respectively.²² From the figure, it becomes clear that the elasticity of the German interest rate in response to the U.S. interest rate for the time period 1958:1–1973:1 has a statistically significant value of 0.90 or 0.77, depending on the lag specification. The further inclusion of the quarters up to 1957:1 does not lead to a visible change in the estimated values, while the addition of the earlier quarters results in a dramatic decline in the estimated long-run elasticities. Basically, this observation can be traced back to a structural break in the constant term and/or the slope parameter.

²² While the SBC generally suggests a lag length of 1 for the varying periods, the F-statistics appear to be compatible with a lag length of 2 when the earlier quarters are included.

Figure 2 Long-Run Coefficient Paths of the ARDL Estimates for Interest Rate Parity



Source: Own calculations.

In order to test first for a structural break only in the constant term²³, a series of alternative step dummy variables is defined which posits the

23 At the outset the constant terms in the long-run solutions, which are not shown in Figure 2, are not statistically different from zero. However, when the earlier quarters are included, their value nearly doubles and appears statistically significant.

structural break in the quarters between 1956:1 and 1958:1. Then these dummy variables enter into the ARDL model and the long-run solutions for the entire period 1952:3–1973:1 are recalculated.²⁴ *Table 4* presents the results of this estimation strategy.

Table 4 Step Dummy Variables for the Structural Break in Interest Parity

Quarter	Constant	t-value	$\hat{\rho}$	t-value	Step dummy	t-value	χ^2
1958:1	0.874	3.960	0.738	3.743	-0.410	-2.022	14.659
1957:4	0.911	4.337	0.779	4.033	-0.498	-2.460	16.792
1957:3	0.917	4.454	0.808	4.150	-0.549	-2.649	17.147
1957:2	0.913	4.368	0.810	4.059	-0.547	-2.529	17.076
1957:1	0.920	4.438	0.843	4.128	-0.608	-2.689	17.631
1956:4	0.955	4.499	0.877	4.064	-0.664	-2.718	17.096
1956:3	0.946	4.227	0.857	3.776	-0.619	-2.370	15.024
1956:2	0.919	3.848	0.791	3.380	-0.491	-1.786	12.628
1956:1	0.917	3.754	0.765	3.259	-0.450	-1.588	11.992

Source: Own calculations.

Since all of the dummy variables are significant, independent from the assumed quarter of the structural break (with the exception of the step dummies for 1956:1 and 1956:2), the highest value of the χ^2 statistic of the Wald test listed in the last column serves to determine the precise date of the structural break. Hence, the structural break in the constant term is assumed to appear in the first quarter of 1957.²⁵ Yet the indicated long-run elasticity of only 0.85 of the German interest rate in response to the U.S. interest rate appears implausible from an economic point of view. Instead, one should expect that in the long-run movements in the U.S. interest rate were fully reflected in its German counterpart.

For this reason, the Johansen ML method is applied to test the restriction of a long-run elasticity of one together with the U.S. interest rate being weakly exogenous. *Table 5* gives the results of the Johansen test statistics based on a bivariate VAR model with the German and U.S. interest rates.

24 The first obvious influence of these dummy variables is that, in line with the SBC, the F-statistic also indicates a lag order of 1 as the appropriate dynamic specification.

25 Alternatively, the t-value of the dummy variable could also have determined the precise occurrence of the structural break. Compare with the diverse test procedures of the stability of cointegrating vectors in Kim (1994).

The VAR model is estimated with both a constant term and the step dummy for 1957:1.²⁶ The constant term and the step dummy are limited to the cointegration vector, however, to prevent a trend in the interest rates.²⁷ According to the ‘ λ -trace’-test statistic the null hypothesis of no cointegration can be rejected at a 5% significance level.²⁸

Table 5 Johansen ML Estimates of the Cointegration Rank

LR test statistic	‘ λ -max’	‘adj. λ -max’	‘ λ -trace’	‘adj. λ -trace’
Null hypothesis				
rank ≤ 0	–	–	26.61*	–
rank ≤ 1	–	–	6.37	–

Notes: The critical value for the ‘ λ -trace’ LR statistic for testing the null hypothesis rank ≤ 0 is 25.6 at a 5% significance level; the critical value for the ‘ λ -trace’ LR statistic for testing the null hypothesis rank ≤ 1 is 12.2 at a 5% significance level. Critical values are computed according to the response surface in JOHANSEN ET AL. (2000), see Footnote 28.

* denotes rejection at the 5% significance level.

Source: Own calculations.

The likelihood ratio test of the restriction of a long-run elasticity of one and of weak exogeneity of the U.S. interest rate results in a χ^2 -statistic of 2.20 with a rejection probability of [0.33].²⁹ Hence, the imposition of these restrictions does not lead to a significant decrease in the likelihood value of the VAR model. The estimated cointegration vector is $i = 0.79 + i^* - 0.76 \cdot D^{1957:1}$ combined with a highly significant speed of the adjustment parameter of $\alpha = -0.24$ (t -value of 3.87). What is of interest here is the similar size but opposite sign of the constant term and the step dummy for 1957:1. The likelihood ratio test of the additional restriction that the constant term and the step dummy are equal but of opposite sign yields a χ^2 -statistic of 0.14 [0.70] which is easily accepted. The cointegration vector now becomes $i = 0.79 + i^* - 0.79 \cdot D^{1957:1}$ with the speed of adjustment parameter unchanged. Hence, a difference of approximately 2.2% existed between the level of the German and U.S. short-term interest rates before

26 The HQC and the F-statistic indicate a lag order of 3 quarters as appropriate dynamic specification. The inclusion of seasonal dummies does not improve the results based on the usual criteria.

27 See HARRIS (1995) p. 95.

28 Because of the structural break in the constant term, critical values for the ‘ λ -trace’ LR statistic are computed according to the response surface for the mean and variance of the Gamma Distribution given in JOHANSEN ET AL. (2000) which is recommended by these authors as the appropriate asymptotic distribution for tests of cointegration rank in the presence of structural breaks in the deterministic components. The response surface does not provide critical values for the ‘ λ -max’ LR statistic.

29 Imposed individually, the restriction of a long-run elasticity of one yields a χ^2 -statistic of 2.19 [0.14]; the restriction of weak exogeneity of U.S. interest rates yields a χ^2 -statistic of 0.47 [0.49].

1957, which disappeared with the *de facto* convertibility of the D-Mark. These results can be interpreted as evidence of a German interest rate which reacts to movements in the U.S. interest rate right before the official conversion to the full convertibility obligations of the Bretton Woods articles. With restricted capital mobility, however, the Bundesbank had the opportunity to exercise a more restrictive monetary policy than the Federal Reserve System until 1957.

4.2 The Bundesbank's Short-Term Reaction Function

The finding of interest rate parity gives the necessary condition for the specification of an ECM for the German short-term interest rate which includes, in addition to the stationary error correction term ($i - i^* - 0.79 + 0.79 \cdot D^{1957.1}$) lagged first differences of the German and U.S. short-term interest rates (and also the contemporaneous first difference of the latter).³⁰ Yet the modelling of such a short-run dynamic equation for the German interest rate can be extended to an exercise in estimating a 'reaction function' of the Bundesbank. Since in the short-run the Bundesbank should have had some leeway to influence the interest rate through its monetary policy measures, one might ask if this short-run independence was used to stabilize the inflation-output trade-off or to fol-

30 Note that, based on the results of the preliminary ADF-tests, a cointegration relationship between both interest rates could not exist because German interest rates appear to be integrated of order zero whereas U.S. interest rates appear to be integrated of order one. In this case, a regression with both variables could be seen as 'unbalanced' and would lead to spurious results, see BANERJEE ET AL. (1993). However, as argued by PESARAN ET AL. (2001), conflicting results of univariate tests for order of integration as a precursor to subsequent multivariate cointegration analysis are quite often encountered in empirical applications – especially for variables such as interest rates, inflation rates, unemployment rates, or the replacement ratio which are widely used in cointegration analyses of money demand or earnings equations. Thus, these authors develop a bounds testing procedure for the existence of a long-run relationship which avoids the usual pre-testing problems associated with the classification of the variables into I(0) and I(1) prior to cointegration analysis. The proposed test is based on the standard F-statistics and t-statistics for testing the significance of the lagged levels of the variables in the error correction form of the underlying ARDL model. They tabulated two sets of critical values, one of which assumes that all the variables are I(1), and the other assuming that they are I(0). This provides a band covering all the possible classifications of the variables into I(0) and I(1). If the computed test statistics fall outside the critical value bounds, a conclusive decision on the existence of a long-run relationship results regardless of whether the underlying variables are I(0) or I(1). If, however, the statistics fall within these bounds, inference would be inconclusive and the investigator may have to carry out further unit root tests on the variables. In our case, the empirical F-statistics and t-statistics of the lagged level variables in the error correction model explaining the first difference of German interest rates exceed the upper bounds of the critical value bands. Thus, we could be reassured that in the long-run interest rate parity exists irrespective of whether we regard interest rates as I(0) or I(1).

low the 'rules of the game' implied by a fixed exchange rate system.³¹ Hence, growth rates of money, output and prices are also included in the ECM. Significant values for the inflation rate, money or output growth can then be interpreted as evidence for 'target variables of monetary policy' in line with the conventional literature on estimating reaction functions.³²

An ECM with a lag order of 4 quarters serves as a starting point for modelling the short-run dynamics. Based on the individual t -values of the coefficients, a simplification of the dynamic structure is undertaken,³³ whereby the exclusion of variables is verified on the basis of recursive t -statistics. However, an examination of the recursive t -values does not yield an unified picture in this process. Toward the end of the 1960s, numerous t -values appear unstable and several coefficients change their sign.³⁴ Due to the obvious specification problems, an attempt is made to model the structural break in the short-run behaviour. Since the test statistics of structural constancy – which are based on the residuals of recursive OLS estimation – take on significant values with the inclusion of the quarter 1968:1 in the estimation period, a structural break is assumed for this quarter.³⁵ Subsequently, we attempt to model the apparent structural break by generating step dummy variables beginning in 1968:1 for both the constant term and the slope parameters. Although some of the dummy variables appear significant, the test statistics for mis-specification as well as for structural constancy remain unacceptable for the whole period 1952:3–1973:1. Consequently, because of the small number of quarters re-

31 A central bank following the 'rules of the game' should reinforce the monetary contraction (expansion) produced by a deficit (surplus) in the balance of payments. ALECKE (1999) presents the results of an examination of the Bundesbank's Monthly Reports ('Monatsberichte'), in which officially published reasons of monetary measures are assigned to the economic policy goals of price stability, output stabilization and external balance. His analysis reveals that the Bundesbank was indeed a very active follower of a discretionary monetary policy during the Bretton Woods era. In the whole period 133 measures were undertaken which amounts to an average of 1.3 measures per quarter. However, the Bundesbank explained nearly half of its measures with the motive "safeguarding of price stability", whereas only two fifths of its interventions were explained by balance of payments considerations. The wish to avoid cyclical downturns accounted for only slightly more than one fifths of its measures.

32 For a similar approach with regard to the estimation of reaction functions under the classical gold standard see BORDO and MACDONALD (1997). If the Bundesbank had followed the rules of the game one should expect a negative relationship between changes in the money supply and changes in interest rates.

33 Step by step, each variable whose t -value has appeared insignificant at the 5% significance level is excluded. The first ones excluded are those with the highest lag and the lowest (absolute) t -value.

34 The instability does not affect the error-correction term which continuously possesses a significant negative t -value.

35 It is noted that the structural break established for the beginning of 1968 in the short-term equation for the German interest rate accompanied the first speculations following the devaluation of the pound and finally resulting in the complete break-down of the Bretton Woods system.

maining for a separate estimation of the period 1968:1–1973:1, the instability at the end of the estimation period must be left unmodelled. The results of the ECM for the period 1952:3–1967:4 are presented below.

$$\begin{aligned} \Delta i_t = & -0.11 + 0.47\Delta i_{t-1} - 0.31\Delta i_{t-2} + 0.51\Delta i_{t-3} \\ & (-2.02) \quad (4.98) \quad (-3.11) \quad (5.3) \\ & + 5.41\Delta m_{t-2} + 2.48\Delta m_{t-3} - 0.15ec_{t-1} \\ & (4.78) \quad (2.14) \quad (-4.59) \end{aligned} \quad (5.3)$$

Notes: $R^2=0.73$. Constant and seasonal dummies are not shown. $DW=1.93$ (which is, however, strictly speaking not valid in a model with lagged dependent variables). None of the diagnostic tests, which cover the Breusch-Godfrey LM test for serial autocorrelation up to the fifth lag (AR), Bera and Jarque's test for skewness and excess kurtosis (BJ), White's test for heteroskedasticity (HK), an ARCH test for autoregressive conditional heteroskedasticity and Ramsey's RESET test of mis-specification, are significant at the 95% level. The probabilities of falsely rejecting the null hypotheses are AR [0.729], BJ [0.612], HK [0.831], ARCH [0.393], and RESET [0.649], respectively.

If one interprets this short-run dynamic equation for the German interest rate as a reaction function of the Bundesbank, it seems that inflation and output growth were not regarded as 'target variables of monetary policy' since they do not make a significant explanatory contribution to changes in the interest rate. Because of the positive coefficients for the lagged money supply growth, however, it becomes clear that – at least until 1968 – the German central bank reacted to previous increases in the money supply by raising interest rates. Hence, the Bundesbank did not follow the 'rules of the game' but instead tried to sterilize the money expansion resulting from the permanent balance of payments surpluses. This can only be explained plausibly with a monetary policy oriented towards price stability. However, it must be noted that sterilization was only a short-run or temporary policy option. In the long-run, interest rate parity reigned.

5 Conclusions and Policy Implications for the CEECs

The aim of this paper is to provide empirical evidence on how the Bundesbank conducted monetary policy in the Bretton Woods era. Based on the long-run implications of the textbook model of a small open economy under fixed exchange rates cointegration analysis is applied, first, to estimate a long-run relationship between money, output, prices and interest rates and, second, to demonstrate that output, prices and interest rates prove to be weakly exogenous. Thus money can be regarded as "Granger non-causal in the long-run". Furthermore, in the second part of the paper, the existence of interest rate parity between German and U.S. interest rates is

established after accounting for the structural break due to the *de facto* transition to full convertibility. Because the U.S. interest rates were weakly exogenous in the long-run the Bundesbank could not influence the conditions on the German money market. Instead, German monetary authorities were forced to accept the rules of the game set by the U.S. Federal Reserve System. Taken together, the empirical evidence of endogenous money, interest rate parity and weakly exogenous U.S. interest rates points to a fundamental aspect of the operation of the Bretton Woods system: central banks in non-reserve countries could not attain control of the money supply. However, during the time of restricted convertibility there was a small degree of long-run monetary autonomy because the equilibrium values of German and U.S. short-term interest rates could deviate by approximately 2.2%.

Because the existence of long-run interest rate parity does not preclude the possibility of a substantial room for manoeuvre for the Bundesbank in the short-run, an error correction model for the German short-term interest rate is estimated including the growth rates of money supply, output and prices as additional variables and, thus, can be interpreted as a money reaction function in the traditional sense. For the period up to 1968 an error correction model is obtained which does not contain the inflation rate and output growth (or lags of these variables) implying the absence of a direct short-run feedback rule of the Bundesbank. But indirectly, due to the significant positive coefficients on lagged money growth, it is possible to argue that monetary authorities were concerned with price stability. Presumably due to the speculative turbulence triggered by the pound crisis in 1968 and lasting until the complete break-down of the Bretton Woods system, however, this short-run money supply rule was no longer feasible in the following years.

From these findings at least two important policy conclusions can be drawn for the CEECs with regard to their exchange rate policy on the route to the final adoption of the euro. First of all, the combination of fixed exchange rates with a liberalization of capital account transactions will imply forsaking an activist monetary policy. Because the EU Treaty stipulates that capital movements be fully liberalized by the candidate countries already before EU accession and because of the much deeper integration of international financial markets, it is safe to assume that capital mobility and, thus, the constraints on the *short-run* scope of monetary policy for safeguarding macroeconomic stability will be much higher today than in the Bretton Woods era. As stressed in the literature on 'Optimal

Currency Areas', the costs of the loss of a discretionary monetary policy will depend on the probability of the occurrence of asymmetrical shocks and the degree of labour mobility to offset regional income differences. If labour is immobile, real wages will have to be flexible enough to allow the necessary adjustment of relative prices. However, on the one hand the probability of asymmetric shocks should not be underestimated due to the still different economic structures and the higher adjustment pressures of the growth process in the CEECs compared to the EU. On the other hand, free mobility of labour will be restricted even after their entry into the EU. In addition, some authors argue that the gradual adoption of the *Acquis Communautaire* with its regulations will lead to increasingly inflexible labour markets in the CEECs (see BELKE and HEBLER 2002). Thus, the costs of forsaking both exchange rate policy and monetary policy as adjustment mechanisms could be quite substantial.

A second point concerns the result that the Bundesbank, despite its legal autonomy from the West German government, did not enjoy substantial leeway to safeguard price stability, although this certainly ranged at the top of its preferences. Instead, interest rate parity and weakly exogenous U.S. interest rates indicate that the choice of West Germany's inflation rate did lie more in the discretion of the U.S. Federal Reserve System than in that of the German Bundesbank. As already mentioned (see *Footnote 19* above), however, this outcome should not be equated with the prediction of (relative) PPP that aggregate inflation rates in West Germany and the U.S. were equal during the Bretton Woods period (on this see also EICHENGREEN 1993). In fact, from 1958 to 1967 the inflation rate in West Germany was, based on the CPI, around 0.7% p.a. above the U.S. level, and based on the GDP deflator even around 1% p.a. above – and this although the D-Mark was appreciated against the dollar by 5% in 1961.³⁶ The reason for this deviation from PPP could be seen in the so-called Balassa-Samuelson hypothesis, according to which countries with a low level of per capita real income have a lower aggregate price level than countries with a higher level of per capita real income. Thus, if these countries will grow faster due to their economic backwardness they will also

36 In addition, to ease the strains on the balance of payments the Bundesbank together with the Federal Government resorted to somewhat artificial measures with respect to the capital account such as the first major programme of aid to developing countries in 1960, the premature repayment of foreign debt in 1961, the subsidization of capital exports by offering favourable terms for hedging against exchange rate risks for West German buyers of U.S. treasury bills in 1964, the prohibition of interest payments on foreign time deposits in West Germany in 1964, and the introduction of a 25% "coupon tax" on interest payments accruing to foreign holders of German bonds in 1965. For details see GIERSCH ET AL. (1994) and ALECKE (1999).

have higher inflation rates, resulting in a revaluation of their real exchange rate.

Obviously, the Balassa-Samuelson theorem implies for the CEECs that, with higher growth rates, their inflation rates will also be higher than in the incumbent countries of the EMU. As long as capital markets, the ECB, and – in contrast to the German Bundesbank during the Bretton Woods system – the central banks of the CEECs will accept higher inflation rates, the resulting revaluation of the real exchange rate would be perfectly compatible with a stable nominal exchange rate. However, the Maastricht criteria specify that, at the time of adoption of the euro, the inflation rates of the CEECs should not exceed the average inflation rate of the three countries with the most stable price level inside the euro area by more than 1.5 percentage points. Thus, the CEECs will find themselves in a kind of dilemma position, since on the one hand accession to the EU and the adoption of the euro will urge them to achieve low inflation rates, whereas on the other hand they have to fully liberalize capital account transactions and peg their currencies – conditions, under which inflation targeting will simply not be a feasible strategy for monetary policy. Although this policy dilemma has been widely recognized in the literature as a theoretical inconsistency of the approach to the monetary integration of the candidate countries taken by the EU, at present there remains considerable uncertainty with regard to its empirical relevance (BACKÉ ET AL. 2002; BELKE and HEBLER 2002). It is here where the history of the Bretton Woods system remains a promising area of future research. The experience of West Germany suggests that Balassa-Samuelson type effects on future aggregate inflation rate differentials between the CEECs and the euro area should not be underestimated.

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Appendix: Data Description

Money: natural logarithm of M1;
Output: natural logarithm of index of industrial production;
Prices: natural logarithm of cost-of-living index;
Interest rate: natural logarithm of German daily money market rate;
U.S. interest rate: natural logarithm of three month treasury bill market rate.

The index of industrial production and the cost-of-living index were used since reliable data for GDP and GDP-price deflator were only available for the period after 1960. The German data stem from DEUTSCHE BUNDESBANK, *Monthly reports* (various issues). The U.S. interest rate was taken from DARBY ET AL. (1983).

Table A.1 ADF-Tests for Levels of Variables

Variable	t-value	Lag-Order	Included Deterministic Variables
Output	-1.53	6	Constant, Trend, Seasonal-Dummies
Price	-0.09	5	Constant, Trend, Seasonal-Dummies
Money	-2.19	4	Constant, Trend, Seasonal-Dummies
Short-Term Interest Rate	-4.27**	4	Constant, Seasonal-Dummies
US-Short-Term Interest Rate	-1.68	2	Constant, Seasonal-Dummies

Source: Own calculations.

Table A.2 ADF-Tests for First Differences of Variables

Variable	t-value	Lag-Order	Included Deterministic Variables
Output	-4.83**	5	Constant, Seasonal-Dummies
Price	-4.43**	2	Constant, Seasonal-Dummies
Money	-3.15*	3	Constant, Seasonal-Dummies
Short-Term Interest Rate	-4.98**	5	Constant, Seasonal-Dummies
US-Short-Term Interest Rate	-7.22**	1	Constant, Seasonal-Dummies

Notes: * denotes rejection at the 5% significance level.

** denotes rejection at the 1% significance level.

The appropriate lag length was established on the basis of a lag's individual t-statistics, in that proceeding from a lag of 8 quarters, the lag order is reduced until the first significant t-value appears at a 5% significance level.

Source: Own calculations.