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GERMAN UNIFICATION AND THE DEMAND FOR GERMAN M_3

by

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Abstract

This paper estimates a demand equation for German M_3 over the period 1971:1-1989:4, and studies its ability to predict all-German M_3 during 1990:1-1992:4 and (a measure of) western German M_3 during 1990:1-1994:1. Although the out-of-sample prediction errors appear serially correlated, the equation passes stability tests for the western German data until 1993:4, but rejects in 1994:1. The model fails stability tests for the all-German data, largely because the jump in the money stock at unification is larger than that in nominal GDP. A slight modification of the model estimated using data for the period up to 1990:4 predicts all-German M_3 very well in the period 1991:1-1992:4.

* This is a much revised and expanded version of a note entitled "Is the Demand for German M_3 Stable? A Note on the Econometric Evidence." I am grateful to seminar participants at the BIS for their very helpful comments.

Contents

1. Introduction

The conduct of monetary policy in Germany has in recent years been complicated by the tendency of M_3 growth to overshoot the Bundesbank's target ranges. In 1992, for instance, M_3 grew by 9.4%, far in excess of the target range of 3.5-5.5%. M_3 growth fell in 1993 to 7.4%, but nevertheless exceeded the target range of 4.5-6.6%. Moreover, between January and April 1994 M_3 expanded by 6.2% (corresponding to an annual growth rate of 15.4%), which should be compared with a target of 4-6% for the entire year. While the Bundesbank has viewed the tendency of M_3 to overshoot the target ranges as being due to a number of temporary disturbances, other observers have questioned whether the relationship between the stock of M_3, income and price levels and interest rates has remained stable following German unification, and whether it is useful to maintain M_3 as an intermediate target.[1]

While the issue of the stability of the money demand function has received substantial attention in the daily press, the econometric literature on the stability of the M_3 demand function is limited. Issing and Tödter (1994) estimate the demand for M_3 using data spanning 1976:1-1993:2, and do not reject the hypothesis of parameter constancy before and after 1990:2. Cassard et al. (1994) estimate a money demand equation using data for 1979:2-1990:2, but reject the hypothesis of forecast stability for the period 1990:3-1992:3. The OECD (1993) studies the demand for M_3 over the period 1970:1-1992:4 and finds that unification might have caused a slight shift in the level of the demand for M_3. Von Hagen (1993) estimates velocity equations for M_3 (and M_1) using data from 1965 to 1991:4, but rejects stability. The fact that these studies are inconclusive suggests that if the demand function has shifted, the shift is too small to be easily detected. Since using a longer span of data from the post-unification period facilitates the detection of changes in the money demand function, further work using more recent data is warranted.

This paper reviews the evidence on the econometric stability of the German M_3 demand function, focusing on the period after unification. The economic theory of the demand for money is well established, and we do not attempt to contribute to it. Instead, we focus squarely on the stability question.

It should be noted from the outset that there are two alternative ways in which this question can be addressed, and that the results are likely to be sensitive to the approach taken. One strategy is to interpret the stability question from a narrow statistical perspective. This can be done by estimating a demand equation incorporating dummies to allow the parameters to differ between the pre- and post-unification periods, and to test whether the dummies are statistically significantly different from zero. If so, the demand equation is said to be unstable.

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1 It should be noted that the Bundesbank uses an estimate of an "acceptable" rate of inflation, 2%, in calculating its monetary target. Inflation rates in excess of 2% will therefore tend to cause M_3 to grow faster than its target rates.

This approach is appealing, in particular since it is very easy to implement. However, there are two reasons why it may not shed much light on the stability question. First, parameter changes may be very significant from a statistical perspective, but be numerically small or for other reasons of little importance for monetary policy. For instance, central banks may attach little significance to short-run fluctuations in the money stock. If so, a statistically significant change in some short-run demand elasticity that leaves the long-run elasticity unchanged may be of little importance for the conduct of policy. Second, the dummy variable approach does not provide any information on "what the structural break looks like," in particular whether it is temporary or permanent. Indeed, a single outlier in the post-unification period may cause a dummy for the constant to be significant, leaving the researcher to wonder whether the money demand function shifted back after the disturbance.

The alternative strategy is to ask whether a researcher who had a good understanding of the determination of the demand for M_3 *before unification* would have reason to change this view in the light of the behaviour of M_3 *after unification.* A natural way to approach this question is to assess the out-of-sample predictive ability of a pre-unification money demand equation. This approach not only has the advantage of giving an indication of the economic importance a structural break, but also provides some information on whether any break is short-lived, persistent or even cumulative over time.

This paper follows this latter approach, and is structured as follows. In Section 2 we estimate a money demand equation on *pre-unification* western German data, emphasising the importance of parsimony and parameter constancy. In Section 3 the resulting equation is used to predict M_3 growth out-of-sample. Since there are large jumps in M_3 and real GDP at the time of unification, we assess the out-of-sample stability of the money demand function using both western and all-German data.

To offer a preview of the results, we find that when data on GDP and prices in the former Federal Republic are used to provide out-of-sample predictions of a measure of post-unification *western German* M_3 demand for the period 1990:1-1994:1, the out-of-sample prediction errors are all within the confidence bands with the exception of the first quarter of 1994. Furthermore, the equation passes Chow tests for stability for the period 1990:1-1993:4, but fails when the first quarter of 1994 is included in the prediction period. However, although small, the prediction errors are typically positive, which suggests that a limited structural shift may have occurred.

Next we use the model estimated on pre-unification western German data to construct out-of-sample predictions of *all-German* money demand for the period 1990:1-1992:4 (the latest date for which all-German data were available). Since the jump in the money stock at unification was larger than that in nominal GDP, the model underpredicts money growth substantially in the unification quarter (1990:3), and also in the two following quarters, and therefore fails econometric stability tests soundly. However, after 1991:2 actual money growth falls within, or on the upper limit of, the confidence bands, which suggests that a structural break, if it occurred, must have been small. Again, the main evidence of a shift in the parameters of the demand function is that the prediction errors are typically positive, although the shift is not obvious.

In Section 4 the model is re-estimated on *western German data* for 1971:1-1990:2 and *all-German data* for 1990:3-1990:4, incorporating two dummies to allow for the fact that at unification the jump in the money stock was larger than that in nominal GDP and for a change in the intercept. We find that both dummies are significant. Furthermore, out-of-sample predictions for the period 1991:1-1992:4 indicate that this all-German demand function predicts very well. In particular, there is no evidence of any further shift in the demand function in the prediction period. Together with the out-of-sample predictions reviewed above, these results suggest that to the extent that unification and the switch from western German to all-German data introduced a shift in the demand function, the shift is small, permanent, and easily captured econometrically.

Some conclusions are provided in Section 5. An inherent problem with studying the stability of the demand for German M_3 is that demand functions have to be estimated on western German data, but are evaluated on all-German data, or on the basis of an *estimate* of post-unification western German M_3. While the results presented in this paper should therefore be interpreted with caution, they suggest a number of conclusions. First, the results are difficult to reconcile with the notion that German unification caused the demand function for M_3 to become fundamentally unstable; the issue is not whether the demand function is subject to an ongoing series of shocks, but rather if there was a once-and-for-all shift. Second, when *western German* post-unification data are used, the out-of-sample predictions and the tests for parameter stability offer little reason to believe that the parameter of the pre-unification demand function shifted before the large movements in M_3 in early 1994.[2] Thus, if a shift in the demand function occurred at unification it is so small that the prediction errors still fall inside the confidence band. Indeed, the only hint of a shift is that, while small, the prediction errors are typically positive. Third, while the model the fails to predict *all-German* post-unification data, this finding appears largely due to the fact that the jump of the money stock at unification was much larger than that in nominal GDP, and is for that reason not very informative. However, the prediction errors after unification are also in this case typically positive. Fourth, a demand equation estimated across the unification break, and incorporating dummies to account for a possible shift in the parameters, does provide support for the hypothesis of a small shift. An assessment of out-of-sample predictions of this model suggests furthermore that the break is well captured by the two dummies.

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2 See the Monthly Report of the Deutsche Bundesbank, June 1994, pp. 18-19, for a discussion of the causes of the movements in M_3 in late 1993 and early 1994.

2. The model

The by now standard approach in empirical studies on the demand for money involves estimating error-correction methods.[3] This methodology is particularly appropriate for the problem at hand for two reasons. First, while money stocks, price levels and income levels are non-stationary, they may well be cointegrated. If so, econometric models that disregard this property of the data are misspecified. Second, error-correction models allow for a broad range of dynamic interrelationships between the variables. As noted by Rose (1985) and Boughton (1992), one important reason why traditional money demand functions of partial adjustment type display parameter instability is that they impose (untested) constraints on lag patterns that are typically rejected by the data. Given that we are interested in the stability of the money demand function, we therefore make use of the error-correction strategy. Before turning to the estimated equations, we first review the data and the results from preliminary unit root and cointegration tests.

2.1 Choice of data

In order to estimate the M_3 demand functions we first need to select the time series to be used. The quarterly data on the money stock, m_t, are an average of the monthly observations. For real income and prices we use real GDP, y_t, and the GDP deflator, p_t. These time series are all seasonally adjusted. We use two interest rates for the analysis: a long bond yield, R_t, and a measure of the yield on M_3, r_t, which, following Issing and Tödter (1994), is measured by a weighted average of the interest rates paid on the components of M_3.[4] Of course, other definitions of variables could be used. However, these definitions are so "standard" that if a demand function estimated using these was stable, it would cast serious doubt on the claim that the behaviour of German M_3 had become fundamentally unstable.

2.2 Unit roots and cointegration

As a preliminary step, we performed unit root and cointegration tests. It is by now well-known that such tests are not very powerful. Despite this, they are useful in that they provide at least some guidance on whether, for instance, the interest rates are stationary or not (and thus whether they should be used in differenced or level form), or what are plausible restrictions on the parameters in the cointegrating vector.

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3 Boughton (1992) surveys the recent empirical literature on money demand. Boughton and Tavalas (1991) provide empirical results on the demand for money in the G-5 countries using several different estimation strategies, and provide a number a references to the literature using the error-correction approach.

4 More precisely, the own yield of M_3 was constructed as a weighted average of the yield on time deposits (with a weight of 0.24) and the yield on savings deposits (with a weight of 0.42) and the (zero) yield on currency (with a weight of 0.34). These weights are the same as those used by Issing and Tödter (1994).

The results from Augmented Dickey-Fuller (ADF) unit root tests are presented in Table 1. Two findings are of interest. First, the tests reject the hypothesis of a unit root in the yield on M_3, and in the spread between the long bond rate and the yield on M_3. Furthermore, given the low power of ADF tests, the results also suggest that the long bond yield may be stationary.[5] Thus, the interest rates should appear in level form in the regressions that follow. Second, while the test on (the inverse of) velocity indicates that we can accept the unit root hypothesis, in the light of the weak power of the test, velocity may also be stationary.[6] If so, the long-run income and price elasticities may well be unity.

Table 1
Unit root tests
Augmented Dickey-Fuller tests

Variable	Trend	No. lags	ADF Stat.
Δm_t	Yes	2	-3.96**
Δp_t	Yes	3	-3.32*
Δy_t	No	3	-3.16**
R_t	No	3	-2.48
r_t	No	4	-3.02**
R_t-r_t	No	1	-3.80**
$m_t-p_t-y_t$	Yes	0	-3.02

Notes: */**/*** indicates significance at 10/5/1 percent level. The data period is 1971:1-1989:4; actual sample period used depends on the number of lags. The number of lags was determined by estimating the equation with four lags and a time trend, and sequentially dropping the last lag if a t-test indicated that it was insignificant. Once the lag length was determined, a t-test on the time trend determined whether it should be dropped or not. Critical values are from MacKinnon (1991).

Table 2 presents the results from tests for cointegration between money, prices and real income. We first test for cointegration between m_t, p_t, and y_t, and reject the hypothesis that these variables are not cointegrated. Next, we assume that the coefficient on income is unity, and test whether m_t-y_t is cointegrated with p_t, and find that imposing this restriction does not change the earlier finding of cointegration. Finally, we impose the restriction of a unit coefficient on the price level, and again find that cointegration appears present.

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5 The test statistic is 2.48, which can be compared with a critical value of 2.59 for a test at the 10% level.

6 The test statistic is 3.02; the critical value for a test at the 10% level is 3.16.

The results in Tables 1 and 2 shed light on the likely size of the long-run price and income elasticities. The test for cointegration between money, prices and income implies that the *point estimate* of the long-run price elasticity is almost 1.4, and that the long-run income elasticity is close to unity. Imposing a unit price elasticity, which is plausible from a theoretical perspective, increases the point estimate of the income elasticity to about 1.6. This suggests, as we show more clearly later, that there is a negative relationship between the point estimates of the price and income elasticities, and that they are imprecisely estimated. One particularly interesting restriction to test is the hypothesis of unit price and income elasticities. However, as noted in the discussion above, when these restrictions are imposed we are unable to reject the null of no cointegration at the 10% level.

Table 2
Cointegration tests
Augmented Dickey-Fuller tests

Estimated cointegrating vector	No. lags	ADF Stat.
$m_t-1.38p_t-1.03y_t$	4	-4.14**
$m_t-1.36p_t-y_t$	4	-4.08***
$m_t-p_t-1.65y_t$	4	-3.27*

Notes: */**/*** indicates significance at 10/5/1 percent level. The data period is 1971:1-1989:4; actual sample period used depends on the number of lags. The number of lags was determined by estimating the equation with four lags and sequentially dropping the last lag if a t-test indicated that it was insignificant. Critical values are from MacKinnon (1991).

In interpreting the cointegration tests on m_t, p_t and y_t, two caveats should be kept in mind. First, as argued by Kremers, Ericsson and Dolado (1992), ADF tests constrain the short and long-run dynamics of the time series to be the same, which impairs the power of the test. The lack of power suggests that it is premature to infer that imposing unit price and income elasticities leads us to reject cointegration on the basis of the evidence above. Second, from the cointegration tests we obtain *point estimates* of the long-run elasticities, but we have no way of performing significance tests on different hypotheses (since t-statistics of cointegrating regressions are of little value). Since Kremers, Ericsson and Dolado (1992) show that a more powerful test of cointegration is given by a test of the significance of the error-correction term, and since it is possible to perform hypothesis tests on the parameters on unrestricted error-correction models, we proceed with the estimation of the money demand equations, and return to the cointegration issue below.

2.3 Estimation

The starting-point for the econometric work is a deliberately overparametrized money demand equation of the form

$$(1) \qquad \Delta m_t = \alpha + \sum_{i=1}^{4} \beta_i m_{t-i} + \sum_{i=0}^{4} (\gamma_i y_{t-i} + \pi_i p_{t-i} + \lambda_i R_{t-i} + \delta_i r_{t-i}) + \mu T_t + \varepsilon_t$$

where Δ denotes the difference operator and where T_t, m_t, y_t, p_t, R_t and r_t denote a time trend, the logarithms of the money stock, real GDP, the GDP deflator and the levels of the long bond yield and the yield on M_3. Since error-correction models impose restrictions on (1), this equation provides a benchmark against which more restricted money demand equations can be judged.

The opening of the Berlin Wall in November 1989 led to expectations of currency union, so that the money demand equation may have shifted already in the spring of 1990. We therefore estimate the equation on quarterly western German data spanning 1971:1-1989:4. The parameter estimates for this "straw man" are not particularly interesting -- as expected most of the parameters are highly insignificant -- and for space reasons we do not report them here. More relevant is the log likelihood (296.53), which is used below to test restricted versions of the equation.[7]

Following the "general-to-specific" strategy, the equation was then "reduced" by sequentially testing and imposing restrictions. This process results in the following regression (t-statistics in parenthesis)

$$(2) \quad \Delta m_t = \underset{(2.14)}{0.42} + \underset{(1.62)}{0.12\Delta y_t} - \underset{(4.06)}{0.0049R_{t-2}} + \underset{(2.21)}{0.0036r_{t-2}} - \underset{(1.44)}{0.09m_{t-1}} + \underset{(1.39)}{0.12p_{t-1}} + \underset{(0.55)}{0.04y_{t-1}} + \varepsilon_t$$

Period: 1971:1-1989:4; $\overline{R}^2 = 0.53$; DW = 1.82; SSR = 0.0024; log likelihood = 285.29; SEE = 0.0059; Schwarz = -9.95; Akaike = -10.16

which links nominal M_3 growth to the contemporaneous growth in real income twice-lagged bond and M_3 yields and the once-lagged level of money, GDP and prices. A likelihood ratio test of the restrictions embodied in equation (2) yields a Marginal Significance Level (MSL) of 0.26, and the restrictions are thus not rejected. Note that the two interest elasticities are of opposite signs as implied by theory, numerically quite similar and very significant. A Wald test of the hypothesis that the coefficients are equal but of opposite sign does not reject (MSL = 0.16), and we therefore impose this restriction and re-estimate the equation. The resulting regression is

[7] Other statistics that are useful in assessing more restricted equations are the $\overline{R}^2$ (0.51), SEE (0.0060), SSR (0.0018), and the Schwartz (-9.16) and Akaike (-9.96) information criteria.

$$(3)\quad \Delta m_t = \underset{(1.75)}{0.33} + \underset{(2.16)}{0.16}\Delta y_t - \underset{(4.14)}{0.0050}(R_{t-2} - r_{t-2}) - \underset{(1.23)}{0.08}m_{t-1} + \underset{(1.15)}{0.09}p_{t-1} + \underset{(0.55)}{0.04}y_{t-1} + \varepsilon_t$$

Period: 1971:1-1989:4; $\bar{R}^2 = 0.55$; DW = 1.81; SSR = 0.0025; log likelihood = 284.23; SEE = 0.0060; Schwarz = -9.97; Akaike = -10.16

The lagged money stock, income and price level in equation (3) form an unrestricted error-correction term, from which we can calculate that the point estimate of the long-run price elasticity is 1.25 and that of the income elasticity 0.52. The estimated price elasticity is thus somewhat large, and the income elasticity is rather low. However, the standard errors for the long-run restrictions are quite large, at 0.21 and 0.58 respectively, and Wald tests do not reject the hypotheses of unit price (MSL = 0.45) and income (MSL = 0.21) elasticities.[8] Nor does a test of the joint hypothesis that the long-run price and income elasticities are unity (MSL = 0.44) reject. It does deserve noting that, while the three level variables individually are insignificant, jointly they are significantly different from zero (MSL = 0.00).

Next we imposed unit long-run elasticities, and re-estimated the equation and obtained

$$(4)\quad \Delta m_t = \underset{(10.40)}{0.09} + \underset{(2.78)}{0.17}\Delta y_t - \underset{(4.02)}{0.0045}(R_{t-2} - r_{t-2}) - \underset{(8.28)}{0.07}(m_{t-1} - p_{t-1} - y_{t-1}) + \varepsilon_t$$

Period: 1971:1-1989:4; $\bar{R}^2 = 0.54$; DW = 1.78; SSR = 0.0026; log likelihood = 283.35; SEE = 0.0060; Schwarz = -10.07; Akaike = -20.19

This regression warrants two comments. First, the coefficients on the interest rate and the growth rate of real income are unaffected by the imposition of the long-run restrictions, and a likelihood ratio test of the restrictions imposed by this equation on (1) does not reject (MSL=0.26). Second, the error-correction term is extremely significant, which suggests that money, income and prices are cointegrated.[9] This finding is interesting since the ADF test does not reject the hypothesis of a unit root in $(m_{t-1} - p_{t-1} - y_{t-1})$ and illustrates the fact that it is quite common that ADF tests fail to reject the hypothesis of no cointegration while at the same time estimated error-correction models indicate that cointegration is present. As shown by Kremers, Ericsson and Dolado (1992), this is due to the fact that the ADF test constrains the short and long-run dynamics to be the same; if this common factor restriction is violated by the data, the power of the ADF test will deteriorate. This issue is of wider interest and we return to it below.

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8 The standard errors are computed as in Bårdsen (1989). See also the discussion in Banerjee et al., (1993), pp. 61-64.

9 One question that arises in this context is that of the distribution -- the ADF or the normal -- to be used in testing for the significance of the error-correction term (see the discussion in Kremers, Ericsson and Dolado (1992)). Given the size of the t-statistic, in this context this issue appears moot.

2.4 Diagnostic tests and recursive estimates

Next, a number of diagnostic tests were performed on equation (4), with the results being shown in Table 3. The Lagrange multiplier and the Ljung-Box Q-statistics do not reject the hypothesis of no fourth-order serial correlation. A Jarque-Bera (1980) test accepts the hypothesis of normality. A White (1980) test for conditional heteroscedasticity and an Engle (1982) test for fourth-order autoregressive conditional heteroscedasticity also fail to reject, as does a Ramsey (1969) RESET test (incorporating 2 powers) for specification error. Finally, a Chow test for a mid-sample break (1980:3) also does not reject the hypothesis of parameter constancy.

Table 3
Diagnostic tests on equations (4) and (8)
Marginal significance levels

Test	MSLs for eqn. (4)	MSLs for eqn. (8)
LM (4)[1]	0.41	0.32
Q-statistics[1]	0.48	0.41
Jarque-Bera[2]	0.77	0.79
White[3] (no cross terms)	0.21	0.35
(with cross terms).........	0.27	0.40
ARCH (4)[4]	0.14	0.12
RESET (2)	0.24	0.20
Chow (1980:3)[5]	0.27	--

Note: The marginal significance level is the estimated probability that the null hypothesis is true (thus, we reject at the 5% level if MSL is less than 0.05); LM denotes Lagrange multiplier test.

[1] Test for fourth order serial correlation. [2] Test for normality. [3] Test for heteroscedasticity. [4] Test for fourth order ARCH effects. [5] Chow test for parameter constancy at mid-sample.

The equation was also estimated recursively. The plots of the estimated parameters in Figure 1 suggest that the equation is stable in the estimation period. This conclusion is supported by the evidence in Figure 2, which presents CUSUM and CUSUM of squares plots, as well as 1-step and N-step ahead forecast errors. With the possible exception of the CUSUM of squares, these plots do not provide any evidence suggesting that the demand equation is unstable.

In sum, we conclude that equation (4) constitutes a parsimonious model of the pre-unification demand for western German M_3, and that the estimated parameters are constant within the estimation period. The question now arises whether this demand function also characterises the post-unification demand for M_3. Before we turn to the out-of-sample

FIGURE 1
RECURSIVE ESTIMATES

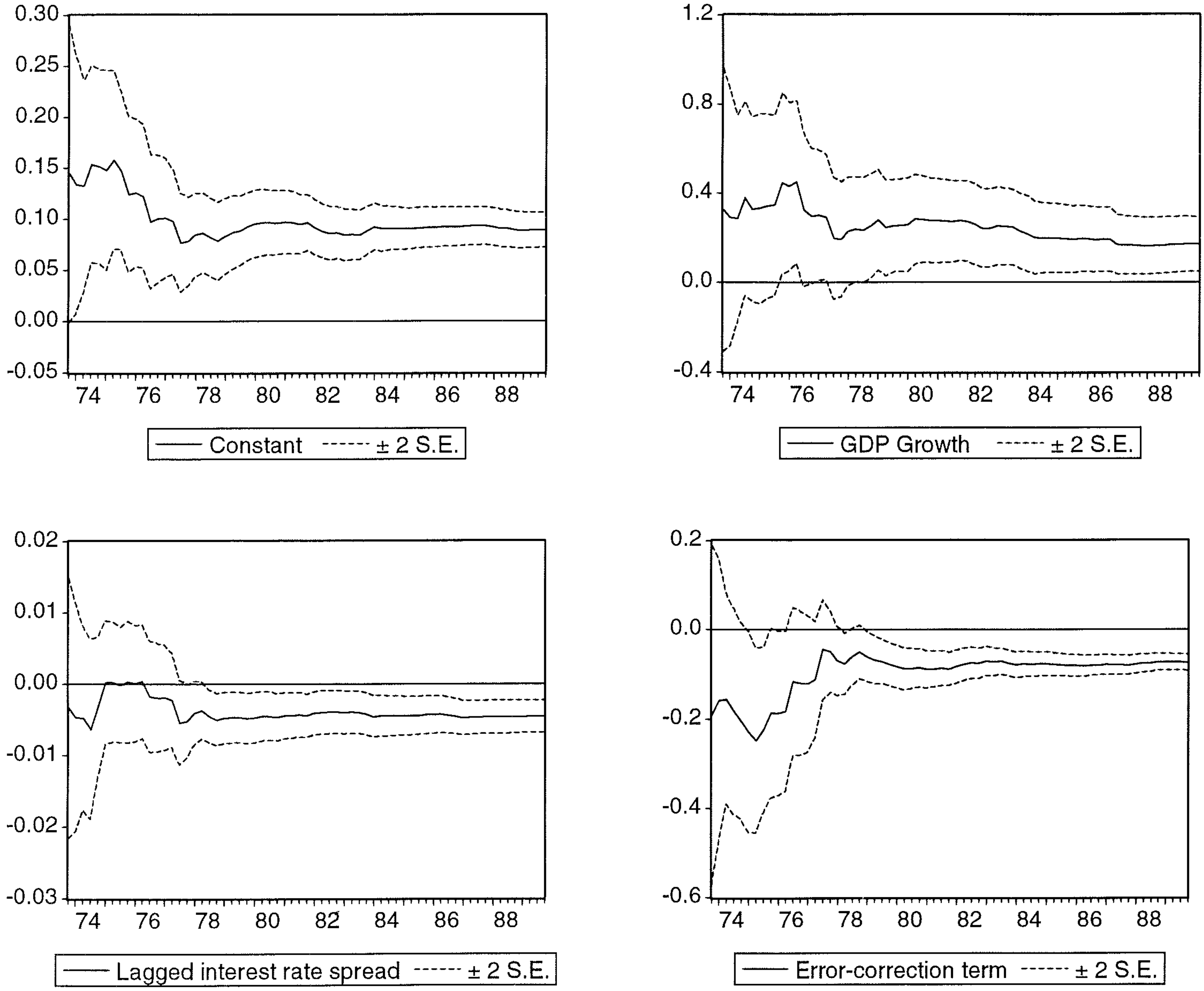
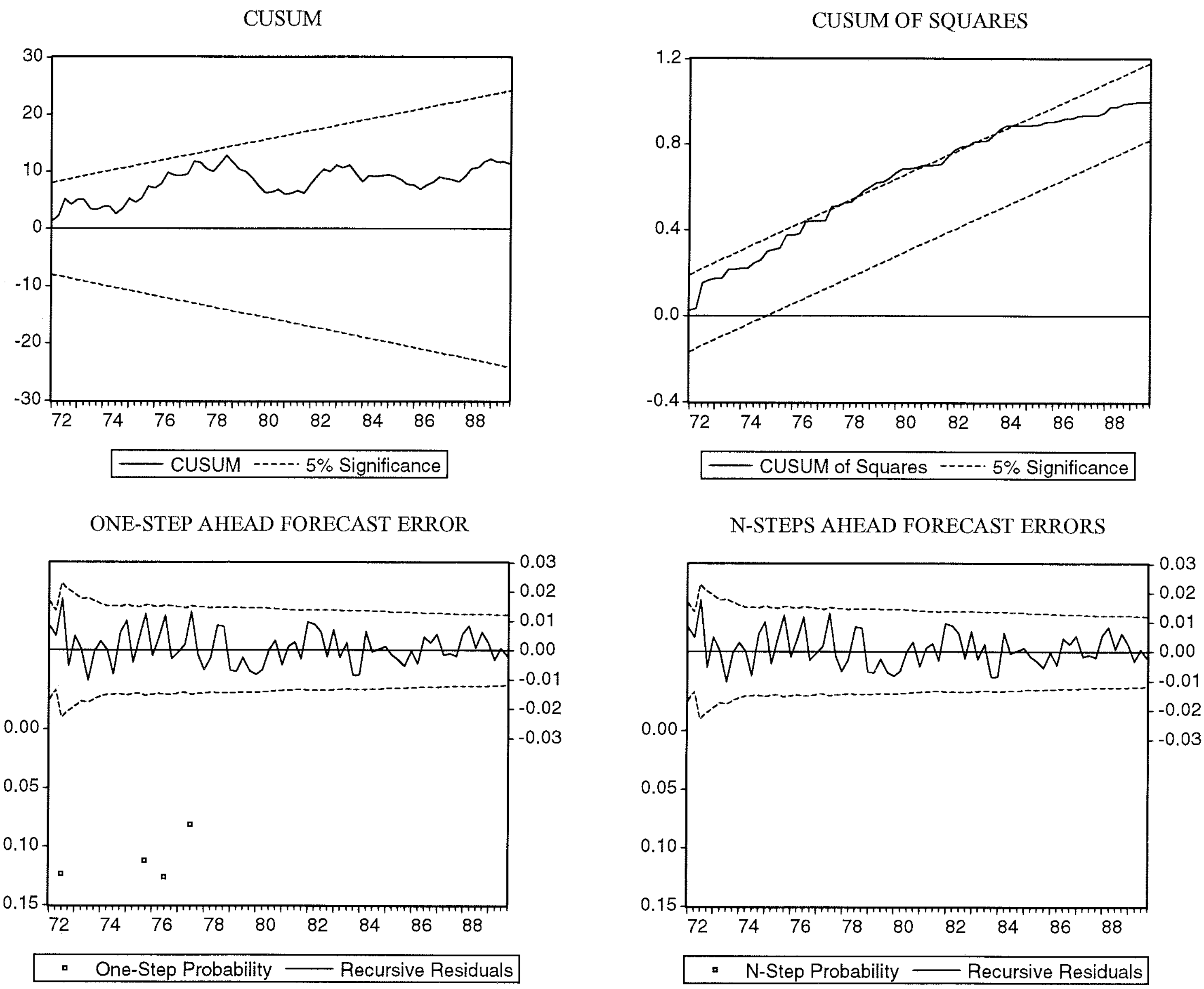


FIGURE 2


CUSUM
30
20
10
0
-10
-20
-30
72 74 76 78 80 82 84 86 88
CUSUM 5% Significance
CUSUM OF SQUARES
1.2
0.8
0.4
0.0
-0.4
72 74 76 78 80 82 84 86 88
CUSUM of Squares 5% Significance
ONE-STEP AHEAD FORECAST ERROR
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
0.00
0.05
0.10
0.15
72 74 76 78 80 82 84 86 88
One-Step Probability Recursive Residuals
N-STEPS AHEAD FORECAST ERRORS
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
0.00
0.05
0.10
0.15
72 74 76 78 80 82 84 86 88
N-Step Probability Recursive Residuals

predictions, however, we return to the issue of whether money, prices and income are cointegrated and, if so, what the likely values of the long-run price and income elasticities are.

2.5 Are money, prices and income cointegrated?

As noted above, while an ADF test fails to reject the hypothesis of a unit root in $(m_{t-1}-p_{t-1}-y_{t-1})$, the error-correction parameter in equation (4) is highly significant. To see the relationship between the regression underlying the ADF test and the error-correction model, we follow the thrust of the paper by Kremers, Ericsson and Dolado (1992) and add Δp_t and a time trend (which we previously dropped since they were insignificant) to the equation, and re-estimate it

$$(5)\quad \underset{}{\Delta(m_t-p_t-y_t)} = \underset{(3.26)}{0.10} - \underset{(11.84)}{0.81}\Delta y_t - \underset{(8.30)}{0.96}\Delta p_t - \underset{(3.87)}{0.0044}(R_{t-2}-r_{t-2}) - \underset{(2.09)}{0.09}(m_{t-1}-p_{t-1}-y_{t-1})$$

$$- \underset{(0.44)}{6.88E{-}05}\text{trend} + \varepsilon_t$$

Period: 1971:1-1989:4; $\bar{R}^2$ = 0.73; DW = 1.75; SSR = 0.0026; log likelihood = 283.49; SEE = 0.0060; Schwarz = -9.96; Akaike = -9.96

Since the time trend remains insignificant, we re-estimate the equation without the time trend and obtain

$$(6)\quad \Delta(m_t-p_t-y_t) = \underset{(8.70)}{0.09} - \underset{(12.82)}{0.83}\Delta y_t - \underset{(8.42)}{0.97}\Delta p_t - \underset{(3.97)}{0.0045}(R_{t-2}-r_{t-2}) - \underset{(6.87)}{0.07}(m_{t-1}-p_{t-1}-y_{t-1}) + \varepsilon_t$$

Period: 1971:1-1989:4; $\bar{R}^2$ = 0.73; DW = 1.77; SSR = 0.0026; log likelihood = 283.38; SEE = 0.0060; Schwarz = -10.01; Akaike = -10.16

which can be compared with the "ADF regression"

$$(7)\quad \Delta(m_t-p_t-y_t) = \underset{(3.18)}{0.12} - \underset{(3.02)}{0.22}(m_{t-1}-p_{t-1}-y_{t-1}) + \underset{(2.68)}{0.0007}\text{ trend} + \varepsilon_t$$

Period: 1971:1-1989:4; $\bar{R}^2$ = 0.10; DW = 2.12; SSR = 0.0088; log likelihood = 236.70; SEE = 0.0109; Schwarz = - 8.90; Akaike = -8.99

Note that the ADF regression (7) fits the changes in velocity relatively poorly: the standard error of the estimate is 80% larger than the standard error in equation (5). Furthermore, the standard error of the parameter on $(m_{t-1}-p_{t-1}-y_{t-1})$ is 70% larger than the standard error in equation (5). The reason why the ADF test fails to reject the hypothesis of no cointegration is that it implicitly imposes the restrictions that the coefficients on Δp_t and Δy_t are zero. As can be seen from equations (5) and (6), these restrictions are blatantly rejected by the data. Note also that dropping the insignificant time trend in (5) yields a large increase in the absolute value of the t-statistic on the error-correction term from 2.09 to 6.87.

2.6 Long-run price and income elasticities

The long-run price and income elasticities are important for the conduct of monetary policy since they are used to compute a benchmark for the M_3 target. Given the importance of the long-run elasticities, it is not surprising that empirical research on money demand relationships typically reviews these elasticities in detail.[10] Unfortunately, such a discussion is moot in the German case, because the data are essentially silent on the important question of what these elasticities are.

To see this, consider Figure 3, which plots 5, 20, and 50% confidence regions for the long-run price and income elasticities implied by equation (4) above. As can be seen, at the 5% level essentially no plausible combination of long-run price and income elasticities is rejected by the data. While the point estimate of the price elasticity is 1.25 and that of the income elasticity 0.52, the hypothesis that both are 0.8 or, for that matter, 1.4 is accepted. Thus, the data do not enable us to infer much about the long-run elasticities.

Two further comments on Figure 3 are warranted. First, note that the confidence regions are elliptical, running from north-west to south-east. Thus, high point estimates of the price elasticity are associated with low point estimates of the income elasticity, as noted earlier. Second, since monetary theory asserts that the price elasticity of money demand is unity, the question arises what, conditional on this assumed value of the price elasticity, is the most plausible value of the income elasticity. While we are unable to reject income elasticities between -0.3 and 2, the confidence regions are vertical at an income elasticity of about unity, suggesting that, assuming a price elasticity of unity, this is the most plausible value of the income elasticity. We therefore conclude that the assumption of unit price and income elasticities does appear plausible given the data.

3. Out-of-sample stability

The conduct of monetary policy using an intermediate monetary target presupposes that the demand function for the selected aggregate is stable. In this section we assess whether the errors associated with out-of-sample forecasts from equation (4) are small relative to estimated confidence bands. We also perform formal tests for parameter instability. Before doing so, however, it is useful to review the effect of German unification on the time series for money, income and prices used here.

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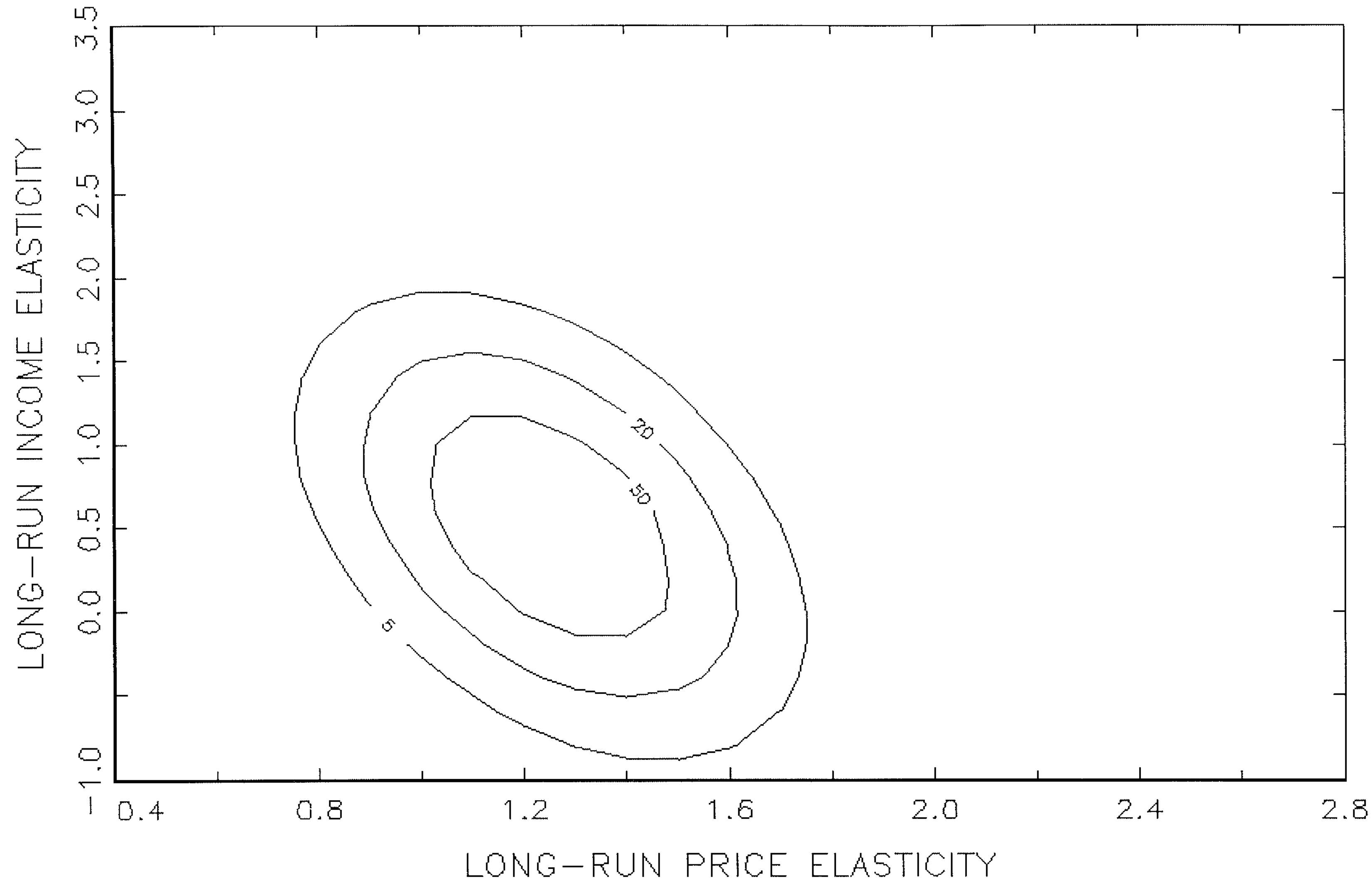
[10] See, for example, the discussion in Fase and Winder (1993), Monticelli and Strauss-Kahn (1992), and Boughton (1991a,b).

FIGURE 3

CONFIDENCE REGIONS FOR ESTIMATED LONG-RUN ELASTICITIES



3.1 German unification

The major difficulty with assessing the stability of the demand for M_3 in Germany is that the monetary and political unification of Germany in 1990 was associated with large breaks in the time series for money and GDP. It is therefore not clear how to assess the stability of the demand function. Essentially, two strategies can be followed to produce out-of-sample forecasts.

A researcher can use data on GDP and the GDP deflator in the former western Germany to predict the *western German money stock.* However, after unification there are neither any data on the "western German" money stock, nor is the notion of a "western German" money stock well-defined, since the geographical location of currency is inherently unknown and the location of banks and depositors need not coincide. Thus, to pursue this approach, an estimate of "western German M_3" must first be made, on which all subsequent results are contingent. Alternatively, a researcher can use data on all-German GDP and prices to predict the *all-German money stock.* Unfortunately, there are problems also with this second strategy. First, estimates of GDP in the former GDR are likely to be subject to significant errors, in particular in the period immediately after unification. Second, since the jump in the money stock at unification was larger than that in nominal GDP, any model estimated on pre-unification data will underpredict money growth in the period immediately after unification. With the model bound to fail formal stability tests, the researcher is left with the question whether it would have failed such tests in the absence of the large prediction error in the unification quarter. Since therefore neither strategy is clearly preferable, we use both strategies below.

Consider the plot of all-German M_3 in Figure 4.[11] The series has been seasonally adjusted by the Bundesbank, and for technical reasons the break in the deseasonalised series does not occur in 1990:3 but rather in 1991:1, when M_3 increased by 14.0%.[12] One simple way in which a measure of western German M_3 after unification can be computed is to subtract the estimated size of the jump from the all-German money stock from 1991:1 onwards.[13] Since the

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[11] The quarterly data are constructed as an average of the monthly observations.

[12] In the seasonally unadjusted series the break occurs in the third quarter of 1990.

[13] In order to adjust the series, a simple ARMA model was estimated on the underlying monthly data, including dummies for the months in which jumps occurred (1985:12 when the reporting basis was expanded to incorporate also "all credit cooperatives" and 1991:1), using data for the period 1970:3-1994:05. Different ARMA yielded very similar results. The model finally selected was ARMA(1,1), and was given by (t-statistics in parenthesis)

$$\Delta m_t = \underset{(7.18)}{0.0063} + \underset{(7.43)}{0.028}\ \text{DUM8512} + \underset{(31.81)}{0.120}\ \text{DUM9101} + \varepsilon_t$$

where

$$(1 - \underset{(3.78)}{0.695}L)\ \varepsilon_t = (1-\underset{(3.20)}{0.521}L)\ \zeta_t$$

jump in all-German M_3 is reported two quarters after unification and after the jump in real GDP, we construct a new all-German M_3 series by adding the estimated size of the jump to the western German series for the quarters 1990:3-1990:4 and use the all-German data thereafter. The resulting all-German and western German M_3 series are also plotted in Figure 4.

Figure 4 also plots all-German and western German real GDP and the GDP deflator. As can be seen, German unification leads to a 10.3% jump in all-German GDP in the third quarter of 1990. Note that since the GDP deflator was not much affected by unification, it follows that the jump in the money supply exceeded the jump in nominal GDP at the time of unification by about 4%. Since the standard error of the estimate of equation (4) is about 0.6%, the model will clearly underpredict the demand for all-German M_3 when unification occurs in 1990:3.

3.2 Predictive ability

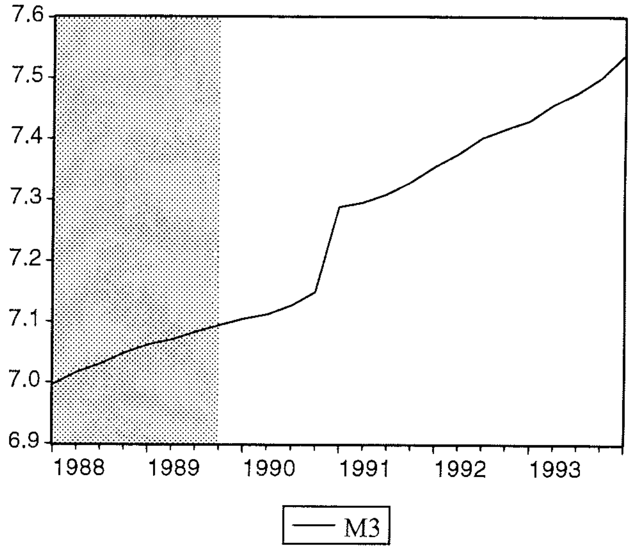
As a first step, the equation fitted on data for 1971:1-1989:4 was used to generate out-of-sample predictions of *western German* M_3 growth in the period 1990:1-1994:1, using western German GDP and the GDP deflator. For expository reasons, the implied four-quarter growth rates are plotted in Figure 5 together with ± 2 standard error wide confidence bands. These predictions are "static", that is, actual values of the exogenous and lagged dependent variables have been used to compute predictions of money growth. As can be seen, the confidence bands are approximately 2.5% wide, that is, of the same order of magnitude as the width of the Bundesbank's target range for M_3. The figure illustrates that actual M_3 growth remains within the confidence bands for most of the prediction period, with the exception of the last two quarters, 1993:4-1994:1, when M_3 growth increased drastically. Actual growth rates also reached the upper edge of the confidence band in 1992:3, when heavy capital inflows led to rapid growth of M_3, and also in 1993:2.

To test more formally the hypothesis that the parameters in the demand function are constant, Chow breakpoint and forecast tests were performed for a break in 1990:1, and the MSLs for the hypothesis of no structural break are plotted in Figure 6. Since the breakpoint test requires the equation to be re-estimated on out-of-sample data, the MSLs for the breakpoint version of the test start only in 1991:1. As the figure shows, it is not possible to reject the hypothesis of parameter constancy when out-of-sample data over the period 1990:1-1993:4 are used; only when data for the first quarter of 1994 are used can the hypothesis of parameter constancy be rejected. Thus, the Chow tests offer little formal evidence of a shift in the demand function for M_3. However, one indication that the equation may have shifted is that fourteen of the seventeen out-of-sample prediction errors are positive. Under the null hypothesis that

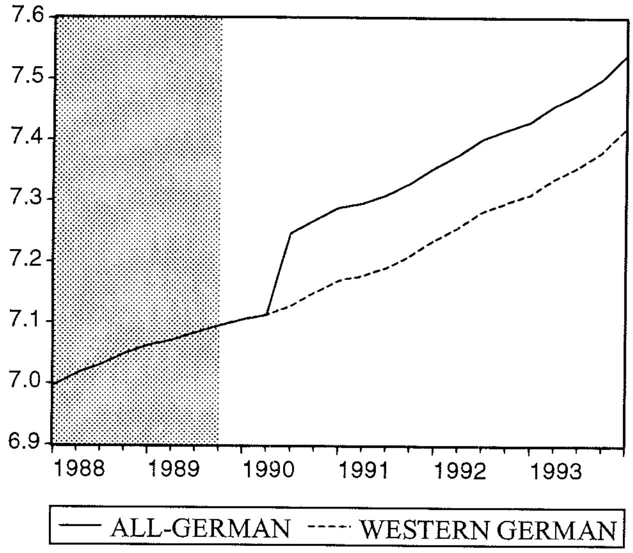
(where L denotes the lag operator) with adj. R^2 = 0.72. The jump at unification was therefore estimated to be 12%.

FIGURE 4
DATA BEFORE AND AFTER UNIFICATION
(Estimation period shaded)

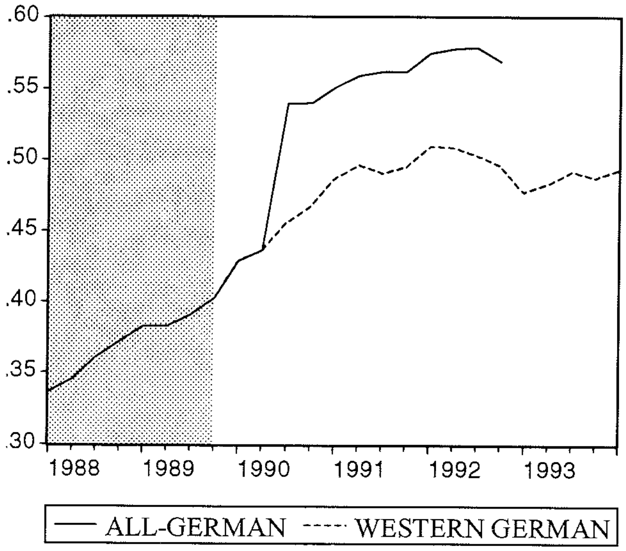
UNADJUSTED M3
(logarithms)



ADJUSTED M3
(logarithms)



REAL GDP
(logarithms)



GDP DEFLATORS
(logarithms)

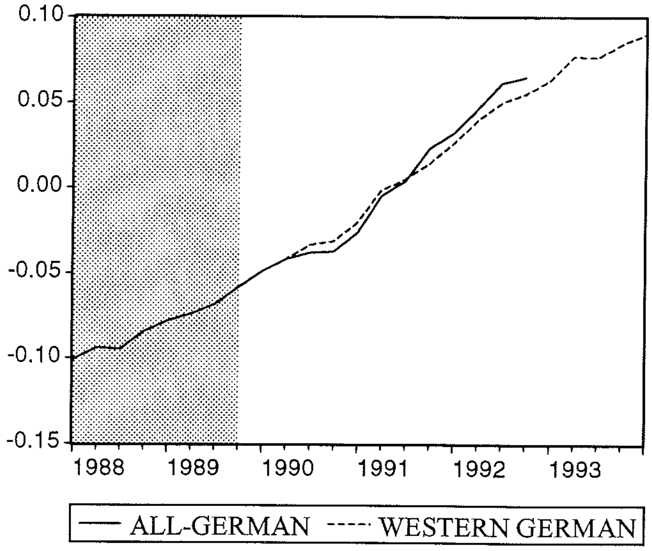


FIGURE 5
OUT-OF-SAMPLE PREDICTIONS
WESTERN GERMAN DATA
(Growth rates over 4 quarters, in %)

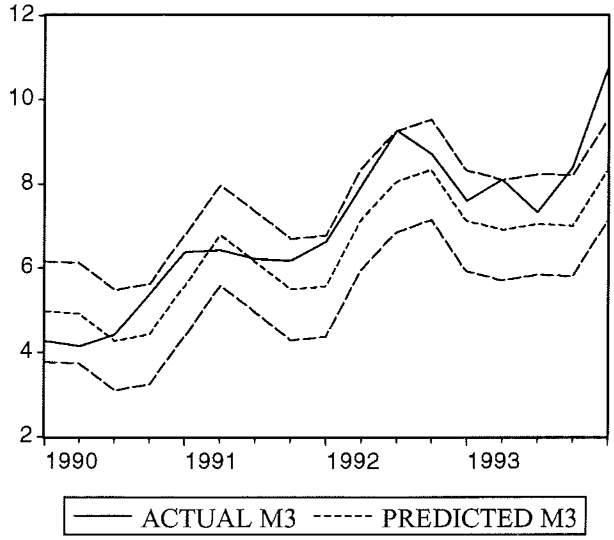


FIGURE 6
MARGINAL SIGNIFICANCE LEVELS
FOR CHOW TESTS

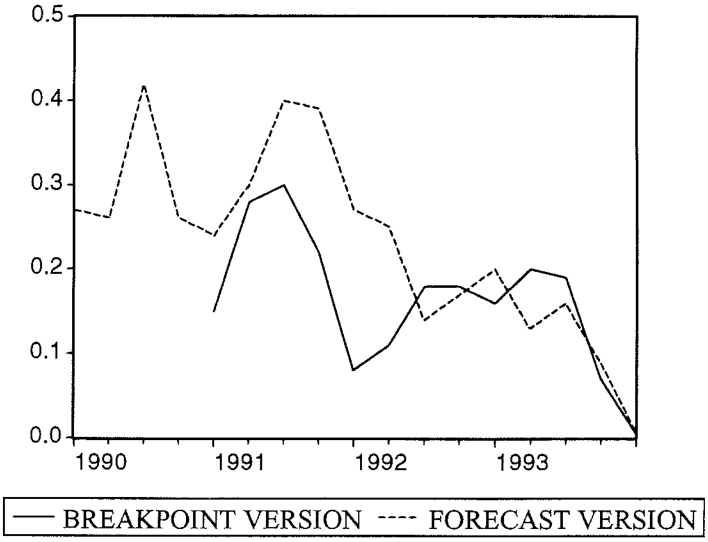


FIGURE 7
OUT-OF-SAMPLE PREDICTIONS
ALL-GERMAN DATA
(Growth rates over 4 quarters, in %)

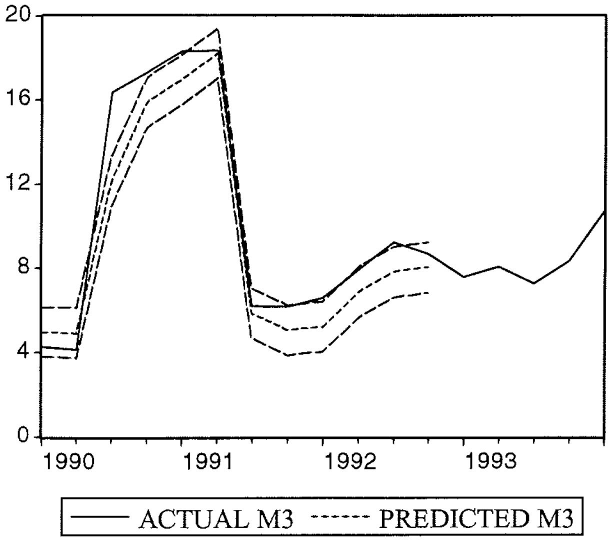
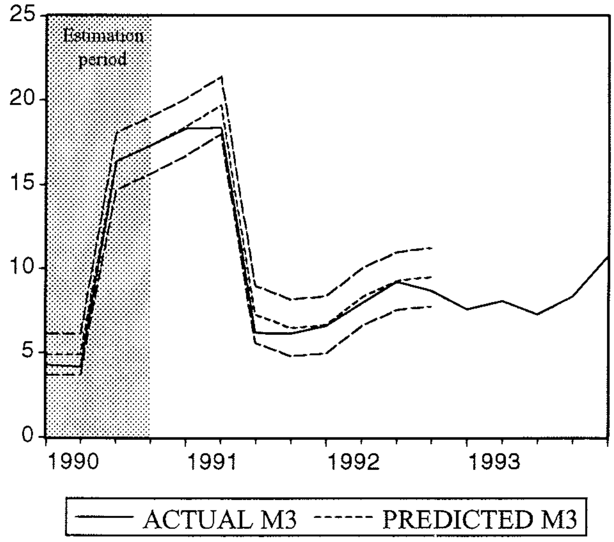


FIGURE 8
OUT-OF-SAMPLE PREDICTIONS
ALL-GERMAN DATA
(Growth rates over 4 quarters, in%)



positive and negative errors are equally likely, the probability of this event is 0.005. The null hypothesis is thus rejected at standard significance levels.

Next, we investigate the model's ability to predict *all-German* M_3 growth. If the demand elasticities in eastern and western Germany were the same, the absolute level of money and income would be of no relevance for the equation's ability to predict out-of-sample. To explore this, we calculate out-of-sample predictions for all-German M_3, using all-German GDP and prices (for which the last observation is 1992:4). The results in Figure 7 indicate that the demand equation underpredicts M_3 growth by a substantial amount in the unification quarter, and by a modest amount in the two quarters thereafter. The equation therefore easily fails Chow tests for stability over the period 1990:1-1992:4.[14] Since this failure is a consequence of the fact that the unification-induced jump in the money stock is much larger than that in nominal GDP, it says little about the stability of the demand for money function. More salient is the fact that actual M_3 growth is at the upper edge of the confidence band between 1991:4-1992:3. Furthermore, ten of the twelve prediction errors are positive. Under the null hypothesis that positive and negative errors are equally likely, the probability of this latter event is 0.016, which suggests that a small shift in the equation may have occurred.

The review of the out-of-sample predictions of western and all-German money stocks suggest that although the actual money stocks typically fall in the confidence band, the forecast errors tend to be positive. While this finding does not provide any strong evidence that the German M_3 demand function has become fundamentally unstable, it is compatible with the hypothesis that a small once-and-for-all shift in the demand function has occurred. To explore this issue further, we next ask whether an all-German money demand equation estimated over the break in the series predicts all-German M_3 growth better in the last two years of the sample.

4. An all-German demand equation

To estimate the all-German demand function, we use western German data up to 1990:2 and all-German data for 1990:3-4, reserving the remaining eight quarters for out-of-sample predictions. We start from equation (4), and add a dummy for the unification quarter to account for the jump in M_3 (D1), and another dummy (D2) for the period 1990:3 onwards to account for the possible shift in the mean growth rate of money. The estimated regression is[15]

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[14] The MSL for the hypothesis of constant parameters before and after 1990:1 is 0.00. The MSL for the forecast version of the Chow test, evaluated over the period 1990:1-1992:4, is also 0.00.

[15] In estimating this equation it is important to distinguish between the change in income stemming from the unification of Germany, which is likely to be reflected immediately in the demand for M_3, and "ordinary" changes in income, which affect the demand for money only gradually. To implement this distinction, we set Δm_t at the time of unification equal to the change in the log-level of money <u>minus</u> the change in the log-level of income (computed by the difference between all-German and western German income). This calculation assumes that the long-run income elasticity is unity. Furthermore, we set Δy_t in the unification quarter equal to the change in western German income.

(8) $\Delta m_t = 0.09 + 0.16\Delta y_t - 0.0044(R_{t-2}-r_{t-2}) - 0.07(m_{t-1}-p_{t-1}-y_{t-1}) + 0.11D1 + 0.01D2 + \varepsilon_t$
(10.44) (2.60) (3.91) (8.58) (12.43) (2.36)

Period: 1971:1-1990:4; $\bar{R}^2$ = 0.86; DW = 1.73; SSR = 0.00269; log likelihood = 298.81; SEE = 0.0060; Schwarz = -9.99; Akaike = -10.16

As can be seen, the parameter estimates of this equation are virtually identical to equation (4), and both dummies are significant. Given that the model as revised above underpredicted money growth in the unification quarter, it is not surprising that the dummy for the jump is highly significant. What is more interesting is that the second dummy is significant, suggesting that allowing for a shift in the constant does improve the fit of the equation. As can be seen from Table 3, the equation also passes the same diagnostic tests as equation (4).[16] The out-of-sample predictive ability of the equation is displayed in Figure 8. The plot illustrates that despite its simplicity the all-German demand equation fits the growth rate of M_3 very well in the 1991:1-1992:4 period.

In sum, the results for this equation suggest that there is a small difference between the pre-unification western German demand function and the post-unification all-German demand function; but that this difference can easily be captured econometrically.

5. Conclusions

The main results in this paper can be summarised as follows. First, on the basis of the out-of-sample forecast performance of the pre-unification western German money demand equation it is not possible to reject the hypothesis that the demand equation is stable until the first quarter of 1994. Second, while the equation's ability to predict all-German money demand in the year immediately after unification is less satisfactory, the forecast performance during the period 1991:3-1992:4 does not provide any strong evidence of a shift of the demand function. The out-of-sample predictions thus suggest that an observer who believed that the fitted demand function accurately characterised the demand for M_3 before unification would have little reason to change this view in the light of the behaviour of the money stock after unification. Finally, this conclusion is tempered somewhat by the money demand function estimated on both pre-unification western German data and post-unification all-German data, which does suggest that the constant in the demand function changed somewhat after 1990.

16 The inclusion of D2 renders it difficult to compute the Chow test for constancy of the parameters across the first and second parts of the sample, and the test statistic is for this reason not computed.

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