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The Stability of the Demand for Money Function in Germany: Myth or Reality?*

Some Comments on the 1994/95 Report of the German Council of Economic Experts

By Michael Funke**

1. Introduction

One of the most heavily investigated subjects in macroeconomics is the stability of the money demand function. A parsimonious and well-behaved demand for money function means that the quantity of money is predictably related to a small set of key variables linking money to the real sector of the economy. For this reason, the German Council of Economic Experts has recently investigated the short-run and long-run dynamics of German money demand in an effort to find a tractable and structurally stable representation.[1] The purpose in this note is to reconsider the stability of the suggested German money demand function following monetary, economic and social union between the Federal Republic and the German Democratic Republic on 1st July 1990.[2]

The note is divided into four parts. In Section 2, we describe the testing procedure of the Council of Economic Experts. The results of our alternative tests are laid out in Section 3. Section 4 contains a summary of the results and some tentative conclusions.

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1 See German Council of Economic Experts (1994), pp. 130-131.

2 The question whether the long-run money demand equation is stable has received ample attention over recent years. Recent discussions of this issue are available in *Boughton* (1991), *Friedman / Kuttner* (1992), *Judd / Scadding* (1982) and *Lucas* (1988). Other studies involving the UK money demand function are *Cuthbertson* (1988) and *Hendry / Ericsson* (1991a, 1991b). A survey of the literature is available in *McCallum* (1985).

2. M0 Money Demand

As is customary, the German Council of Economic Experts assumes that money demand is related primarily to some measure of real domestic income as well as a measure of the opportunity costs of holding money.

$$m_t = f(y_t, i_t) \tag{1}$$

where $f_y > 0$ and $f_i < 0$. The variables are defined as follows: m is the logarithm of real base money (M0).[3] The scale variable is chosen as the logarithm of real GDP, y. The short-term interest rate (three months maturity) is used as the competing rate. The GDP deflator is used to deflate the monetary aggregate. All variables are seasonally adjusted and refer to unified Germany from 1990Q3 onwards.. Following a general-to-specific procedure, the tested down version of the ECM for M0 was found to be:[4]

$$\Delta m_t = a_0 + a_1 \Delta y_{t-1} + a_2 \Delta i_{t-1} + a_3 \Delta i_{t-2} + a_4 \Delta i_{t-3} + a_5 m_{t-4} + a_6 y_{t-4} + a_7 i_{t-4} + \epsilon_t \tag{2}$$

In order to test for a one-time regime shift after monetary, economic and social union between the Federal Republic and the German Democratic Republic, the Council of Economic Experts has finally added interactive dummy variables to the equation. These were constructed by multiplying the variables in (2) with a dummy variable defined as

$$D = \begin{cases} 0 & for \;\; t = 1974Q1 - 1990Q2 \\ 1 & for \;\; t = 1990Q3 - 1994Q2 \end{cases} \tag{3}$$

Adding (2) and (3) the Council of Economic Experts suggested the following ECM in order to test for structural change in the cointegrating relationship:

$$\begin{aligned} \Delta m_t = {} & a_0 + a_1 \Delta y_{t-1} + a_2 \Delta i_{t-1} + a_3 \Delta i_{t-2} + a_4 \Delta i_{t-3} + a_5 m_{t-4} + a_6 y_{t-4} + a_7 i_{t-4} \\ & + b_0 D + b_1 D \Delta y_{t-1} + b_2 D \Delta i_t + b_3 D \Delta i_{t-1} + b_4 D m_{t-4} + b_5 D y_{t-4} + b_6 D i_{t-4} + \epsilon_t \end{aligned} \tag{4}$$

[3] Contrary to the German Council of Economic Experts, the Bundesbank has opted for a use-oriented and not a basic monetary aggregate in taking M3 as a yardstick. Recently the Deutsche Bundesbank (1995), *Gerlach* (1994) and *Hansen / Kim* (1995) have presented empirical evidence that the long-run demand for broad money (M3) was structurally stable after German unification. The OECD (1993) studies the demand for M3 over the period 1970Q1 - 1992Q4 and finds that unification might have caused a slight shift in the level of the demand for M3.

[4] The OLS parameter estimates and diagnostic tests, based upon quarterly seasonally adjusted data from 1974Q1 to 1994Q2, are given in German Council of Economic Experts (1994), Table 28, p. 131. The Council of Economic Experts has excluded the single outlier period 1990Q3 from the data set. Contrary to this arbitrary omission of observations I have used all available data in the following empirical work.

The estimated error-correction terms a_5, a_6 and a_7 are correctly signed and well-determined indicating cointegration. Of special interest are the coefficients of the interactive terms. The three interactive error-correction terms b_4, b_5 and b_6 are all individually insignificant, while with respect to the dynamic part of the equation the opposite appears to be occurring. The Council of Economic Experts interprets these results as evidence in favour of structural stability of the *long-run* M0 money demand equation.

3. Tests for Structural Change

In the above work of the German Council of Economic Experts on money demand, tests for structural change were conducted by splitting the relevant sample period at the point where the change allegedly occurred. This approach is appealing, in particular since it is very easy to implement. However, there are at least three reasons why it may not shed much light on the stability question. First, a clear drawback of this procedure is the requirement of prior knowledge as to the timing of the structural change. Second, the dummy variable approach does not provide any information on "what the structural change looks like", for example, whether it is temporary or permanent. Third, Banerjee et al. (1986) have noted that the small sample properties of the OLS estimator are poor. Additionally, if the regressors in (4) are endogenous (which they are highly likely to be) then the asymptotic distribution of the parameter estimates will depend upon nuisance parameters. In this light and given that we do not have any unambiguous a priori knowledge of when exactly change may have occurred, we have employed two procedures to determine directly from the data if and when structural change has occurred.[5] These procedures are recursive estimates of Johansen's cointegration likelihood ratio test and Hansen's (1992) SupF-test.[6]

3.1. Recursive Estimates of the Steady-State Relationship

Since the steady-state relationship is at the centre of the debate, we first examine the validity of the hypothesis that the long-run German money demand equation remained structurally stable after German unification using the Johansen procedure. The Johansen method is a full maximum likelihood

[5] The data for the following empirical work were kindly provided by the Council of Economic Experts.

[6] Before turning to the results, we should mention that the foregoing are independent tests. It is therefore possible for the outcomes to differ with respect to individual tests.

method that uses both the short-run and the long-run information in the data. The procedure is based on estimating a dynamic equation system given as

(5) $$\Delta X_t = \mu + \lambda_1 \Delta X_{t-1} + \cdots + \lambda_{k-1} \Delta X_{t-k+1} + \pi X_{t-1} + \epsilon_t$$

where $X' = [m, y, i]', \mu$ is a vector of constants, and ϵ_t is a vector of white noise residuals. The lag length k is chosen using information criteria.[7] The parameter matrix which is of interest for the subsequent analysis is π. This matrix can be decomposed in an α and β matrix

(6) $$\pi = \alpha\beta'$$

where α, β are $(v \times r)$ matrices, where v is the number of equations and r is the rank of π. As explained in Johansen (1988) and Johansen and Juselius (1990) the rank of π determines the number of cointegrating vectors. The procedure amounts to testing the dimensionality of the space spanned by whatever cointegrating vectors exist for the set of variables in question. If $r = 1$ there is one cointegrating vector, i.e. one stable long-run relationship between the variables. The tests set up the hypothesis that a vector is not a cointegrating vector and then attempt to reject that hypothesis by exceeding the critical value. The elements of the normalized eigenvector β are the long-run elasticities. The elements of the estimated α matrix measure the speed of adjustment towards steady state. So much for the method. Next follow the maximal eigenvalue tests for cointegration.

Table 1

Likelihood Ratio Test Statistics for the Cointegration Rank

Test of r =	Asymptotic LR-Test	Small Sample LR-Test	5% Critical Value
0	28.66	26.71	29.68
1	7.858	7.31	15.41
2	0.97	0.91	3.72

Notes: The Table provides log-likelihood ratio statistics for determining the number of cointegrating vectors r, using Johansen's maximal eigenvalue procedure. The test statistics have been calculated with an unrestricted constant and $k = 2$. The small sample adjustment procedure is defined in *Reimers* (1992) and *Reinsel / Ahn* (1988).

[7] *Hall* (1991) has shown that the LR test statistics seem fairly sensitive to the choice of VAR lag length. We have therefore used the Akaike, the Schwarz and Hannan-Quinn criterion to determine k.

The results for the sample period 1974Q1 to 1994Q2 are reported in Table 1. We can see that even in the case of the first cointegrating vector we do not exceed the critical value, although we are rather close to it. Thus, the hypothesis of cointegration is *rejected* by the maximal eigenvalue test. In order to check for structural stability, we have also estimated Johansen's LR tests recursively. The results are given in Figure 1.

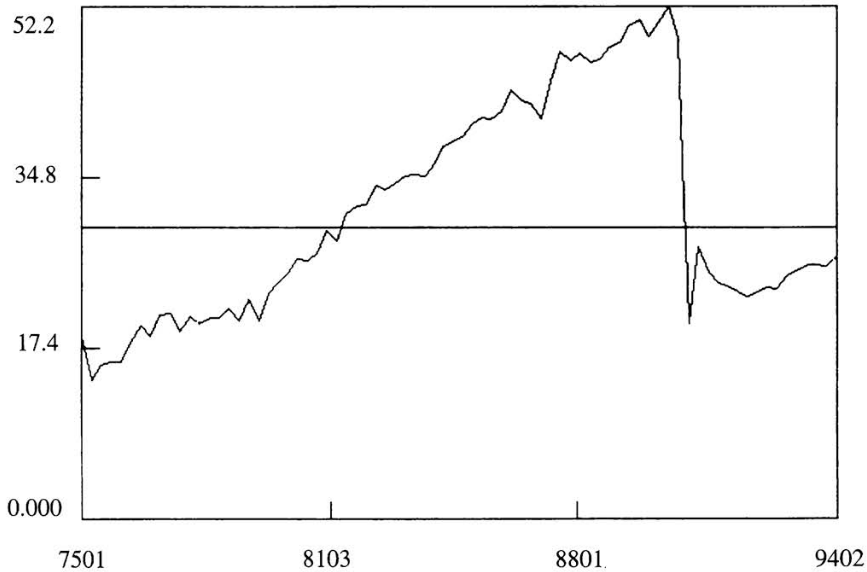

Figure 1: Recursive LR-Test $r = 0$

Notes: The test statistics have been calculated with an unrestricted constant and $k = 2$. The horizontal line indicates the 5% critical value.

The plot indicates that one significant cointegrating vector has existed up to German unification which, however, falls into insignificance after 1990Q3. Therefore, it is not possible to discern from the data a stable long-run relationship between m, y and i. This result contradicts the findings of the Council of Economic Experts. Figure 2 gives the same recursively estimated LR-test under the assumption of a restricted constant in the cointegrating relationship.[8] Extending the sample period to include post-unifica-

[8] The asymptotic distribution of Johansen's LR test is not invariant to the assumption made about the underlying VAR model. In particular, there are two alternative assumptions which may be made. (1) The VAR has a restricted constant term which appears only as part of the cointegrating vector. (2) The VAR has an unrestricted constant. This means that if the ECM form of the VAR has some equations which do not

tion data again sharply weakens the time-series evidence for cointegration although – contrary to Table 1 and Figure 1 – the test statistic remains significant. Nevertheless there is again strong evidence of structural change occuring in 1990.

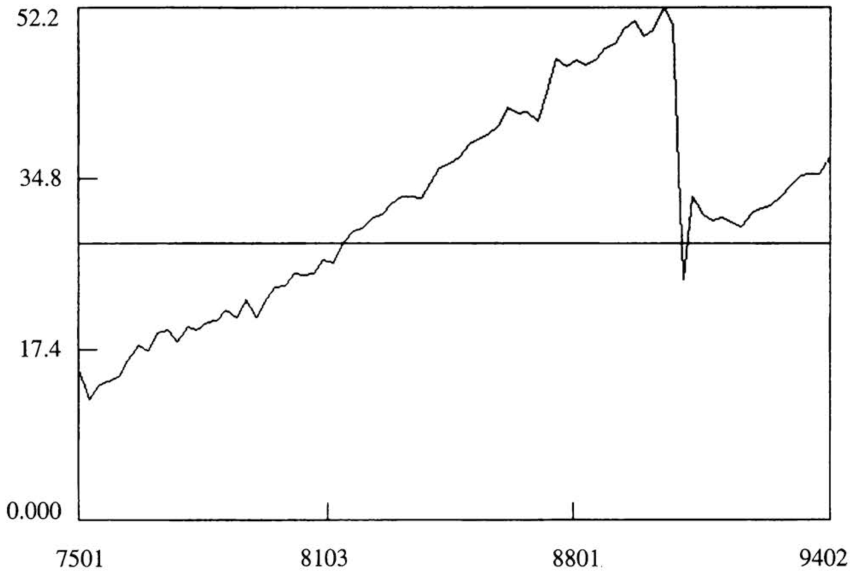

Figure 2: Recursive LR-Test r = 0

Notes: The test statistics have been calculated with a restricted constant in the cointegrating relationship and k = 2. The horizontal line indicates the 5% critical value.

3.2. Hansen's SupF-Test

Finally we have used the semi-parametric fully modified estimation and testing procedure suggested by *Hansen* (1992) which yields asymptotically efficient estimates of cointegrating vectors.[9] The underlying principle of the

contain a cointegrating vector, these equations will still contain constants. So these variables will behave like generalised random walk variables but with a drift term and the data will contain deterministic trend terms.

[9] The procedure builds on and extends the setup used by Phillips and Hansen (1990). See *Harris* (1995), *Phillips / Loretan* (1991) and *Lim / Martin* (1995) for informative reviews. *Phillips / Loretan* (1991) have suggested the use of a single equation frequency domain estimator which is equivalent to applying the *Phillips / Hansen* (1990) estimator to the frequency domain. *Inder* (1993) and *Montalvo* (1995), however, found in their Monte Carlo experiments that the modified OLS estimates of the long-

single equation estimator is to filter the short-run variables semi-parametrically by estimating a model which includes both short-run and long-run variables. The estimator contrasts with the Engle-Granger estimator where the cointegrating vector is estimated without taking into account the short-run dynamics.[10] Within the procedure *Hansen* (1992) explicitly considers the possibility of structural change in a cointegrated system. The intercept and/or slope coefficients of an existing cointegrating vector are allowed to experience a regime shift at an unknown date.[11] A brief description of the technique is given in the appendix. The SupF test suggested by *Hansen* (1992) is based upon the FMOLS estimation procedure. The sequence of test statistics for time varying break points is given by

(7) $$F_{nt} = tr(S'_{nt} V_{nt}^{-1} S_{nt} \hat{\Omega}_{1.2}^{-1})$$

where

(8) $$V_{nt} = M_{nt} - M_{nt} M_{nn}^{-1} M_{nt}$$

(9) $$M_{nt} = \sum_{i=1}^{t} x_i x_i^{'}$$

(10) $$S_{nt} = \sum_{i=1}^{t} \hat{s}_i$$

(11) $$\hat{s}_t = \left(x_t \hat{\epsilon}_{1t}^{+} - \begin{pmatrix} 0 \\ \hat{\Lambda}_{21}^{+} \end{pmatrix} \right)$$

and

(12) $$\hat{\Omega}_{1.2} = \hat{\Omega}_{11} - \hat{\Omega}_{12} \hat{\Omega}_{22}^{-1} \hat{\Omega}_{21}$$

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run relationship yielded little or no improvement on the precision of the standard OLS estimator. They blame the particular generating process used by *Phillips / Hansen* (1990) as the reason for the good performance of the FM estimator in their Monte Carlo experiment.

10 The estimator has been shown to perform better than the Engle-Granger estimator in small samples.

11 The procedure is therefore not crippled by the need to specify a priori the one-time or repeated structural change.

where $\hat{\epsilon}^{+}_{1t}$ are the residuals of the FMOLS estimation, and the other concepts refer to the appendix. The actual test statistic is then given as the *supremum or upper bound of* F_{nt} over the interval, i.e.

$$SupF = \sup_{[t/n]\in\zeta} F_{nt} \tag{13}$$

where ζ is some compact subset of (0,1), and [.] denotes integer part.[12] Following *Hansen* (1992), the statistic is calculated over the [0.15; 0.85] interval of the sample period.[13] The above procedure is used to test for regime shifts in the three-variable cointegration vectors. The plot of the sequence of F statistics is displayed in Figure 3. The supF test crosses the 5% critical

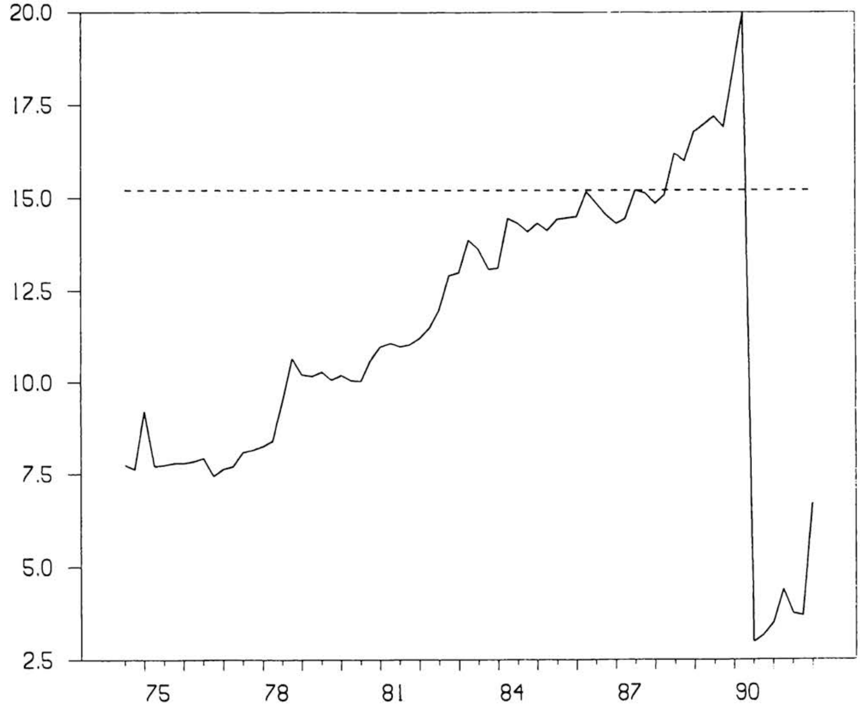

Figure 3: SupF Test Statistic

Notes: The dashed line indicates the 5% critical value.

[12] A fundamental property of the real number system is that every nonempty subset of real numbers having an upper bound also has a supremum.

[13] The trimming region over which the test statistic is calculated should not include the end-points 0 and 1 since for these values the test statistic will diverge to infinity almost surely. The fix suggested by *Hansen* is to select [0.15, 0.85].

value line several times, achieving its maximal value after German unification. This again points the finger at the year 1990 as the source of structural instability.

4. Concluding Remarks

The object of this note was to show how the passage of time -in particular, the experience since German unification – has altered familiar empirical relationships previously taken to support a central role for base money in the monetary policy process. Recent investigations of the German Council of Economic Experts had suggested evidence of no structural change in 1990Q3 on the basis of split samples. As illustrated in the analysis, I believe that empirical investigations will be best served by using a number of complementary statistical tests.[14] I have used two alternative tests that permitted the data to indicate the presence of structural change. In all procedures, the money demand equation exhibits parameter nonconstancy in the long-run. The results therefore reject the findings of the Council of Economic Experts. While some effort has been made to test for structural breaks, we still lack a systematic and complete explanation. Better specification of cyclical variables and of the opportunity cost of holding money might add to our understanding of money demand. 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. In the meantime, applied economists should be careful about using unchanged specifications of money demand equations over long periods of time and to take to heart what Hendry (1980) has called the three golden rules of econometrics: test, test and test.[15]

Appendix: Fully Modified OLS Estimation

The FMOLS estimation methods used here are those proposed by *Hansen* (1992) and *Phillips / Hansen* (1990). The starting point is the static cointegration relationship

(A1) $$y_t = \beta x_t + \epsilon_{1t}$$

where

[14] One difficult task for the applied researcher might then be to juggle these separate pieces of the puzzle.

[15] *Hendry* (1980), p. 403.

(A2) $$x_t = (x_{1t}^{'}, x_{2t}^{'})'$$

is determined by

(A3) $$x_{1t} = k_{1t}$$

(A4) $$x_{2t} = \Pi_1 k_{1t} + \Pi_2 k_{2t} + x_{2t}^0$$

(A5) $$y_2^0 t = x_{2t-1}^0 + \epsilon_{2t}$$

and the elements of k_t are nonnegative integer powers of time. The specification given above is particularly useful for defining the stochastic behaviour of the regressors and separating these from any trends that may enter the regression equation directly. Thus the element k_{1t} places any trends directly into the regression equation, whilst the trends k_{2t} determine the behaviour of the stochastic regressors x_{2t} (which are not entered directly into the regression equation). One of the advantages of this approach over alternative methods of cointegration, such as *Johansen* (1988), is that it facilitates a complete analysis of the inclusion of deterministic trends in the cointegration set. An additional benefit of the above framework is that it facilitates a test of cointegration, where cointegration is taken to be the null hypothesis. In the statistics literature this would be the natural way to test for cointegration. However, in the recent econometrics literature the general tendency has been to test the null of no cointegration (see, for example, *Engle / Granger* (1987) and *Johansen* (1988). Equations (A4) to (A5) can also be written in first-difference form

(A6) $$\Delta x_{2t} = \Pi_1 \Delta k_{1t} + \Pi_2 \Delta k_{2t} + \epsilon_2 t$$

OLS estimation of (A1) and (A6) yields residuals

(A7) $$\hat{\epsilon}_t^{'} = (\hat{\epsilon}_{1t}^{'}, \hat{\epsilon}_{2t}^{'})'$$

Because of serial correlation we estimate a VAR(1) to $\hat{\epsilon}_t$ and get the corresponding coefficient matrix $\hat{\Phi}$ and whitened residuals $\hat{e}_t$. In order to proceed with a kernel estimation we first fit AR(1) processes to the elements of $\hat{e}_t$ and obtain coefficients $\hat{\rho}_a$ and variances σ_a^2 for each element $\hat{e}_{at}$ out of $\hat{e}_t$. These are used to calculate the quadratic spectral bandwith QS estimator recommended by Andrews (1991). For the QS kernel, the choice of the bandwith parameter is

(A8) $$\hat{M} = 1.3221[\hat{\alpha}(2)T]^{\frac{1}{5}}$$

where

$$\text{(A9)} \qquad \hat{\alpha}(2) = \frac{\sum_{a=1}^{p} \frac{4\hat{\rho}_a^2 \hat{\sigma}_a^2}{(1-\hat{\rho}_a)^8}}{\sum_{a=1}^{p} \frac{\sigma_a^2}{(1-\hat{\rho}_a)^4}}$$

We now calculate the following two matrices:

$$\text{(A10)} \qquad \hat{\Lambda}_e = \sum_{j=0}^{T} w\left(\frac{j}{M}\right) \frac{1}{T} \sum_{t=j+1}^{T} \hat{e}_{t-j} \hat{e}_t^{'}$$

and

$$\text{(A11)} \qquad \hat{\Omega}_e = \sum_{j=-T}^{T} w\left(\frac{j}{M}\right) \frac{1}{T} \sum_{t=j+1}^{T} \hat{e}_{t-j} \hat{e}_t^{'}$$

where the quadratic QS weight function (or kernel) recommended by *Andrews* (1991) takes the form[16]

$$\text{(A12)} \qquad w(x) = \frac{25}{12\pi^2 x^2} \left(\frac{\sin\left(\frac{6\pi x}{5}\right)}{\frac{6\pi x}{5}} - \cos\left(\frac{6\pi x}{5}\right) \right)$$

The two matrices given in (A10) and (A11) which are based on e_t can be retransformed (or recolored) to be based on ϵ_t :

$$\text{(A13)} \qquad \hat{\Lambda} = (I - \hat{\Phi})^{-1} \hat{\Lambda}_e (I - \hat{\Phi}')^{-1} - (I - \hat{\Phi})^{-1} \hat{\Phi} \frac{1}{T} \sum_{t=1}^{T} \hat{\epsilon}_t \hat{\epsilon}_t^{'}$$

$$\text{(A14)} \qquad \hat{\Omega} = (I - \hat{\Omega})^{-1} \hat{\Omega}_e (I - \hat{\Omega}')^{-1}$$

Phillips / Hansen's (1990) FMOLS estimator for the coefficient vector ß in equation (A1) is now given by

$$\text{(A15)} \qquad \hat{\beta}^{+} = \left(\sum_{t=1}^{T} \left(y_t^{+} x_t^{'} - \left(0 \ \hat{\Lambda}_{21}^{'+}\right) \right) \right) \left(\sum_{t=1}^{T} x_t x_t^{'} \right)^{-1}$$

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16 The weight function $w(\cdot)$ yields positive semi-definite estimates.

where

$$y_t^{+} = y_t - \hat{\Omega}_{12}\hat{\Omega}_{22}^{-1}\hat{\epsilon}_{2t}$$

and

$$\hat{\Lambda}_{21}^{+} = \hat{\Lambda}_{21} - \hat{\Lambda}_{22}\hat{\Omega}_{22}^{-1}\hat{\Omega}_{21} \tag{A17}$$

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Zusammenfassung

Im Jahresgutachten 1994/95 des Sachverständigenrates zur Begutachtung der gesamtwirtschaftlichen Entwicklung wird in einem Exkurs (Textziffer 152-154) eine ökonometrische Untersuchung zur langfristigen Stabilität der Geldnachfrage in der Bundesrepublik Deutschland vorgestellt. Dabei wird insbesondere die Hypothese eines Strukturbruchs zum Zeitpunkt der Währungsunion 1990 untersucht. Das geschätzte Modell liefert das Ergebnis, daß die Hypothese einer langfristig stabilen Nachfrage nach Zentralbankgeld nicht verworfen werden kann. Im Gegensatz zu diesem Ergebnis des Sachverständigenrates wird in dem Papier gezeigt, daß verschiedene Strukturbruchtests für Kointegrationsbeziehungen auf einen Strukturbruch im Jahre 1990 hindeuten.

Abstract

Recent empirical work by the German Council of Economic Experts suggests that structural change in the German long run M0 demand for money equation has not occurred after German unification. This evidence is based upon a somewhat arbitrary splitting of the sample period. In this note we investigate the question of structural change using procedures that let the data determine if and when structural change may have occured. Contrary to the Council of Economic Experts we find strong evidence for structural change in the cointegrating relationship following German unification.

JEL-Klassifikation: E 41, C 22, C 32
Keywords: Money demand, Time Series Models, Structural Change