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Money as an Indicator in the Euro Zone

by

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Abstract:
This paper attempts to evaluate the information content of money for the forecast of inflation, output, investment and consumption in the euro zone. It considers M1 and M3; a number of modifications to these aggregates is also proposed to enhance their forecast performance. The evaluation employs Granger-causality tests, stability tests and historical out-of-sample forecasts. On balance the information content of money appears to be rather limited. An improvement of the forecast is confined to the real variables and to the second half of the nineties. For the first half of the nineties the forecast performance of money is generally poor.

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Contents

1. Introduction

The primary objective of the European Central Bank (ECB) is the maintenance of price stability. To achieve this objective, a broadly based assessment of the outlook for future price developments in the euro area is conducted (see ECB (1999a)). In addition, special attention is paid to broad money. A reference value for the growth rate of this aggregate is specified, suggesting that deviations from this path signal risks to price stability. The aim of this paper is to take a closer look at the information content of money with respect to inflation and to explore on the basis of historical out-of-sample simulations its performance as an indicator. In addition, the role of money as a predictor for real activity variables in the euro zone is investigated. Real activity is defined here as comprising output, consumption and investment, as these are of interest for policy makers and the public in general. With respect to the money variables, both narrow and broad money and several modifications to these aggregates are considered.

For money to serve as an information variable in the assessment of future developments in the real and nominal sphere, it is a reasonable precondition that this variable possesses some worthwhile indicator qualities. Following Berk and van Bergeijk (2000) this is taken here to include a stable and predictable relationship between the information variable and real activity or inflation. A further requirement is that an information variable should possess leading indicator properties.[1] Also, indicator variables can be either incremental or corroborative. In the first case monetary aggregates embody information that other variables do not have. Bernanke and Blinder (1992) provide evidence for the US that short-term interest rates absorb the information contained in the monetary aggregates, suggesting that money is a poor incremental indicator. Nevertheless, money quantities can still be corroborative indicators of activity trends, which confirm signals from other indicators without providing extra information. It is the corroborative properties of money that the present paper will focus on, because this is a minimum requirement money should fulfill to qualify as an indicator.

The empirical analysis in this paper is based on bivariate systems containing the respective money quantities as the first variable and the inflation or the activity variables as the second. In a first step Granger-causality tests are run to evaluate the in-sample links between money and the variable to be forecasted, testing whether the monetary aggregates improve the forecast quality in a systematic way. In a next step, the in-sample analysis is supplemented by stability tests of the empirical relationships. As a final step, the out-of-sample performance of the bivariate systems is analysed. The methodology used here follows closely the concept introduced by Davis and Fagan (1997), who suggest to compare the forecast performance of a bivariate system containing the indicator variable with the corresponding univariate model for the variable of interest. The univariate

[1] However, failure to establish such properties does not imply that there is no role for money with respect to the monetary policy strategy, just that it is not a useful information variable. To illustrate the limits of the analysis pursued here assume that money matters in the transmission mechanism and that the monetary authority conducts a successful monetary targeting strategy, keeping money balances always on some predetermined path. In this scenario money is by design a poor indicator for developments in the real or nominal sphere, because it does not deviate from its path no matter what happens there due to other sources of disturbances than monetary policy. While this scenario clearly is a hypothetical one for the case of the euro zone, it illustrates that care is needed in drawing strong policy conclusion from evidence regarding the information content of money. For a detailed discussion of this issue see Woodford (1994).

model appears to be an obvious competitor; if the bivariate system with money does not outperform the univariate version, this suggests that money does not offer much information not already contained in the history of inflation or real activity.[2]

The paper is structured as follows. In section 2 the potential usefulness of money as an indicator is discussed from a theoretical point of view. Section 3 outlines the methodology. In section 4 the empirical results are presented and section 5 concludes.

2. Money as an Indicator

The clearest case for money as an indicator can be presented in a framework where the money stock is assumed to be set by the monetary authorities and money demand is taken to be a stable function of a number of macroeconomic variables.[3] Equating money demand to the money stock gives the money market equilibrium. A common form of the money market equation is

$$(1) \qquad m_t - p_t = b_0 + b_1 y_t + b_2 r_{s\,t} + b_4 r_{l\,t} + e_t$$

where all variables except interest rates are in logarithms. The terms m_t, p_t, y_t, $r_{s,t}$, $r_{l,t}$ and e_t denote the money stock, price level, real income, a short and a long

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2 However, it is also possible that the information in money cannot be extracted in full measure by the conventional indicator set-up used here. This leaves the option to employ a more structural model, for instance a P*-model as pioneered by Hallman et al. (1991), to make better use of the information content of monetary aggregates. The present paper is still useful in this regard as a pre-screening device to evaluate which money variable is the most promising candidate for such a modelling exercise.

3 For a more detailed presentation of the issues discussed in this section see Milbourne (1988).

interest rate and a white noise random shock. In empirical applications of (1) the dynamic adjustment process towards equilibrium needs to be modelled as well, but can be omitted here. The key assumption in this framework is that the money stock is being exogenously determined by the central bank while the price level, income and interest rates are endogenous variables, which adjust in response to a disequilibrium to ‘clear’ the money market.

With money being truly exogenous it is useful to rearrange equation (1) in a way that the money stock is not a dependent but an explanatory variable. One common transformation is to rearrange (1) so that it becomes a semi-reduced form equation for the price level. Together with additional assumptions regarding output and velocity this leads to the widely used P*-approach, where the equilibrium price level P* is a function only of the money supply set by the central bank and equilibrium values for output and velocity. Given that the actual price level is assumed to move towards its equilibrium value, the difference between P* and the actual price level serves as a predictor for changes in the price level, which illustrates the potential usefulness of money as an inflation indicator due to its role as the driving force behind P*.[4] But clearly the transmission mechanism running from money to real and nominal variables cannot be fully described by a single equation.[5] In monetarist theory, which emphasizes the role of money in the monetary transmission mechanism, there are a multitude of portfolio responses, triggering complex adjustment in the real sphere.[6] This implies

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[4] For recent applications of the P*-approach to the euro zone see Gottschalk and Broeck (2000) and Gerlach and Svensson (1999).

[5] This is the reason why (1) as a money market equation is a structural equation, but when rearranged to yield one of the endogenous variables on the left hand side it needs to be considered as a semi-reduced form equation, because in the rearranged form (1) shows only the final link between money and the endogenous variable, but not the workings of the transmission mechanism.

[6] For an account of the monetarist perspective see Meltzer (1995) and De Long (2000).

that the role of money as an indicator need not be confined to forecasting nominal variables like inflation.[7] In particular money supply shocks may be an important source of business cycles. In the empirical section of this paper the information content of money is investigated for real output, capital investment and consumption. While the proposition that money might help forecast output movements is a conventional one, the inclusion of the latter two may need some additional motivation. Investment spending is generally held to be relatively interest rate sensitive, while this is probably less so in the case of consumption spending. If changes in money supply induce significant interest rate movements, this will affect investment, so that money could be a good predictor of capital spending. Regarding consumption, an increase in the money supply may ease liquidity constraints of consumers by inducing the financial sector to expand the credit volume. Or there could be wealth effects leading to higher consumption.[8] If these channels of monetary policy are non-negligible, monetary aggregates may contain useful information regarding future consumption.

A very different view of money as an indicator emerges if equation (1) is thought of as representing a money demand equation; the main difference to the above

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[7] Note that for money to be a useful indicator in this framework the transmission mechanism needs to be stable over time. In particular the relevant lead/lag structures should remain constant. In the context of this paper one has to assume additionally that the transmission mechanism in the euro zone can be analysed by aggregating over the member countries and that this mechanism is unaffected by the transition from national central banks to the European Central Bank. Obviously the famous Lucas critique suggests that this need not be the case. The possible pitfalls involved here have been discussed in numerous studies investigating the stability of money demand in the euro zone. For an excellent review see Browne et al. (1997). While these issues cannot be conclusively answered, there is not much of a practical alternative but to use aggregated data covering the pre-EMU period, because the empirical analysis of the euro zone can hardly wait until an acceptable data set is available.

[8] For a review of determinants of private consumption see Döpke and Kamps (1999).

framework being that the money stock is now endogenously determined.[9] This does not preclude the monetary authorities from targeting the money stock, but this is accomplished by using interest rates as an instrument to control money demand.

Note that interest rates are usually guided by the monetary authorities into the desired direction by suitably adjusting the supply of high powered money via open market operations. The point made by Meltzer (1995) is that because of the importance of open market operations, money supply shocks still matter in the transmission mechanism even if interest rates are the policy instrument of choice. But keeping the short rate on course implies that any money demand shock has to be accommodated by adjusting the money supply correspondingly. So the money stock is determined both by supply and demand shocks. To complicate matters, determining to what extent variations in the money stock are due to each is often subject to a large degree of uncertainty. The problem for the indicator qualities of money is that the information content of the money supply and demand components is quite different. While a rise in the money stock due to a money supply shock signals a shift in monetary policy towards a more expansionary stance, this is not the case if the rise in money holdings is due to a shift in the money demand function. Such an upward shift could be due to a fall in long-term interest rates, which lowers the opportunity costs of money and thus raises money demand. While the change in the long rate may or may not affect output or inflation, the change in the money stock itself only indicates a shift in the equilibrium in the money market but not a more expansionary policy stance.

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[9] Another view is given by buffer stock theories. These are very similar in spirit to the framework outlined above where money is exogenous, but disequilibrium in money markets is allowed for. For further discussion see Milbourne (1988).

Leaving money supply shocks for the moment aside and assuming for the following argument that the money stock is completely demand determined, equation (1) specifies the factors influencing money demand.[10] Note that this relation gives the demand for real balances, which is the conventional specification. The determinants are real output as a variable capturing the transaction motive of holding money balances and the interest rates to model the opportunity costs. While a rise in long-term interest rates unambiguously raises opportunity costs and lowers money demand, the effect of a rise in short rates depends on whether a narrow monetary aggregate like M1 or a broad aggregate like M3 is considered. While in the former case an interest rate hike is usually found to lower the demand for real balances, in the latter case rising short rates increase the demand for money because of the high correlation between the short rate and the return on interest rate bearing components of M3 like term deposits.[11] With respect to the monetary policy strategy this latter finding implies that if the ECB observes for instance overly buoyant growth of M3 and decides to respond by raising the short rate, it is presumably the contractionary output effect of the rate hike which dampens money demand eventually, while the direct rate effect on money demand should be of second order magnitude only, if this policy move is to be

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[10] In other words, any change in money demand is assumed to be fully accommodated by money supply. Note that Milbourne (1988) argues that M1 is likely to be endogenously determined because of central bank practice to accommodate money demand shocks to smooth interest rates. So for narrow money this is a reasonable assumption, but it may not hold for broad money.

[11] For empirical evidence on interest rate elasticities in the euro zone see Browne et al. (1997), Gottschalk (1999) or Clausen (1998).

effective with respect to controlling broad money growth.[12] To simplify the following argument, interest rate effects are assumed to be negligible so that money demand is determined alone by the output variable. In this case real money holdings may be a good contemporaneous indicator of developments in the real sector. A real demand shock for instance raises output and via the money demand relationship this shows up in rising real balances. But of course there are a large number of alternative indicators leading activity and thus the independent explanatory power of money may be quite low if these indicators are accounted for.[13] Still, Astley and Haldane (1995) stress that just because money may not contain much information not already provided by other indicators this does not imply that it is useless as an indicator. They argue that economy watching is a probabilistic science and so even indicators which replicate information elsewhere are useful for helping to confirm a trend. In addition, they point out, while money is corroborative of real activity, it may lead inflation if the world worked according to some short-run, non-vertical Phillips curve. Finally, even if there are no behavioural lags between money and activity, monetary statistics are usually sooner available than statistics for the real sphere, so that money may

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12 Note that the positive direct effect on money demand due to rising short rates may be offset by a rise in the long rate, which increases opportunity costs. A close link between short and long rates is suggested by the expectations theory. For an empirical investigation of the controllability of broad money in the euro zone see Coenen and Vega (1999), Vlaar and Schuberth (1998) or Cabrero et al. (1998). The results suggest that this task may be rather difficult to accomplish.

13 Alternative indicators being for example the short rate to indicate the monetary policy stance, financial variables to capture the information content of market expectations or indicators of real activity like order inflows etc.

turn out after all to be a reasonable good indicator for activity at least at short forecast horizons.[14]

The discussion has so far proceeded under the assumption of a stable money demand function. For the euro zone this seems to be a reasonable assumption.[15] Still, it is worth raising two points. First, while the empirical evidence suggests that there is a long-run relation between the variables given in (1) and that the parameters of the money demand function are stable in time, it remains of course a stochastic function.[16] The presence of money demand shocks may adversely affect the quality of money as an indicator by introducing noise into the forecast. Second, these shocks may have quite persistent effects even if real money balances return to equilibrium eventually. Empirical evidence suggests that the adjustment process may take several years.[17] This implies that real money may not correspond to its equilibrium value for long periods, which again puts the quality of money as indicator into doubt.[18] Focusing here on broad money, graph 1

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14 For a careful discussion of the latter point see Friedman (1975). He stresses that the stability of the money demand function and a low interest rate sensitivity are two preconditions which need to be satisfied for this argument to hold.

15 For a discussion of stability concepts and their application to the euro zone see Clausen (1998). He finds that money demand functions both for M1 and M3 are fairly stable.

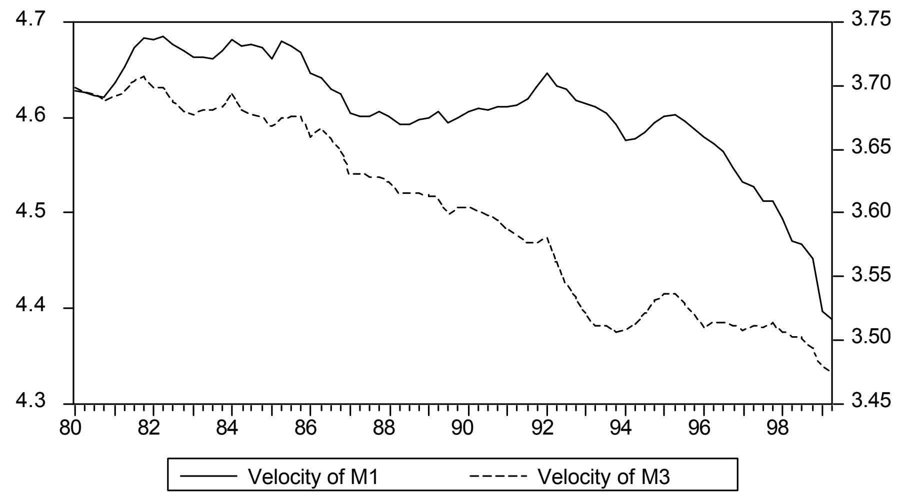
16 The forecast errors discussed here are of course not unique to a monetary model but are present in all forecast models. The question is whether the variance of money demand shocks is so large that the forecasting ability of a money based model is seriously impaired.

17 Clausen (1998) reports for M3 a mean lag (derived from the error correction term) of 19 quarters. The results in Gottschalk (1999) suggest a similar magnitude. In Coenen and Vega (1999) the mean lag is with approximately six quarters shorter, but still substantial.

18 This argument is stressed by Christiano (1989) in his seminal critique of the P*-approach, where he argues that the quantity theory may hold in the long-run, but that this theory has nothing to say about shorter horizons. He concludes that the agreement between the P* model and the quantity theory says nothing about the former ability to predict inflation in the short-run. The quantity theory is foremost a money demand theory. The deviations from the quantity theory in the short-run emphasised by Christiano correspond to money demand shocks.

shows that the velocity of M3 (in logarithms) has at times deviated substantially from its trend path, particularly so in the years from 1992 to 1995. The ECB (1999a) argues that this was due to exchange rate turbulence in the course of the ERM crisis, substantial interest rate movements and far reaching changes in the way interest is taxed in many countries.

Graph 1: Velocity of Narrow and Broad Money in the Euro Zone



This paper attempts to account for the noise emanating from money demand shocks in two ways. First, one variant of the forecast procedure considers only variables transformed into annual growth rates. Computing the change over four quarters is supposed to serve as a filter for high frequency noise in the data, in particular to remove the transitory components in the monetary aggregates due to money demand shocks. This is a very common transformation; in particular in public discussions of the money growth path it is often the annual growth rate and not the change quarter on quarter which is commented on. Second, an approach pioneered by Estrella and Mishkin (1997) to model the change in velocity is employed. Before discussing their proposed adjustment to the monetary aggregates, note that the existence of a stable money demand function does not imply that velocity follows a smooth trend-stationary path. Velocity may very well have a stochastic trend, and if it is interest rate sensitive (or is a function of the exchange rate, as suggested by the ECB (1999a) in their review of velocity in the nineties) velocity may actually be quite volatile.[19] Estrella and Mishkin's starting point is to assume that velocity in the current period is unknown, but the optimal prediction of velocity can be adequately characterised by an ARIMA model:[20]

(2) $$\Delta v_t = a\Delta v_{t-1} + e_t + be_{t-1},$$

where Dv_t and e_t denote the change in velocity and a white noise term respectively. The optimal predictor of velocity is then

(3) $$A_t = a\Delta v_{t-1} + be_{t-1}.$$

Estrella and Mishkin propose to adjust the monetary aggregates with this measure of the expected change in velocity:

(4) $$\Delta m_t^A = \Delta m_t + A_t .$$

For the USA they find that this adjustment produces some empirical gains regarding the significance of monetary aggregates in equations explaining nominal

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19 An obvious starting point for modelling velocity is a fully specified money demand model. But this is unsuitable for the task at hand, because such a model requires as input information regarding output, prices and interest rates, which makes it difficult to isolate the information content of money in the further investigation.

20 They show that this ARIMA model is more general than the widely used approximation of the change in velocity with a four year moving average over its rate of change, as pioneered by McCallum. For an application of the McCallum rule for the euro zone see Gern et al. (1999), p. 324.

growth and inflation.[21] To help account for the changes in velocity in the euro zone this procedure will be applied in the following section to narrow and broad monetary aggregates.

So while there is a clear case for money as an indicator, the preceding discussion has also pointed to a number of possible difficulties. First, presuming that the money stock is under the control of the central bank, the transmission mechanism from money to output and finally prices implied by (1) need not be stable in time.[22] Second, maintaining the assumption regarding the exogeneity of the money stock and assuming in addition that the central bank operates a monetary targeting regime where the money supply is expanded according to a predetermined schedule, money balances will not be allowed to be affected by real demand or supply disturbances. If these shocks account for a substantial part in the variation of output and inflation, the money stock will be a poor indicator by design. Third, considering the form of the money demand function, interest rate effects may matter, shifting the money demand function so that a given growth path of the money stock may imply quite different forecasts for output and inflation. This is a problem regardless whether the money stock is exogenously or endogenously determined. Fourth, the money stock may be characterised by having both a substantial money supply and a money demand component. This makes it hard to use money as an indicator because the respective information content is quite different. Finally, money demand shocks may prove to have a high variance and to be quite persistent, introducing substantial noise into the forecast, even if there is a stable long-run money demand function. This is rea-

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[21] But they also find that this improvement is too marginal for monetary aggregates becoming useful information variable.

[22] The empirical evidence suggests only that the money demand function is stable, but nothing is said about the money supply process or the transmission mechanism from money to output and prices.

son for concern to the extent that the proposed modifications to reduce high frequency noise prove to be insufficient. All this leaves it as an empirical question whether money is a useful indicator.[23]

3. Methodology

The information content of monetary aggregates with respect to inflation and change of output, investment and consumption is evaluated on the basis of in-sample significance tests and historical out-of sample forecasts. In addition the stability of the forecast equations is tested. The analysis is conducted within the context of bivariate Vector Autoregressive (VAR) models containing money as an indicator variable and inflation or a real activity variable as the respective quantities of interest. The methodology resembles that of Davis and Fagan (1997), who used this procedure to investigate the information content of yield spreads for a number of European countries.

There are a number of approaches in the literature where larger VAR models are used to investigate the information content of money over and above that of other indicator variables, in particular interest rates or spreads.[24] However, this paper is concerned with the absolute and not the relative information content of money. For this more limited objective bivariate systems are sufficient.[25] The motivation for this focus is twofold. First, if money has poor indicator there is

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[23] Note that finding evidence against the usefulness of money as an indicator does not imply that the monetarist perspective of the role of money is refuted. See in particular the discussion in De Long (2000) that only a very simplified version of monetarist theory claims that money is always and everywhere a good indicator.

[24] See for example Friedman and Kuttner (1992) and Bernanke and Blinder (1992). For a general VAR approach to forecasting inflation see Henry and Pesaran (1993).

[25] Due to the limited number of observations available for the euro zone, it is also advisable to conserve degrees of freedom by restricting the analysis to a small system.

no need to compare its performance relative to other indicators. So establishing the absolute information content of money should precede a 'horse race' with other competitors. Second, as outlined in the previous section, Astley and Haldane (1995) make a convincing argument that money is still useful even if it is not an incremental but a corroborative indicator.[26]

The choice of VAR models implies that the empirical evaluation proceeds within the context of reduced form models. From this follows that no structural inference can be drawn from the results. This also holds for Granger-causality tests, because these are neither necessary nor sufficient conditions for the existence of a structural relationship between a monetary aggregate and the predicted variable. So if for instance money is found to be statistically significant in a regression explaining inflation, this does *not* suggest that money causes inflation in a structural sense.[27] A formulation of a structural macroeconometric model which could answer this kind of questions is beyond the scope of this paper. However, as discussed by Friedman (1975) an information variable need not have a long-run structural relation with the variable of interest; it suffices to show that it possesses short-run information supplementing the existing information set.

Before proceeding with the analysis of the bivariate system the specification issue needs to be addressed. Since many macroeconomic time-series contain unit roots (see, inter alia, Nelson and Plosser (1982)), and Stock and Watson (1989) have shown that the asymptotic distribution of Granger-causality test statistics is

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[26] This paper extends Astley and Haldane's empirical approach by considering the out-of-sample forecast performance of monetary aggregates.

[27] For an excellent discussion of the limitations of reduced form analysis with respect to structural inference see Leamer (1985). A similar point is made by Henry and Pesaran (1993), p. 235.

sensitive to the presence of unit roots and time trends in the data, the stationarity properties of the time-series are investigated first. The analysis of the unit root properties proceeds on the basis of the widely used augmented Dickey Fuller (ADF) test and the Phillips-Perron (PP) test. In addition the stationarity test developed by Kwiatkowski, Phillips, Schmidt and Shin (KPSS) is employed. The ADF and PP procedures test the null hypothesis of non-stationarity, whereas the KPSS test has stationarity as the null hypothesis. All series turn out to be non-stationary.[28] To decide whether the bivariate system should be specified in differenced variables, the presence of cointegration relationships is tested using the Johansen (1992) procedure.[29] Evidence for cointegration is obtained for the narrow money aggregate with respect to the real activity variables.[30] For these systems the following analysis proceeds in the framework of a Vector Error Correction Model (VECM) with the rank restriction imposed.[31] The lag lengths of the VAR systems are chosen on the basis of the Hannan-Quinn information criterion. This criterion typically chooses a more parsimonious model than the widely used Akaike criterion, which is a useful property in light of the relatively short sample period.[32]

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[28] The results are presented in the Appendix, table A2. Unit root tests are known to have low power, so the stationarity properties are evaluated on the basis of a number of tests. Still, considerable uncertainty with regard to the order of integration remains as in some cases contradictory results are obtained. In this case the decision is based on the result supported by two out of the three tests.

[29] If no cointegration relationship is found, the price and the broad money variable needs to be differenced twice to obtain stationarity.

[30] The results are presented in the Appendix, table A3.

[31] The VECM is analysed using MALCOLM.

[32] The Hannan-Quinn criterion chooses here the optimal lag length over one to five lags.

The information content of money is first assessed with the help of the Granger-causality tests. Consider the following equation of the bivariate system in first differences:[33]

$$(5) \qquad \Delta z_t = c + \sum_{i=1}^{p} a_i \Delta z_{t-i} + \sum_{i=1}^{p} b_i \Delta m_{t-i} + e_t \,.$$

Here, c is a constant, Δz are deseasonalised and suitably differenced price or real activity variables while Δm denotes the indicator variable based on a monetary aggregate. The error term e is Gaussian white noise. If the money variable contains useful information for forecasting Δz, then some of the b coefficients should be significantly different from zero. The Granger-causality test is an F-test of the null hypothesis H_0: $\sum_i b_i = 0$. In other words, the Granger-causality test establishes on the basis of in-sample information whether money possesses systematic, leading indicator information with respect to the variable to be predicted.

In addition to the Granger-causality tests, the forecast error variance decomposition is computed.[34] Of interest is the proportion of the h-step forecast error vari-

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[33] With respect to a system with cointegrated variables, the Granger-causality test is computed as proposed by Mosconi and Gianinni (1992). To illustrate, consider the bivariate vector autoregression:

$$\Pi(L)y_t = \begin{pmatrix} \Pi_{11}(L) & \Pi_{12}(L) \\ \Pi_{21}(L) & \Pi_{22}(L) \end{pmatrix} \begin{pmatrix} m_t \\ z_t \end{pmatrix} = \begin{pmatrix} e_{m_t} \\ e_{z_t} \end{pmatrix} = e_t$$

Mosconi and Giannini suggest that in order to check if the variables in y_t are cointegrated and m_t does not cause z_t one has to test jointly whether $\Pi(L)$ is upper blocker triangular - $\Pi_{21}(L) = 0$ - and $\Pi = \Pi(1)$ is nonzero and has reduced rank. They argue that this procedure leads to an efficiency gain compared to the common procedure to establish first whether the variables are cointegrated and then to go back to the VAR system in levels (with no cointegration restrictions imposed) to perform the standard non-causality test.

ance of the variable to be predicted accounted for by innovations in the money variable. Here the results for a horizon of eight quarters are reported. Although Granger-causality and variance decompositions have an exact equivalence in bivariate systems (see Dufour and Tessier (1993)), the forecast error variance decomposition gives some additional insights by quantifying the importance of money in the system.[35]

Granger-causality tests are silent about the stability of the relation between the indicator and the second variable in the system. To shed some light on this issue, the estimated bivariate systems are subjected to the joint stability test proposed by Hansen (1992). This test is approximately a Lagrange multiplier test of the null of constant parameters against the alternative that the parameters follow a martingale. This alternativ incorporates simple structural breaks of unknown timing as well as random walk parameters. The asymptotic distribution theory for the test is given by Hansen (1990) and asymptotic critical values can be found in Hansen (1992). To conserve space, only the results for equation (5) are presented.[36]

However, within-sample significance and stability of the relationship do not guarantee good out-of-sample forecasting performance.[37] Historical out-of-

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34 For the variance decomposition, the residuals of the VAR representation are orthonormalised by Cholesky factorisation with the money variable ordered first.

35 The computation of the variance decomposition for the VECM is in principle similar to the VAR in differences.

36 The stability tests for the VECM are based on a recursive procedure suggested by Hansen and Johansen (1992).

37 For instance, if an indicator has only a short lead and is itself hard to predict, then the forecast performance over longer horizons can be quite poor, even if the indicator has respectable in-sample properties.

sample forecasts are a useful way to quantify the findings of in-sample significance and stability in terms of forecast errors by simulating the actual forecast process as closely as possible.

To generate the forecasts an additional equation for the indicator variable is estimated:

$$(6) \qquad \Delta m_t = c + \sum_{i=1}^{p} g_i \Delta m_{t-i} + \sum_{i=1}^{p} f_i \Delta z_{t-i} + u_t \,.$$

Together with (5), these two equations constitute the bivariate VAR, which is at the center of the empirical analysis.[38] This system can be used to generate forecasts out to any desired horizon.

To provide a benchmark for the assessment of the forecast performance of the indicator variable, a univariate model for the variable to be predicted is chosen:[39]

$$(7) \qquad \Delta z_t = c + \sum_{i=1}^{p} a_i \Delta m_{t-i} + e_t \,.$$

A univariate model appears to be a natural benchmark. The bivariate model can be seen as an extension of the univariate model, employing in addition the indicator variable. If the forecast of the bivariate model cannot outperform the uni-

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[38] In case of the VECM, the bivariate system has the form:

$$(5') \quad \Delta x_t = c + \sum_{i=1}^{p} \Gamma_{x,i} \Delta x_{t-i} + \Pi_x x_{t-1} + e_t \,.$$

The vector x contains the variables *m* and *z*, while the matrix Π is restricted to have a rank of one. That is, the cointegration restriction is imposed on the system.

[39] The univariate model is specified like the bivariate VAR on the basis of the Hannan-Quinn criterion.

variate model, this suggests that either the information content of the indicator variable is rather small or that additional assumptions are needed to extract the information; an example is the P*-approach, where money is employed together with assumptions regarding potential output and equilibrium velocity. In both cases this provides evidence against the particular indicator. In the first case money does not provide much extra information, in the second case the relevant indicator is the price gap derived from the P*-model, not the money variable per se.[40]

The bivariate VAR consisting of (5) and (6) and the univariate model (7) are used to generate forecasts for one, four and eight periods ahead.[41] The forecasts are computed for the k-period-ahead inflation (P_{t+k} - P_t) and the k-period-ahead change in the real activity variables (y_{t+k} - y_t), where P denotes the price level and y the real variables.[42] The out-of-sample forecasts are computed over the period from the first quarter 1992 to the second quarter 1999. The generation of the forecasts proceeds in a recursive way. The equations (5) to (7) are first estimated and specified with the help of the information criterion till the end of 1991. Based upon this estimate the forecasts are calculated. Then the sample period is extended by one quarter, the equations are reestimated and respecified and a new set of forecasts is computed. This procedure is repeated until the second quarter 1997, where the final eight step ahead forecast reaches the second quarter 1999. The sequence of historical out-of-sample forecasts is used to calculate the Root Mean Squared Errors (RMSE) statistic, which gives the standard deviation of the forecast error, for all models and forecast horizons. The forecast performance of

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[40] For a discussion of this point see Gerlach and Svensson (1999).

[41] Forecasts for periods longer than two years are not very common in business cycle research.

[42] The system (5) to (7) and the VECM actually generate forecasts for Δp and Δy. These are then used to calculate the implied forecasts (P_{t+k} - P_t) and (y_{t+k} - y_t).

each model is evaluated by forming the ratio of the RMSE of the bivariate model to the RMSE of the corresponding univariate model. This measure can be viewed as a more general version of Theil's *U*-statistic, which uses a random walk model as a competitor. Here instead the univariate forecast is the benchmark. The interpretation is straightforward: a value of the ratio of RMSE's smaller than unity indicates that the indicator variable improves the forecast of inflation or real activity relative to the univariate model.

The forecast performance is evaluated over the period 1992 to 1999 (23 observations) and in addition over 1996 to 1999 (7 observations). The reason for this split in the sample is that as discussed in the previous section the velocity for broad money deviated between 1992 and 1995 substantially from its trend path. The ECB argues this was due to the ERM crises, changes in interest rate taxation and substantial interest rate movements. A further factor could have been the recession in a number of European countries in 1993/94. So the first half of the period considered here may have been substantially influenced by events that have been somewhat exceptional. Considering only the latter period controls for this. However, the full period gives some insight how the monetary aggregates fare as indicators in turbulent times. Also, events like strongly rising long rates, changes in the tax regime and recessions are not occurring frequently, but they are not so exceptional either. In this context it will prove interesting to see whether the modification of the monetary aggregates based on the ARIMA model for velocity turns out to be useful. After all, this modification is used here precisely because of the substantial shifts in velocity during the earlier period.

4. Empirical Results

The results for the evaluation of the forecast performance of the money-based indicators are given in table 1.[43]

Beginning with inflation it becomes apparent that none of the money based indicators performs well on all counts. With respect to Granger-causality, only the narrow money series modified for changes in velocity on the basis of an ARIMA model passes this criterion. But there is evidence for instability in the relationship between this indicator and inflation and the out-of-sample performance is quite poor in the forecast period covering the years from 1992 to 1999, even though there is some improvement in the latter period from 1996 onwards. Transforming the money series into annual growth rates helps to reduce instability, but the forecast properties are rather poor, as shown by the Granger-causality tests and the historical out-of-sample forecasts. Focusing on the out-of-sample forecast performance, the broad money series performs quite well. This holds in particular for longer forecast horizons. Still, the poor in-sample properties of this indicator weaken the case for using this variable as an information variable.

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43 The table does not include the results for real broad money, which has been considered as another money based indicator. The inclusion of this variable has been at first motivated by the idea that a variable representing money demand could be useful as a indicator. In fact, its forecast performance did not differ markedly from nominal broad money; in most cases it performed less well than the nominal series. Another variable considered was the modification of narrow and broad money based upon the McCallum rule for velocity as discussed in section 2. This model failed to outperform the more general ARIMA velocity model in case of broad money for all series. With regard to narrow money, the modification based on the McCallum rule outperformed the ARIMA specification in case of the investment and output series, but overall the performance was quite poor. To conserve space, these results are not presented here, but are available from the authors upon request.

Considering next output growth, the stability of the relationship between the money based series and this variable appears to be less of a problem here compared to inflation. Regarding Granger-causality, there is evidence for systematic leading behaviour of narrow money, broad money based on the ARIMA specification and narrow money transformed into annual growth rates. For the latter two the variance decomposition at the two year horizon shows that innovations to the indicator variables explain a substantial part in the variation of the output growth series. Turning to the out-of-sample properties of these three indicators, it becomes apparent that narrow money has some information content at short horizons, while broad money may improve the forecast on long horizons. The narrow money series in first differences outperforms the univariate forecast in both forecast periods at the one quarter horizon, but only marginally so. Transforming this series into fourth differences yields some information content at the one year horizon, but this holds only for the forecast period from 1996 onwards.[44] The out-of-sample performance of the broad money series with the ARIMA modification is generally quite poor with the exception of the two year

[44] Note that for the full forecast period beginning in 1992 the forecast error of this indicator model is not smaller than the corresponding measure of the univariate model specified in first differences.

Table 1: Empirical Results

D^2**CPI / D CPI (a)**						D^2**4CPI / D CPI (a)**		
	D**M1**	D**M1arima**	D^2**M3**	D^2**M3arima**		D**4M1**	D^2**4M3**	
Lag length	2	2	2	2		5	5	
F-statistic (b)	2.0584	7.4755***	0.9714	1.9493		0.4825	1.9036	
FEVD (%) (c)	12.1147	25.7925	2.7799	6.1608		3.9119	21.3448	
Stability (d)	2.3554***	1.9360**	2.5505***	2.6562***		2.0818	1.9661	
	Ratio (RMSE)	**Ratio (RMSE)**	**Ratio (RMSE)**	**Ratio (RMSE)**	**RMSE AR**	**Ratio (RMSE)**	**Ratio (RMSE)**	**RMSE AR**
Forecasts starting in 1992								
One quarter ahead	1.3977 (0.0020)	1.2876 (0.0019)	1.0975 (0.0016)	1.0266 (0.0015)	0.0015	.	.	.
Four quarters ahead	1.4158 (0.0068)	1.3768 (0.0066)	0.8065 (0.0039)	0.8516 (0.0041)	0.0048	1.8246 (0.0082)	1.7284 (0.0078)	0.0045
Eight quarters ahead	1.5300 (0.0147)	1.6175 (0.0155)	0.7266 (0.0070)	0.8697 (0.0083)	0.0096	2.4067 (0.0230)	2.0111 (0.0192)	0.0095
Forecasts starting in 1996								
One quarter ahead	0.9902 (0.0017)	1.0001 (0.0017)	0.9760 (0.0017)	1.0083 (0.0018)	0.0017	.	.	.
Four quarters ahead	0.8646 (0.0037)	0.8585 (0.0037)	0.8264 (0.0035)	1.0890 (0.0047)	0.0043	0.9572 (0.0042)	1.2789 (0.0056)	0.0043
Eight quarters ahead	0.8361 (0.0067)	0.8478 (0.0068)	0.7950 (0.0064)	1.0745 (0.0086)	0.0080	0.8559 (0.0078)	0.9901 (0.0091)	0.0091

DY						D4Y		
	M1	D**M1arima**	D^2**M3**	D^2**M3arima**		D**4M1**	D^2**4M3**	
Lag length	2	1	1	2		1	5	
F-statistic (b)	17.645*** (e)	0.4611	0.4442	11.0704***		6.6965**	0.5866	
FEVD (%) (c)	10.01	2.0371	1.8763	24.9023		22.0218	5.1516	
Stability (d)	n.r. (f)	0.9357	0.8165	1.1692		0.3435	2.1469	
	Ratio (RMSE)	**Ratio (RMSE)**	**Ratio (RMSE)**	**Ratio (RMSE)**	**RMSE AR**	**Ratio (RMSE)**	**Ratio (RMSE)**	**RMSE AR**
Forecasts starting in 1992								
One quarter ahead	0.9744 (0.0049)	1.0362 (0.0053)	1.0534 (0.0054)	1.4220 (0.0072)	0.0051	.	.	.
Four quarters ahead	1.0280 (0.0154)	1.0394 (0.0156)	1.0201 (0.0153)	1.0812 (0.0162)	0.0150	0.8746 (0.0150)	1.0923 (0.0188)	0.0172
Eight quarters ahead	1.2448 (0.0214)	1.0821 (0.0187)	1.0254 (0.0177)	1.1703 (0.0202)	0.0172	0.9919 (0.0227)	1.1507 (0.0264)	0.0229
Forecasts starting in 1996								
One quarter ahead	0.9729 (0.0036)	1.0974 (0.0041)	1.0163 (0.0038)	1.4331 (0.0054)	0.0038	.	.	.
Four quarters ahead	1.1416 (0.0090)	1.0957 (0.0087)	0.9906 (0.0078)	1.2282 (0.0097)	0.0079	0.7810 (0.0059)	1.3667 (0.0103)	0.0075
Eight quarters ahead	1.6627 (0.0159)	1.0850 (0.0104)	0.9650 (0.0092)	0.6314 (0.0060)	0.0096	1.2755 (0.0129)	0.6537 (0.0066)	0.0102

Table 1 (continued)

D**GFCF**						D**4GFCF**		
	M1	D**M1arima**	D^2**M3**	D^2**M3arima**		D**4M1**	D^2**4M3**	
Lag length	2	1	2	5		1	5	
F-statistic (b)	17.556*** (e)	0.2794	0.8357	3.4106***		9.2418***	0.6508	
FEVD (%) (c)	40.56	0.8775	4.3097	9.8279		36.6114	0.7363	
Stability (d)	n.r. (f)	1.2608**	1.0696	2.0864		0.9880	1.8771	
	Ratio (RMSE)	**Ratio (RMSE)**	**Ratio (RMSE)**	**Ratio (RMSE)**	**RMSE AR**	**Ratio (RMSE)**	**Ratio (RMSE)**	**RMSE AR**
Forecasts starting in 1992								
One quarter ahead	0.9937 (0.0170)	1.0232 (0.0173)	0.9560 (0.0162)	0.9355 (0.0158)	0.0169	.	.	.
Four quarters ahead	1.0222 (0.0503)	0.9179 (0.0462)	0.88278 (0.0416)	0.8271 (0.0416)	0.0503	1.4540 (0.0626)	1.1786 (0.0507)	0.0430
Eight quarters ahead	1.1120 (0.0833)	0.8509 (0.0651)	0.7474 (0.0572)	0.7656 (0.0586)	0.0765	1.7970 (0.1084)	1.2523 (0.0755)	0.0603
Forecasts starting in 1996								
One quarter ahead	0.9620 (0.0183)	1.0357 (0.0201)	1.0009 (0.0195)	0.8689 (0.0168)	0.0194	.	.	.
Four quarters ahead	0.8220 (0.0245)	1.1075 (0.0330)	0.8681 (0.0259)	0.7069 (0.0211)	0.0298	0.8236 (0.0233)	1.2313 (0.0349)	0.0283
Eight quarters ahead	1.0124 (0.0529)	1.1971 (0.0624)	0.9156 (0.0478)	0.7800 (0.0407)	0.0522	1.2406 (0.0479)	0.9769 (0.0378)	0.0386

DCONS						D4CONS		
	M1	D**M1arima**	D^2**M3**	D^2**M3arima**		D**4M1**	D^2**4M3**	
Lag length	2	1	2	2		1	5	
F-statistic (b)	28.106*** (e)	0.6927	0.3925	2.5067		2.8767*	0.4137	
FEVD (%) (c)	48.59	2.3600	0.9521	8.8780		15.7344	1.9298	
Stability (d)	n.r. (f)	1.2358*	1.4692	1.2111		0.5915	1.3820	
	Ratio (RMSE)	**Ratio (RMSE)**	**Ratio (RMSE)**	**Ratio (RMSE)**	**RMSE AR**	**Ratio (RMSE)**	**Ratio (RMSE)**	**RMSE AR**
Forecasts starting in 1992								
One quarter ahead	1.0696 (0.0071)	1.2240 (0.0082)	1.0660 (0.0071)	1.0722 (0.0071)	0.0067	.	.	.
Four quarters ahead	1.1173 (0.0181)	1.3190 (0.0214)	0.9860 (0.0160)	0.9998 (0.0162)	0.0162	0.8881 (0.0141)	1.3276 (0.0210)	0.0158
Eight quarters ahead	1.2403 (0.0339)	1.5619 (0.0427)	0.9047 (0.0247)	0.9793 (0.0268)	0.0273	0.9097 (0.0242)	1.4848 (0.0395)	0.0266
Forecasts starting in 1996								
One quarter ahead	1.2209 (0.0042)	1.1220 (0.0039)	1.0676 (0.0037)	1.3767 (0.0048)	0.0035	.	.	.
Four quarters ahead	1.3459 (0.0088)	1.1218 (0.0074)	0.9863 (0.0065)	1.2675 (0.0083)	0.0066	0.8114 (0.0057)	1.9183 (0.0135)	0.0070
Eight quarters ahead	1.9913 (0.0210)	1.0775 (0.0114)	0.8715 (0.0092)	0.7829 (0.0083)	0.0105	0.7486 (0.0088)	1.1729 (0.0137)	0.0117

Legend:

* = significant at 10% level

** = significant at 5% level

*** = significant at 1% level

Ratio stands for the relative out-of-sample RMSE of the bivariate model and the univariate model. The RMSE of the bivariate model is given between brackets.

(a) Since the CPI was found to be integrated of order 2, the relevant models are estimated using the stationary growth rate of inflation (Δ^2CPI). However, the calculation of the RMSE is based on the implied forecast for ΔCPI.

(b) The F-statistic results from the F-test of the exclusion of lags of the indicator in the equation of the bivariate model that has the growth rate of inflation or the real variables as dependent variable. For cointegrated systems, see note (e). See also equation (5).

(c) FEVD is the per cent of variance of the dependent variable, *viz.* growth in inflation or real activity, explained by innovations in the monetary aggregate at the eight quarter horizon.

(d) Joint stability test given in Hansen (1992). The reported statistic refers to the equation having growth in inflation or in real activity as the dependent variable. For cointegrated systems, see note (f).

(e) Test statistic of the Granger non-causality test in a cointegrated system as discussed by Mosconi *et al* (1992). Computed with MALCOLM.

(f) Stability test based on recursive R-model as discussed by Hansen *et al* (1992). n.r: not rejected, r: rejected. Computed with MALCOLM.

ahead forecast in the forecast period beginning in 1996. A closer look at the forecast performance of this indicator reveals that it does not predict turning points well. This is the reason why the forecast quality in the full period from 1992 onwards is less than impressive, because this period includes the recession in 1993, the upswing in 1994 and the renewed slow down in activity in 1995. From 1996 onwards output expands more smoothly and in this period the money indicator model turns out to be more successful than the univariate model. Difficulties in forecasting turning points is not confined to this indicator model, they are rather a general characteristic of the money based indicators investigated in this paper. Summarising the results for output growth, a case for money as an indicator can be made here, but only for periods like the latter part of the nineties where no major shocks occurred.

Turning to changes in investment, the picture is very similar to output growth. Problems with the stability property are again not an issue here. There is evidence for Granger-causality to hold for the same indicators as with output growth. The share in the variance decomposition explained by innovations to the narrow money aggregates in first and fourth differences is quite impressive. With regard to the historical out-of-sample forecasts the major difference is that the standard errors for the forecasts for the investment series are about ten times higher than those for the output series. This is presumably due to the higher volatility of this aggregate, which makes forecasting this series much harder. Turning to the indicators, narrow money in first differences still consistently outperforms the univariate model at short horizons like it did with output growth, but again only marginally so. Transforming this aggregate into annual growth rates is less successful here. The best performing money indicator on the basis of the historical out-of-sample forecasts is broad money with the ARIMA adjustment. It outperforms the univariate model in first differences at all horizons and over both sample periods. But the second AR model considered here holds its own; the money based system hardly improves upon this model, if at all. The second AR model is specified in specified in annual growth rates and this apparently helps to filter out some of the high frequency noise in the investment growth series, improving its forecast performance relative to the model in first differences. But this transformation is not successful with the money based models. So while the in-sample properties of the three money based indicators are quite encouraging, they are less convincing when it comes to the out-of-sample forecast performance.

Finally consumption is considered. Like with the other two real activity variables there is again no evidence for instability in the relationship between the indicators and consumption growth. But evidence for Granger-causality is found only for the narrow money series in first and fourth differences. The share of the forecast error variance explained is particular respectable with regard to the former. But when the historical out-of-sample performance is considered it becomes clear that the latter indicator is first choice. Narrow money transformed into annual growth rates outperforms the univariate model consistently in both forecast periods and over all forecast horizons. The only other indicator that is noticeable for predicting the consumption series well is broad money adjusted for changes in velocity. But again this only holds for the second half of the sample period and only for long forecast horizons. Also, the in-sample properties of the modified broad money series are not convincing. This leaves the narrow money series in fourth differences as the preferred indicator, which passes all criteria.

5. Conclusion

On balance, the information content of money with respect to inflation and real activity variables appears rather underwhelming. The univariate models turn out to be formidable competitors. Hardly any of the money based indicators manages to outperform these models substantially over both forecast periods considered here. The suggested modifications to account for high frequency noise and for shifts in velocity enhance the forecast performance of the money variables somewhat. This holds in particular for narrow money with regard to the transformation into annual growth rates and for broad money the modification based on the ARIMA model of velocity turns out to be helpful, but the improvement of the quality of the forecast is not always substantial. At least with respect to real activity variables the broad money series with the ARIMA correction forecasts well over long horizons, while narrow money on balance appears to be more successful at shorter horizons. But for both it generally turns out that they work well only in the second half of the sample period. The changes in velocity and the recession in the first half of the nineties apparently lead to a substantial deterioration of the forecast performance of money based indicators relative to the univariate models, suggesting that these indicators have some difficulties with predicting turning points.

The finding that the indicator qualities of money are somewhat lacking is a result that has been established also by other studies, in particular for the USA.[45] But care is needed not to overinterpret the empirical evidence presented here. It is well possible that money may matter very much in the monetary transmission mechanism, but that countercyclical policy makes it hard to extract its information content. Still, if the prominent role of money in the monetary policy strategy of the ECB is not so much based on evidence regarding its indicator qualities, then other arguments demonstrating the validity of its presumed role in the transmission mechanism need to be forwarded. While there is a large body of literature providing evidence that there is a stable money demand relationship in the euro zone, this alone is not sufficient to make the point.[46] In addition one has to show that the ECB actually can control the money supply and that the difference between money supply and money demand is a quantitatively important factor for price developments, also relative to other determinants of inflation. For both points the evidence is still relatively scarce, leaving broad scope for further research.

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45 See for example Stock and Watson (1999) and Friedman and Kuttner (1992) for the USA and Estrella and Mishkin (1997) for the USA and Germany.

46 For a detailed discussion of this point see Ericsson (1999).

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Data Appendix

The data are aggregates for the EU-11 countries and cover the period 1980:1 until 1999:2. The monetary aggregates are taken from the ECB Monthly Bulletin, where data on the EU-11 monetary aggregates denominated in billions of euro are regularly published. The aggregated series, based on the harmonised system of money and banking statistics, is available back to September 1997. Longer series can only be constructed by aggregating national contributions to the monetary aggregates based on non-harmonised definitions of the monetary aggregates. This was done in a special issue from the ECB Monthly Bulletin (ECB (1999a)). The real activity variables are all based on the new accounting procedures of ESA-95. Eurostat provides estimates for the Euro zone beginning in 1991. Real GDP, real consumption and real gross fixed domestic investment have been estimated backward based on historical series for the Euro zone provided by the OECD and the ECB. The inflation series is based upon a CPI-index provided by Datastream; all variables are seasonally adjusted. Details are given in table A1.

Table A1: The Data[47]

	Series	Period	Source
m1	Nominal monetary aggregate M1; billions of euro.[2] Seasonally adjusted[1].	Q1 1980 - Q2 1999	European Central Bank[3]
m3	Nominal monetary aggregate M3; billions of euro.[2] Seasonally adjusted[1].	Q1 1980 - Q2 1999[2]	European Central Bank[3]
rm3	Difference between m3 and cpi.	Q1 1980 - Q2 1999	-
y	Real gross domestic product (GDP); billions of euro. Seasonally adjusted[1].	Q1 1980 - Q2 1999	Eurostat on Datastream (EMESGD95D) and European Central Bank[4]
gfcf	Real gross fixed domestic investment. Seasonally adjusted[1].	Q1 1980 – Q2 1999	Eurostat on Datastream (EMESGF95D and BDESGF95D)
cons	Real consumption. Seasonally adjusted[1].	Q1 1980 – Q2 1999	Eurostat on Datastream (EMESPN95D and BDESPN95D)
cpi	Consumer price index; 1996=100. Seasonally adjusted[1]	Q1 1980 - Q2 1999	Eurostat on Datastream (EMCP….F)

[1] Seasonally adjusted with Census X-11 Multiplicative.

[2] Original data in monthly frequency, transformed into quarterly with arithmetic averages.

[3] ECB (1999a) and ECB (1999b).

[4] Coenen and Vega (1999).

[47] The data set and the programs are available from the authors on request.

Table A2: Time Series Properties of the Data

	Series in differences			Series in levels			
	ADF	**PP**	**KPSS**	**ADF**	**PP**	**KPSS**	**ORDER OF INTE-GRATION**
m1	-1.17 (8,c)	6.82***	0.17 (mu)	-2.25 (9,c,t)	-1.53	1.08 (tau)***	I(1)
D**m1-ar**[a]	-2.79 (2,c)*	8.01***	0.52 (mu)**				I(0)
m3	-2.11 (7,c)	-3.24**	0.77 (mu)***	-	-	-	I(2)
D**m3-ar**[a]	-2.07 (7,c)	3.92***	0.74 (mu)***	-	-	-	I(1)
y	-7.64 (0,c)***	7.72***	0.16 (mu)	-2.02 (0,c,t)	-2.23	0.13 (tau)*	I(1)
gfcf	-2.13 (11,c)	6.65***	0.20 (mu)	-3.71 (11,c,t)**	-2.33	0.10 (tau)	I(1)
cons	-2.25 (11,c)	8.00***	0.14 (mu)	-2.11 (4,c,t)	-1.63	0.14 (tau)*	I(1)
cpi	-2.57 (3,c)	-2.01	0.78 (mu)***	-	-	-	I(2)

[a]-ar denotes the ARIMA-modification of the money series. Note that this modification is applied to the differenced series only.

The asterisks indicate a rejection of the null hypothesis at the 10% (*), the 5% (**) or the 1% (***) level.

ADF and PP tests: the critical values are taken from Hamilton (1994). ADF(lags, c, t), where c and t stand for constant and trend.

KPSS test: the critical values are taken from Kwiatkowski et al (1992). KPSS(μ) denotes H0: {X(t)} is stationary around a level, while KPSS(τ) denotes H0: {X(t)} is trend stationary.

Table A3: Results for the Rank Test

Bivariate system	**H0**				**Critical values**
	r=0		**r=1**		**5%**
	Trace	**Adj. Trace**	**Trace**	**Adj. Trace**	**significance level**
			y		
m1	24.71***	24.07***	0.77	0.75	r=0 18.11
D**m3**	10.20	9.66	0.08	0.08	r=1 8.19
			gfcf		
m1	18.86**	18.37**	2.35	2.29	r=0 18.11
D**m3**	8.25	7.81	0.00	0.00	r=1 8.19
			cons		
m1	19.93**	19.41**	0.73	0.71	r=0 18.11
D**m3**	8.05	7.40	0.12	0.11	r=1 8.19
			D**cpi**		
m1	3.62	3.33	0.00	0.00	r=0 18.11
D**m3**	11.00	10.01	2.85	2.62	r=1 8.19

The asterisks indicate a rejection of the null hypothesis at the 10% (*), the 5% (**) or the 1% (***) level.

Critical Values for the trace statistic are taken from MacKinnon et al. (1998).

Adj. Trace = Trace * (T-nk)/T, where T is the sample size, n is the dimension of the VAR model and k gives the lag order.