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Euro Area Money Demand: Measuring the Opportunity Costs Appropriately

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Abstract

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The existence of a well-specified and stable relationship between money and prices has long been perceived as a prerequisite for the use of monetary aggregates in the conduct of monetary policy. This paper contributes to the ongoing discussion about the stability of euro area money demand by constructing an own rate of return on euro area M3 and by analyzing its implications in a standard money demand system. Over the sample period, one cointegrating vector relating real M3, real GDP and the spread between the short-term interest rate and the own rate of M3 can be identified and interpreted as a long-run euro area money demand equation. A dynamic money demand system is subsequently estimated. Standard diagnostics stability tests and out-of-sample forecasts confirm the good statistical performance of the model.

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I. INTRODUCTION

Money is a key element in the monetary policy framework of most central banks. This is because, based on the observation that inflation is ultimately a monetary phenomenon, money constitutes a natural "nominal anchor" for the monetary policy of central banks aiming at price stability such as the European Central Bank (ECB) for the euro area. More generally, the existence of a well-specified and stable relationship relating the money stock to the price level and some explanatory variables is usually perceived as a prerequisite for the use of monetary aggregates in the conduct of monetary policy. The stability of this relationship is usually assessed in a money demand framework.

Money demand functions typically include two main sets of explanatory variables: (1) scale variables; and (2) opportunity cost measures (*i.e.* the difference between the returns on money and on its alternative assets).[2] In empirical work, the choice of the scale variable is relatively little controversial. This is because, although alternative theories of money demand may emphasize the importance of different scale variables (for instance, transaction-related theories suggest to choose income, while portfolio approaches stressing the role of money as an asset support the use of financial wealth), in practice the very large majority of money demand studies include only a measure of income (usually real GDP) due to measurement problems associated with wealth data.[3] By contrast, the choice of the appropriate opportunity cost variable is less straightforward.

A. Issues Related to the Correct Measurement of the Opportunity Costs of Money

The problem of identifying the correct measure of the opportunity cost of holding money is twofold since it involves the choice of appropriate measures for both the own rate of money and the rates of return on the relevant alternative assets. Following the results of monetary theory (see e.g. Friedman, 1956, 1959) showing that, for the purpose of portfolio decisions, money-holding agents treat a large variety of assets as alternative to money, it is generally accepted that a wide spectrum of the rates of return of alternative assets should be taken into account. However, for reasons of collinearity among these rates, most of the empirical literature restricts itself to one representative interest rate. This is usually justified on the grounds that, since the interest rates of different financial instruments tend to move together, it is probably sufficient to include one representative rate to obtain reasonable results.[4]

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[2] See Goldfeld and Sichel (1990) and Laidler (1993) for comprehensive accounts of the literature on money demand.

[3] See Laidler (1993, pp. 98-100).

[4] See Laidler (1993, pp. 155-157).

In particular, the short-term market interest rate is often included in the money demand equation as the representative rate of alternative assets on the grounds that negotiable instruments with short maturity are the closest substitutes for money. In this respect, it is argued that longer-term assets cannot represent close substitutes since they have a different risk/return profile. This procedure is sometimes justified, more formally, with reference to the work by Ando and Shell (1975) who argue, in the context of a three-asset model and assuming perfect capital markets, that the rate of return on the long-term risky asset determines the overall allocation of financial portfolios between such asset and those with certain nominal return (*i.e.* money and savings deposits), but has no influence on the demand for money (which would rather depend on the rate of return on savings deposits and transaction costs). This argument has, though, been criticized by Baba et al. (1992) who demonstrate that, if capital market imperfections are introduced in the Ando and Shell model, money is demanded for both transactions and portfolio motives and the rate of return on the risky long-term asset enters the money demand equation. Thus, the results by Baba et al. (1992) are generally interpreted as providing support to the inclusion of the long-term interest rate as the representative rate.

In practice, the relevant representative rate on alternative assets will depend to a large extent on the composition of the wealth portfolio of the money-holding sector. Thus, in countries that have endured fiscal profligacy and high inflation over protracted periods, the probable existence of a large stock of debt with a relatively short maturity may lead to economic agents focusing on short-term negotiable instruments as substitutes for money. By contrast, in countries that have traditionally enjoyed fiscal discipline and low inflation, long-term financial instruments might play a more important role as alternative assets to money. Dedola et al. (2001) provide some evidence of this behavioral divergence for the individual euro area countries.[5] These considerations raise the interesting question – addressed in the empirical part of this study - of which representative rate, whether the short-term or the long-term interest rate, should enter the money demand equation of the euro area as a whole, given that this comprises countries which exhibited a somewhat heterogeneous behavior before the start of the convergence process towards Monetary Union.

Nevertheless, as noted above, the identification of the appropriate rates of return on alternative assets is only one part of the problem of how to measure correctly the opportunity cost of holding money. A number of authors (*e.g.* Ericsson, 1999) have argued that the inclusion of the own rate of money is of critical importance when the analysis refers to broader monetary aggregates including deposits bearing an explicit interest or other remunerated components. While no-one seems to question that in the case of broad aggregates a non-zero own rate of money exists and has to be taken into account, in practice, in order to circumvent the difficulties associated with computing historical data on the rate, authors usually prefer using the short-term market interest rate as a proxy variable for the own rate of money, while also including the

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[5] On the basis of a panel data study Dedola et al. (2001) find that the short-term interest rate is more relevant in Spain and Italy, while the long-term interest rate seem to represent the correct measure of the return on the representative alternative asset in Germany and the Netherlands.

long-term bond yield as a representative outside rate.[6] The fact that the short-term rate then enters the long-run money demand function with a positive sign is usually interpreted as providing support to its use as a proxy for the own rate of money. However, this procedure can be criticized on the basis of evidence provided by several empirical studies (see, for instance, Baba et al., 1992, for the USA and Filosa, 1995, for the EU countries) regarding the importance for the proper estimation of the elasticity of the opportunity cost of money of including an accurate measure of the own rate of money.[7]

The inclusion of the short-term interest rate as a proxy for the own rate can create additional problems. First, assuming that the short-term interest enters the long-run money demand, a positive sign of the long run coefficient of this variable would imply that a rise in the rate – for example, following a monetary policy tightening – might, as a direct effect, lead to higher demand for M3. Second, in the steady-state, if the spread between the long-term and the short-term market interest rates or yield curve is stationary (*i.e.* if the elasticity of the short-term interest rate equals the elasticity of the long-term interest rate in absolute terms), real balances are not affected directly by an upward shift in the term structure. In other words, these results imply that when a short-term market interest rate is used as a proxy for the own rate of money, the model will - under certain circumstances - represent the direct effect of monetary policy tightening as either perverse (in the first case) or ineffective (in the second case).[8] In order to avoid these problems, it is inevitable to use an appropriate measure of the own rate of M3.

Opportunity cost measures in the recent empirical literature on euro area money demand

The number of contributions to the empirical literature on European money demand has rapidly grown over the last ten years prompted by the developments of monetary integration. Hayo (1998) includes an interesting account of the developments of European money demand research during this period, while Browne et al. (1997), Filosa (1995) and Golinelli and Pastorello (2000) provide comprehensive surveys of empirical studies for different monetary aggregates in various groupings of EU countries. While some of these studies differ to a varying extent in respect to issues such as country coverage, econometric methodology or datasets used (in particular, regarding the procedure used to aggregate historical national data), they all seem to conclude that it is possible to estimate a stable European money demand function.

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[6] See Fagan and Henry (1998), Coenen and Vega (1999) and Müller and Hahn (2000) for examples referring to the euro area.

[7] In particular, Filosa (1995) shows that at least for the major EU countries, the positive sign of the semi-elasticity of the short-term market rate is likely to be due to the omission of the own rate from the equation rather than to the appropriateness of the former.

[8] However, money demand would still be indirectly reduced by the effect of the interest rate rise on income and prices.

In this section we include a short survey of the opportunity cost measures used in recent empirical studies on euro area demand for M3 (the broad definition of money chosen by the ECB as its reference monetary aggregate). However, for the sake of consistency, we restrict this exercise to those recent studies based on the historical series for M3 officially released by the ECB. The issue of the correct measurement of the own rate of money is of significant importance in euro area money demand studies since most of the components of M3 are remunerated.[9] This is illustrated in Figure 1, where the rate of return on M3 is plotted (for illustrative reasons, together with the market interest rates) for the period 1980 and 1999. Nevertheless, most recent studies on euro area demand for M3 in the euro area have only partly taken these considerations into account.

Figure 1: The own rate of M3 and market interest rates in the euro area.
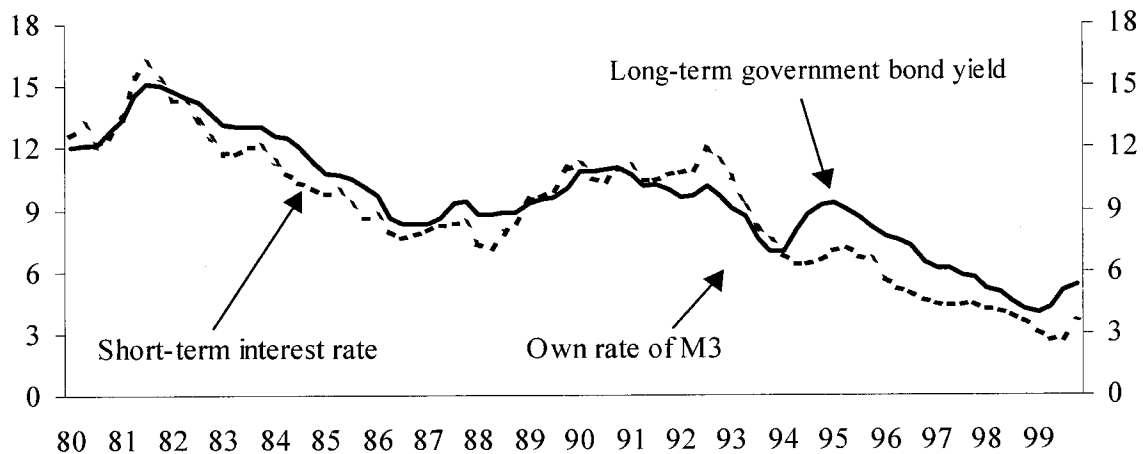
Coenen and Vega (1999) consider the spread between the long-term and the short-term interest rate (hereafter, the yield curve) as the opportunity cost of M3. However, as Figure 2 effectively illustrates, between 1980 and 1999 both the level and the dynamics of the yield curve differed fairly significantly from those of two more appropriate opportunity cost measures based on the own rate of money: the spread between the short-term interest rate and the own rate of money and that between the long-term government bond yield interest rate and the own rate of money (for the sake of brevity, hereafter we refer to these as the short-term and long-term spread, respectively).[10] Like Coenen and Vega (1999), Müller and Hahn (2000) include the short-term

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[9] The euro area definition of M3 comprises currency in circulation, overnight deposits, other categories of short-term deposits and some marketable instruments. At the end of 1999 these four main components of M3 accounted for 7%, 34%, 45% and 14%, respectively, of the aggregate.

[10] The first spread might be interpreted as capturing some kind of "arbitraging" behaviour, while the latter would refer to a more "speculative" behaviour.

interest rate and the long-term government bond yield to proxy the returns on money and on its alternative assets, respectively (though in their case the interest rates enter the equation separately).

Figure 2: Alternative Measures of the Opportunity Cost of M3 in the Euro Area
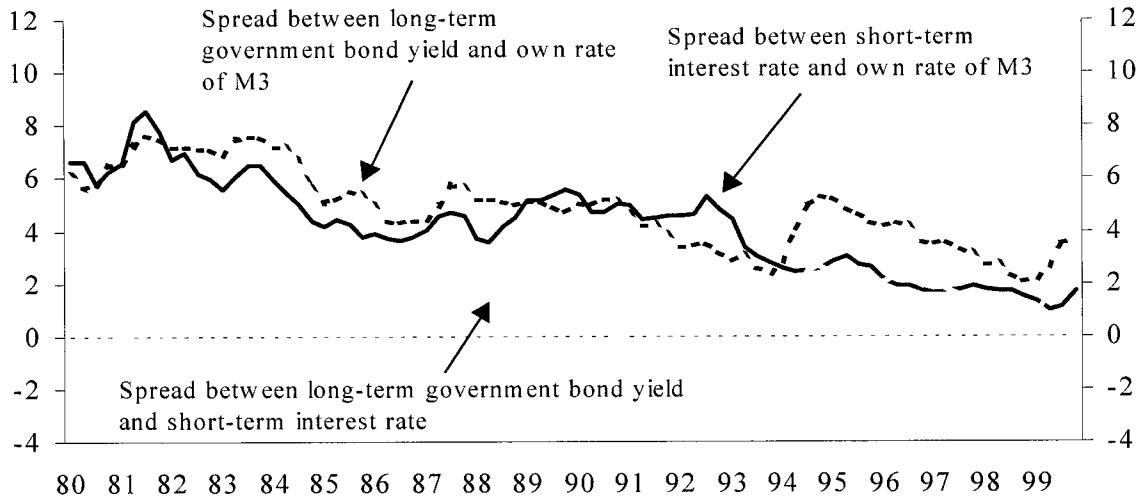
While recognizing the importance of using the own rate of money, in a more recent study Brand and Cassola (2000) choose to include only a single interest rate, namely the nominal long-term government bond yield, in their long run demand equation for M3. This is justified by the authors on the grounds that this rate broadly reproduces the dynamics of the spread between the long-term interest rate and the own rate of M3. Likewise, Golinelli and Pastorello (2000) include only the long-term interest rate in their preferred specification.[11] Although such specification can be seen as facilitating the estimation process, it ignores that, because M3 includes components which are remunerated, the use of the nominal long-term interest rate alone might lead to distorted estimates of the opportunity cost of holding money.

Levy (1999) is, to our knowledge, the first author using the ECB official data to develop a M3 demand model explicitly incorporating an estimate of the own rate of this monetary aggregate. The author estimates alternative systems linking real money balances, real income and individual measures of the opportunity cost of holding M3 over the period 1980 - 1998. One of the main conclusions of the study (confirmed by the results of the empirical investigation in this study) is that the systems based on the use of the short-term spread as the relevant measure of the opportunity cost of holding M3 behave better than those including the long-term spread. Dedola et al. (2001) also model euro area money demand explicitly including the own rate of

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[11] Although the authors also find an alternative long run money demand equation including the short-term market interest rate.

M3.[12] The authors estimate a cointegrating relationship linking real money balances, real income and the spreads between market interest rates and the own rate of M3 for the period Q3 1983 – Q1 1999. However, a significant difference compared with Levy (1999) is that, for practical reasons, the authors choose a single equation framework.[13] The authors find that euro area money demand is positively related with income and negatively with the long-term spread. However, the long-run coefficient of the short-term spread is not statistically significant.

The main purpose of this study is to address the issue of the inclusion of the own rate of money in the modeling of demand for euro area M3 building on the results of Levy (1999). Consistent with Dedola et al. (2001) we argue that the own rate of money cannot be ignored. However, we also argue that the demand for M3 in the euro area should be modeled using a system of equations rather than in a single-equation framework. This modeling approach is confirmed in our case by formal econometric tests showing that the money system considered in the empirical part of this work cannot be reduced to a single equation without incurring in a loss of information.

The remainder of this note is organized as follows. Section 2 describes a standard money demand function using two opportunity cost variables based on the own rate of M3. Section 3 focuses on the analysis of the long-run behavior of money demand and its economic implications. Section 4 proceeds by presenting and assessing the dynamic specification of the money demand system. Section 5 summarizes and concludes.

II. A STANDARD MONEY DEMAND FUNCTION

A. The Long-Run Model

As common in the empirical literature on euro area money demand (see, for instance, Coenen and Vega, 1999, Brand and Cassola, 2000, and Müller and Hahn, 2000), the starting point for the analysis consists of a system approach that allows for a broad range of interdependencies among the variables included. Consistent with standard theories of money demand, the basic system includes real M3, real GDP and measures of the opportunity cost of holding real monetary balances. In particular, rather than choosing *a priori* one specific opportunity cost measure we decide to include in our system both the short-term and the long-term spread. As explained in Ericsson (1999), the use of separate spreads helps to organize the information

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[12] Cassard et al. (1994) use the own rate of money in an earlier exercise referring to some EU countries. They estimate a money demand function including the spread between the short-term market rates and the own rate of money for the "ERM core group of countries". This is a group of countries participating in the ERM (namely, Belgium, Denmark, France, Germany, Luxembourg and the Netherlands) characterised by low inflation and stable currencies.

[13] This choice aims to facilitate the purpose of the study which is to compare an estimate of the euro money demand equation based on aggregate data with the area-wide parameters obtained by averaging country estimates using panel data techniques.

contained in the outside rates when, due to the heterogeneity of financial instruments and the presence of transaction costs of moving between them, it is necessary to consider several assets as alternative to money. In our case, the inclusion of both the short-term and the long-term interest rate also reflects uncertainty about the relevant alternative asset for the euro area as a whole.

More formally, the long run relationship is specified in the following (semi-) log linear form:

$$(m - p)_t = \beta_0 + \beta_1 \cdot gdp_t + \beta_2 \cdot (ST - OWN)_t + \beta_3 \cdot (LT - OWN)_t \quad (1)$$

where m, p and gdp denote nominal M3, the GDP deflator and real GDP; while ST, LT and OWN denote the short-term market interest rate, the long-term interest rate and the own rate of return on M3, respectively.[14] While money, GDP and the GDP deflator are transformed into logs, the own and outside rates enter in levels as suggested by Fair (1987). The anticipated signs are $\beta_1 > 0, \beta_2 \le 0$ and $\beta_3 \le 0$, with some theories providing more precise predictions of the long-run income elasticity (e.g. $\beta_1 = 1$ according to the quantity theory or $\beta_1 = 0.5$ in the Baumol-Tobin model of transaction demand for money).

B. The Data

In this study, we analyze quarterly data for the euro area over the period 1980 Q1 to 1999 Q4 based on the original 11 member countries. Real M3 holdings are measured by the logs of quarterly averages of end-of-month outstanding amounts of M3 (seasonally adjusted, EUR billions) deflated by the GDP deflator. Until Q3 1997, the series for M3 is based on stock data, from Q4 1997 on flow statistics. The nominal and real GDP series are constructed up to 1998 Q3 by aggregating logs of seasonally adjusted national accounts data (both ESA79 and ESA95) converted into euro using the irrevocably fixed conversion rates announced on 31 December 1998; from Q4 1998, the aggregate series is extended using quarter-on-quarter growth rates drawn from the ESA95-compliant series for seasonally adjusted euro area GDP from Eurostat. The short-term market interest rate is a weighted average (based on GDP weights at 1995 purchasing power parities) of national 3-month interbank interest rates up to end of 1998; from January 1999, it corresponds to the three-month EURIBOR interest rate. Similarly, the long-term interest rate is constructed as a GDP-weighted average of yields on national 10-year government bonds or their closest substitutes. The computation of the own rate of M3 is described in detail in the Data Annex. From January 1990 onwards, the own rate has been

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[14] It is worth noting that in line with recent results for the euro area (see Brand and Cassola, 2000, Dedola et al., 2001, Golinelli and Pastorello, 2000), our long run specification does not include inflation as a measure of the opportunity cost of holding money rather than goods. The fact that inflation does not enter the long run relationship could be interpreted in the sense that this variable is regarded as not having additional explanatory content on money demand compared to the nominal long-term interest rate.

calculated as the weighted average of the rates of return on the components of M3 using the share of these components as weights. This series has been extended backwards using a proxy rate given by the weighted average of the own rates of money in the five largest euro area countries, with the weights given by the relative share of the countries in the ECU basket of currencies. Quarterly interest rates are period averages expressed in percentage points per annum.

C. The Time Series Properties of the Data

The time series properties of the variables included in the system are formally investigated by means of both standard unit root tests and a stationarity test. The unit root tests performed – Dickey-Fuller (DF), its Augmented variant (ADF) and Phillips-Perron (PP) – rely on the null hypothesis of non-stationarity. By contrast, the KPSS test suggested by Kwiatkowski et al. (1992) tests the null of stationarity against the alternative hypothesis of non-stationarity. The results of the unit root tests (reported in Table B.1 in the Appendix) suggest that all the variables in the system should be modeled as I(1); and this is confirmed by the outcome of the KPSS test (see Table B.2).

These results may appear at first glance surprising for the spreads between market interest rates and the own rate of M3, particularly for that between the short-term market interest rate and the own rate of M3. This is because, since interest rates could be expected to follow the same long run trends, it is usually argued that, from an economic perspective, interest rate spreads should be stationary. Indeed, with the exception of currency in circulation, the instruments included in the euro area M3 are, in principle, interest-rate bearing. However, over most of our sample period some of the categories of deposits included in M3 (notably, overnight deposits) were little or no remunerated in several euro area countries. Besides, in most euro area countries changes in the policy-controlled interest rate have been historically passed through to rates on remunerated deposits only partially and in a sluggish fashion. These factors might to some extent explain the result of non-stationarity for the differential between the market interest rates and the own rate of M3. More generally, these results should be taken with caution since it is also possible that changes in the composition of money over the sample period (for instance, due to financial innovation) may have affected the statistical properties of the interest rate spreads and induced apparent unit roots.

III. ANALYSIS OF LONG-RUN MONEY DEMAND

A. Cointegration Analysis

In the next step, we test for the number of co-integrating relationships in the system using the Johansen procedure (see Johansen, 1995). This, in addition to determining the number of cointegrating vectors, enables - subject to appropriate specification testing - to identify and estimate such vectors. The procedure provides two separate test statistics for the determination of the number of cointegrating vectors: the likelihood ratio (LR) trace statistic and the maximum eigenvalue statistic. We interpret the test on the basis of the trace statistic rather than

the alternative maximum eigenvalue statistic following findings in the empirical literature suggesting that the former is more robust in the presence of either skewness or excess kurtosis.[15]

As reported in Table B.3, on the basis of the trace statistics, the econometric evidence reveals the existence of one long-run relationship at the 5% significance level among the variables included in the system.[16] When normalized with respect to real M3, the co-integrating vector has the following form (asymptotic standard errors in parentheses):

$$(m - p)_t = k + \underset{(0.04)}{1.34} \cdot gdp_t - \underset{(0.25)}{0.83} \cdot (ST - OWN)_t + \underset{(0.34)}{0.01} \cdot (LT - OWN)_t \qquad (2)$$

This vector can be interpreted as a long-run demand function for real holdings of M3, with money demand being positively related to real GDP and negatively to its opportunity cost as measured by the short-term spread. Although the coefficient of the alternative measure of the opportunity cost - the long-term spread - carries the "wrong" sign, it is very close to zero. Indeed, when we proceed to test for the exclusion of variables from the cointegrating vector by placing zero restrictions, we find that the null hypothesis of exclusion of the long-term spread cannot be rejected at the conventional significance levels (see results in Table B.4). By contrast, the null of exclusion of real GDP and the short-term spread can be rejected by the data.

B.   Tests for Irreducible Cointegrated Variables

In order to check this result for robustness, we re-run the Johansen procedure on all the possible sub-sets including real M3 of the variables of the system (see Table B.5). As mentioned above, cointegration can be found for the set including real money, real GDP, the short-term spread and the long-term spread. If the long-term spread is removed from the set, a cointegration relationship remains. If, however, the short-term spread is excluded from the set, the Johansen procedure fails to detect any cointegration. We, therefore, tend to conclude that the long-run relationship including real money, real income and the short term spread forms a set of irreducibly cointegrated variables as defined by Davidson (1998). This seems to confirm the robustness of the results.[17]

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[15] See e.g. Cheung and Lai (1993), p. 324.

[16] The lag order of the VAR is set at two. The specification includes an unrestricted constant, which allows for a linear trend in the data.

[17] In line with Cassard et al (1994), the fact that the short-term spread rather than the long-term spread enters the long run money demand function might be interpreted as supporting the controllability properties of the monetary aggregate.

Restricted cointegration analysis

On the basis of the results of the long-run exclusion tests, we proceed by restricting the long-term spread to zero and re-estimate the system including only the variables significantly different from zero. This yields the following results for the cointegrating relationship (asymptotic standard errors in parentheses):

$$(m - p)_t = k + \underset{(0.04)}{1.34} \cdot gdp_t - \underset{(0.29)}{0.86} \cdot (ST - OWN)_t \qquad (3)$$

According to the re-estimated cointegrating vector, long run demand for real balances of M3 is positively related to real GDP (with an elasticity of 1.34) and negatively to its opportunity cost as measured by the short-term spread (with a semi-elasticity of -0.86).

Some authors have argued that the Johansen approach, being based on reduced rank analysis would be vulnerable to spurious co-integration in some specific cases.[18] It has been, therefore, suggested that the results of the Johansen procedure should be compared with those of other estimation methods in order to assess their robustness. We therefore re-estimate the long-run relationship using three alternative methods: (1) the Engle and Granger (1987) procedure; (2) the Autoregressive Distributed Lag Modeling approach in Pesaran and Shin (1998); and (3) the fully-modified OLS technique by Phillips and Hansen (1990).

The results of this exercise are shown in Table B.6. All estimation procedures yield a higher than unitary income elasticity of money.[19] In addition, the point estimates are almost of the same magnitude across the alternative approaches suggesting significant robustness of the estimated elasticity to the choice of estimator.[20] Money, therefore, tends to increase proportionally more than real GDP, suggesting that monetary holdings reflect to some extent portfolio decisions in addition to transaction motives. More recently, Fase and Winder (1999) have argued that estimates of the income elasticity above one in the case of Europe might be due to the omission of financial wealth from the money demand function. The point estimate of the (semi-) elasticity of the short term spread also appears fairly robust to the choice of the

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[18] For instance, Gonzalo and Lee (1998) consider the case in which the system tested includes variables that, though not pure I(1) processes, exhibit some long-memory trending behaviour that standard unit root tests might not be able to distinguish from unit roots.

[19] This result confirms the downward trend in velocity for the euro area documented by the ECB on various occasions, notably in the calculation of its reference value for M3 growth as part of the first pillar of the Eurosystem's monetary policy strategy (see ECB, 1999).

[20] The estimated income elasticity is remarkably close to in the Brand and Cassola (2000) and Golinelli and Pastorello (2000) money demand systems (1.34 and 1.37, respectively) and not far away from that obtained by Dedola et al. (2001) in a single equation framework (1.26).

estimator. Overall, the differences for both coefficients seem to be minor suggesting that we can proceed with the results of the Johansen procedure during the rest of the study.

Figure 3 shows the plot of the restricted cointegrating vector obtained with the Johansen procedure. In general terms, the cointegrating vector represents the deviations of the endogenous variable from its long run equilibrium level. In the context of money demand models, the positive (negative) difference between the actual money stock and the equilibrium level implied by the model can be interpreted as a measure of the monetary overhang (shortfall). Figure 3 suggests that over the period 1980-1999 the deviations of the stock of M3 from equilibrium were stationary, which is critical for their use as an error correction mechanism. Moreover, such deviations were relatively small, with the main exception of the period 1992-1993 during which a significant overhang emerged. More recently, the years 1997 to the beginning of 1999 were characterized by a shortfall in M3, followed by the beginning of a small overhang in the last two quarters of 1999. This observation is consistent with evidence on the basis of alternative money demand models of the accumulation of a monetary overhang in the euro area during 1999.[21]

Figure 3: Restricted Cointegrating Relationship (Used as the Error Correction Term in the Dynamic Model, in Percentage Points)
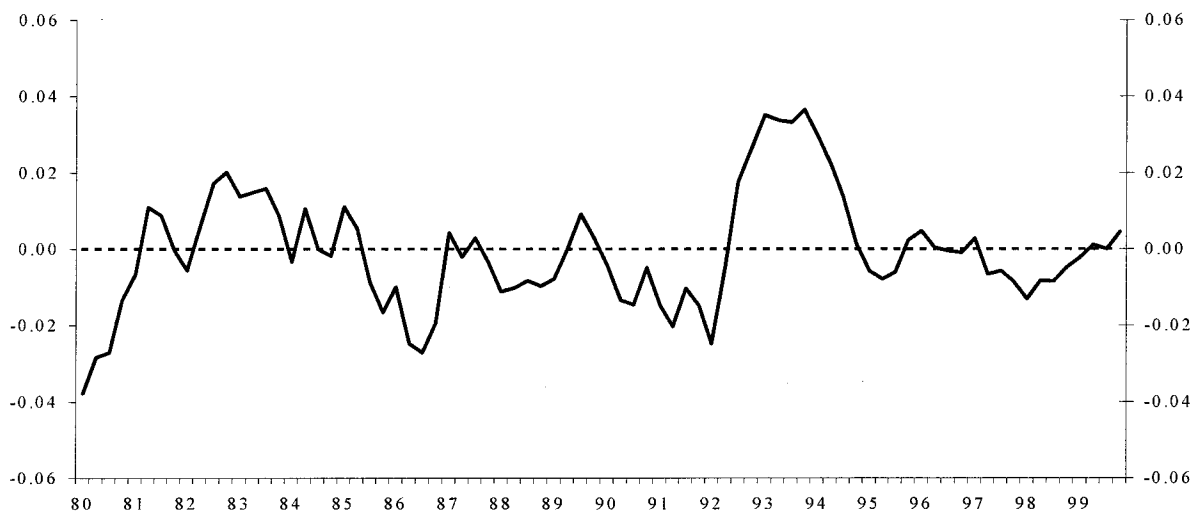
Note: values re-scaled to average zero over the sample period

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[21] See, for instance, Masuch et al. (2000, pp.174-175) for an illustration of the monetary overhang in the euro area based on the model by Brand and Cassola (2000).

IV. ANALYSIS OF THE DYNAMIC MONEY DEMAND SYSTEM

A. Dynamic Specification of the Money Demand Model

In the next step, the appropriate Vector Error Correction model (VEC model) is estimated to model the short run dynamics of the money demand system. In addition to the variables entering the long-run relationship, changes in (the logarithm of) an index of world oil prices converted into euro are included in the model as an exogenous variable. Moreover, one dummy variable for the second quarter of 1981 is added to the equation for the spread to correct for one additive outlier which seemed to cause non-normality of the residuals.[22] More formally, the system is specified as the following VAR model of lag order two:

$$\Delta X_t = \sum_{i=1}^{2} \Gamma_i \Delta X_{t-i} + \alpha\ ECT_{t-1} + \sum_{i=1}^{2} \Psi_i \Delta oilp_{t-i} + \Phi DUM81Q2_t + u_t \quad (4)$$

where X_t is a vector containing the non-stationary variables $(m-p)_t$, gdp_t and $(ST-OWN)_t$; ECT_t denotes the error correction term defined as the difference between the actual stock of real M3 and the equilibrium level implied by equation (3); $oilp_t$ and $DUM81Q2_t$ stand for oil prices and the dummy variable, respectively; and u_t is the error vector (assumed to be serially uncorrelated with zero mean and constant covariance matrix). Moreover, α denotes the vector of loading factors; Γ_i and Ψ_i contain the short-run coefficients of the i-lagged modeled and non-modeled variables, respectively; while Φ is the vector of coefficients of the dummy variable.

It might be useful to explain in more detail the rationale for the inclusion of changes in oil prices as an exogenous or "non-modeled" variable. These are sometimes included as a proxy for the developments in import prices in national money demand equations of relatively open economies in order to control for the impact of external influences (see *e.g.* Lütkepohl and Wolters, 1999, for Germany). However, in this study the main reason to include changes in oil prices is rather to correct for some difficulties arising from the use of the GDP deflator as a measure of the general price level. Because it only reflects prices of goods produced domestically, at times of rapidly rising or declining import prices (for instance, due to commodity price shocks or pronounced exchange rate movements over protracted period), the GDP deflator can only partly capture the impact of external developments on domestic prices. This can translate into erroneous measures of the real variables and affect the performance of the model even in the absence of changes to the underlying relationships.

In the next step, tests for weak exogeneity as suggested in Boswijk (1997) are carried out on the estimated model to investigate whether the data support the reduction of the system to a single

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[22] This outlier is probably related to increased volatility in short-term interest rates of euro area countries at a time of ERM realignments.

equation in the spirit of the general-to-specific approach. The tests consist of testing for the exclusion of the cointegrating vector from each equation of the model. If the null of exclusion (i.e. the null that the loading factor in the equation is not significantly different from zero) cannot be rejected for a variable included in the system, this means that this variable is weakly exogenous to the system and consequently there is no loss of information from not modeling its short term behavior when estimating the parameters of the model.[23] The results of the test (reported in Table B.7) show clearly that the null hypothesis of weak exogeneity cannot be rejected for real GDP. By contrast, it can be rejected at the 5% significance level for the spread.

Given the outcome of the weak exogeneity tests, it seems advisable to proceed with the evaluation of a system, rather than reducing it to a single-equation. However, on the basis of the finding of weak exogeneity for real GDP, we condition on this variable and proceed to estimate a smaller model including only equations for money demand and the short-term spread:

$$\Delta Y_t = \Gamma_0 \Delta gdp_t + \sum_{i=1}^{2} \Gamma_i \Delta X_{t-i} + \alpha\, ECT_{t-1} + \sum_{i=1}^{2} \Psi_i \Delta oilp_{t-i} + \Phi DUM81Q2_t + u_t \quad (5)$$

where Y_t contains only $(m-p)_t$ and $(ST-OWN)_t$. In the next step, the conditional model is reduced to a more parsimonious version following Hendry and Richard (1983). For this purpose, non-significant common lagged regressors are removed from the dynamics of the model and the resulting restriction is tested by means of a Wald test. The exclusion of the second lag from the two equations results in the reduction of the system by ten parameters and is supported by the result of the restriction test.[24] This essentially results in the model of lag order one in the dynamics reported in Table B.8.

The coefficients of the error correction term in the two equations are statistically significant. In particular, the coefficient of the error correction term in the equation for money (-0.116) is highly significant and has the right sign, indicating the existence of a long-run relationship between demand for real balances, real GDP and the short-term spread. The magnitude of the coefficient – which is in line with previous estimates (-0.136 and –0.144, respectively, in Coenen and Vega, 1999, and Brand and Cassola, 2000) - suggests that the speed of adjustment to monetary disequilibria is relatively slow.

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[23] The concept of weak exogeneity was developed in the seminal paper by Engle, Hendry and Richard (1983). In a more technical sense, this means that the marginal distribution of the weakly exogenous regressor contains no information relevant to the parameters of the conditional equation.

[24] The Wald-test for the restriction yields Chi-square(10) = 11.102 [0.35].

B. Evaluation of the Estimated Model

Figure B.2 in the Appendix shows the residuals of the individual equations of the system. The residuals of both the money demand equation and that of the spread generally fall within the confidence band defined by ± two times the standard error (although in case there is no dummy included in the short-term spread equation, disturbances of non-negligible magnitude can be observed at the beginning of the sample period). More formally, the statistical properties of the model are evaluated by means of standard misspecification tests (reported in Table B.9). The tests point towards satisfactory properties of the money demand equation, which shows no major signs of misspecification at the conventional significance levels. The results of the equation of the short term spread are equally satisfactory. The multivariate tests show no sign of autocorrelation, non-normality or heteroscedasticity for the money demand system as a whole.

Stability tests

Parameter constancy is of primary importance for the purpose of this money demand study. This is because our sample covers a period over which the euro area experienced a number of major events affecting the variables included in the system and, more recently, the shift to a regime of low inflation driven by the monetary union process.[25] However, as is well known, parameter constancy across regime shifts is of critical importance to ensure the reliability of policy simulations based on the model. To test for parameter constancy, we first run recursive estimates of the long run coefficients and the coefficient of adjustment of the money demand equation. The recursive estimates (plotted in Figure B.3) indicate that the long run parameters seem to be fairly stable over the period from Q1 1993 onwards.

In addition to this, we report the results of Chow one-step ahead, predictive failure and break-point tests (Figure B.4). Overall, there is no sign of parameter instability in the system, in particular since the start of Stage Three of Monetary Union in Q1 1999. As for the individual equations, whereas there is no sign of instability for the short-term spread equation, the one-step ahead test seems to suggest the presence of a break in the last quarter of 1993 for the money demand equation. Nevertheless, it is worth noting that this type of Chow test is more suitable to investigate the existence of outliers rather than that of structural breaks. In order to identify breaks, it is more appropriate to consider the predictive failure and break-point tests since these are better able to distinguish between outliers and more fundamental structural breaks. In the case of the money demand equation, these tests do not reveal any sign of instability suggesting that the failure of the one-step ahead test in one specific quarter should be interpreted as just signaling the presence of an outlier.

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[25] The oil shock at the beginning of the 1980s, German unification and the ERM-II turmoil at the beginning of the 1990s are among these major events. Other factors that may have also affected the stability of the parameters include significant financial innovation, the reform of the reserve requirement systems and increased competition in the banking sector during the second part of the sample period.

Finally, the parameter stability of the coefficients of the individual equations is assessed on the basis of one-step-ahead forecasts. The results do not show signs of major breaks for either equation (see Figure B.5), though the fact that the test statistics of the money demand equation is close to the upper bound of the error band in the last quarter of 1993 is in line with the evidence of a potential outlier in that quarter.

C. Forecasting Ability

Finally in this section, we focus on the forecasting abilities of the model. In order to do so, it is quite common in the literature to re-run the model on a shortened sample and to compare the multivariate out-of-sample forecasts with the actual data (extended to include also the observations that have become available after the development of the model). For this purpose, we re-estimate the model on a shorter sample covering the period from 1980 to the end of 1998 (that is, just before the introduction of the euro) and, in a subsequent step, we generate multivariate out-of-sample forecasts for the first differences in real M3 and the short-term spread from the first quarter of 1999 to the last quarter of 2000.

As can be seen from Figure B.6, the actual observations always lie within the 95% confidence interval of the forecasts (as delimited by the vertical prediction error bars) for both changes in real M3 and the short-term spread. Although in the first quarter of 1999 the actual quarter-on-quarter change in real money is close to the upper bound of the forecast interval (reflecting the high preference for liquidity at the time, possibly prompted to some extent by uncertainty related to the move to a new monetary policy regime), there is no sign of structural break in the money demand equation during the first two years following the introduction of the euro. Overall, the good forecasting performance of the system seems to provide further evidence of its favorable stability properties.

V. CONCLUSIONS

The main purpose of this paper is to address the issue of the correct measurement of the opportunity cost of holding money in the euro area. In order to do so, we produce an estimate of the historical own rate of euro area M3 and, on the basis of theoretical consideration and empirical results, compute two alternative measures of the opportunity cost of holding M3: (1) the spread between the short-term interest rate and the estimated own rate of M3; and (2) the differential between the long-term government bond yield and our estimate of the own rate of M3. We subsequently investigate whether the inclusion of these measures in a standard money demand framework where money is related to the price level, a scale variable and the opportunity cost of holding money yields plausible results.

The starting point of the empirical analysis consists of a system including real M3, real GDP and the two alternative measures of the opportunity cost of M3 (we decide to include both in our system rather than choosing *a priori* one specific measure). Using the Johansen methodology, we find evidence of one cointegrating vector over the sample period from 1980 to 1999. This cointegrating vector can be interpreted as a long-run money demand equation linking real M3 to real GDP (with an elasticity of 1.34) and to the spread between the short-term market

interest rate and the own rate of M3 (with a semi-elasticity of -0.86). Somewhat unexpectedly, we find that the spread between the long-term government bond yield and the own return on M3 does not enter the long-run demand function for M3. However, a further investigation reveals that real money, real GDP and   the short-term spread form the only irreducibly-cointegrated set of variables in the system, which seems to confirm the robustness of the cointegration results. The coefficients of the long-run money demand equation appear to be stable over the sample period and rather robust across alternative estimation procedures.

The short run dynamics of the money demand system is subsequently specified by means of a Vector Error Correction model (VECM), also including changes in oil prices as an exogenous variable (in order to correct for some difficulties arising from the use of the GDP deflator as a measure of the general price level). The results of weak-exogeneity tests show that the model cannot be reduced to a single equation without incurring in a loss of information. However, on the basis of the finding of weak exogeneity for real GDP, we condition on this variable and proceed to estimate a smaller model including only equations for money demand and the spread between the short-term market rate and the own rate of M3. The estimations yield plausible signs and magnitudes. In particular, the coefficients of the error correction term in the equation for money is highly significant and has the right sign (-0.116), supporting the interpretation of the error correction term as a long-run demand equation. Nevertheless, the relatively small magnitude of the coefficient suggests that the speed of adjustment to monetary disequilibria is relatively slow. Standard diagnostics and stability tests confirm the good statistical performance of the model. Further evidence in support of the stability of the model derive from its positive forecasting performance over the first two years following the introduction of the euro.

To sum up, the main aim of this study is to emphasize the need to take an adequate measure of the own rate of money explicitly into account while modeling the demand for money in the euro area. In order to do so, a model is developed which attempts to model the complex interactions between euro area M3, real income and interest rates. On balance, its relatively satisfactory properties seem to provide support to the prominent role assigned to money in the monetary policy strategy of the ECB.

Data Annex
The Computation of the Own Rate of Return on M3

In this study, the own rate of M3 is computed for the period January 1980 – December 1999 by splicing two separate measures of the rate: (1) the estimated aggregate own rate of M3 in the largest euro area countries between January 1980 and December 1989; and (2) the own rate of M3 in the euro area as a whole from January 1990 onwards.

1.   For the period January 1980 to December 1989 we consider a weighted average of the estimated own rates of M3 in Germany, Spain, France and Italy computed by Levy (1999). The country own rates are computed using national data on M3 and its components as well as market and retail interest rates from the BIS database, while their weighted average is calculated using the share of each country in the basket of currencies included in the ECU as its weight.[26]

2.   From January 1990 onwards, we use a measure of the own rate of M3 in the euro area as a whole obtained as the weighted average of the rates of return on the components of M3. In particular, a zero rate of return is assumed for currency in circulation, while retail bank deposit rates from the ECB database and national sources are applied to overnight deposits, deposits with agreed maturity up to 2 years, and deposits redeemable at notice up to 3 months. In addition, the three-month market interest rate is considered as the relevant return on marketable instruments. The (variable) weights of the individual components of M3 are measured by their share in M3.

In order to assess whether or not it is legitimate to splice them, we have compared the two series over the period for which both are available. Between 1990 and 1998, the two measures of the own rate of M3 followed the same pattern, though the euro area rate remained consistently above the series for the average rate of return on M3 in the four largest countries.[27] However, if we re-scale the latter to the same value recorded by that for the euro area as a whole at the beginning of the period, the difference between the two series becomes rather negligible over the whole sample period. Thus, we use this re-scaled version of the series for the period prior to January 1990.

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[26] The share of Spain is null during the part of the sample period preceding the country's entry to the ERM in October 1989.

[27] Two potential explanations for this difference in the level of the two series are: (1) the significantly larger weight given to low-yielders such as Germany in the calculation of the latter; and (2) the fact that the BIS usually reports base deposit rates, while ECB's bank interest rates mostly refer to retail deposits which are normally higher.

The Database

Date	Nominal M3	Price level	Real GDP	Short-term interest rate	Long-term government bond yield	Own rate of M3
80Q1	13.95570	3.88641	15.17915	12.60730	12.05860	6.09175
80Q2	13.97732	3.90508	15.17390	13.09870	12.10000	6.63919
80Q3	14.00061	3.92379	15.17115	12.13230	12.14930	6.48796
80Q4	14.02721	3.94116	15.17080	12.56590	12.77190	6.46297
81Q1	14.05443	3.95970	15.17428	13.36850	13.38510	6.93822
81Q2	14.08314	3.97828	15.17896	15.47680	14.52760	7.47078
81Q3	14.10338	4.00153	15.18078	16.08140	15.14810	7.69838
81Q4	14.12706	4.02561	15.18217	15.35320	15.04850	7.74903
82Q1	14.15568	4.04653	15.18515	14.25510	14.71830	7.70541
82Q2	14.18232	4.06364	15.18530	14.30210	14.47170	7.47265
82Q3	14.21073	4.07915	15.18121	13.25180	14.16720	7.25591
82Q4	14.23432	4.09570	15.18303	12.49140	13.62620	6.69253
83Q1	14.25808	4.11585	15.18834	11.75690	13.09190	6.30060
83Q2	14.27803	4.12989	15.19513	11.66310	13.00410	5.70982
83Q3	14.29955	4.14753	15.20000	12.01080	13.06850	5.63003
83Q4	14.32101	4.16254	15.21020	12.00270	13.04810	5.62472
84Q1	14.33905	4.17832	15.21695	11.28900	12.56270	5.52407
84Q2	14.35879	4.18694	15.21203	10.74570	12.45180	5.42598
84Q3	14.38282	4.19924	15.22596	10.31640	12.07370	5.42697
84Q4	14.40251	4.21013	15.22977	10.03480	11.26660	5.77903
85Q1	14.42742	4.22155	15.22878	9.76910	10.73070	5.74008
85Q2	14.44485	4.23149	15.24039	9.85900	10.64270	5.56447
85Q3	14.45955	4.24522	15.25042	9.24460	10.52500	5.13483
85Q4	14.47379	4.25653	15.25554	8.55330	10.14860	4.90465
86Q1	14.49080	4.27053	15.25383	8.64250	9.72150	4.83953
86Q2	14.50386	4.28180	15.26516	7.91970	8.56080	4.29002
86Q3	14.52186	4.28910	15.27448	7.64290	8.31730	4.08739
86Q4	14.54211	4.29510	15.28011	7.75500	8.32880	4.07797
87Q1	14.56011	4.30336	15.27164	7.95760	8.32120	3.98024
87Q2	14.58219	4.31097	15.29058	8.22220	8.59370	3.72198
87Q3	14.60048	4.31544	15.29786	8.31530	9.32460	3.71321
87Q4	14.62056	4.32429	15.31017	8.29220	9.40270	3.82697
88Q1	14.63586	4.33225	15.31591	7.34500	8.78830	3.72525
88Q2	14.65855	4.34044	15.32517	7.17160	8.74460	3.68231
88Q3	14.67959	4.34753	15.33797	7.90250	8.87720	3.83252
88Q4	14.70064	4.35851	15.34884	8.37870	8.82430	3.96377
89Q1	14.72194	4.36854	15.36024	9.41190	9.28050	4.30381
89Q2	14.74564	4.37582	15.36640	9.58140	9.51340	4.53454
89Q3	14.77086	4.38515	15.37275	9.99100	9.55400	4.73382
89Q4	14.79139	4.39803	15.38460	10.96510	10.07720	5.49782

| Date	Nominal M3	Price level	Real GDP	Short-term interest rate	Long-term government bond yield	Own rate of M3
90Q1	14.81601	4.40832	15.39920	11.11330	10.81640	5.85216
90Q2	14.83096	4.41963	15.40504	10.51270	10.82170	5.84303
90Q3	14.85147	4.42981	15.41344	10.43380	10.92620	5.79431
90Q4	14.87316	4.43667	15.41968	10.94850	11.02560	5.92884
91Q1	14.89255	4.45041	15.43043	11.00220	10.64430	6.11237
91Q2	14.90777	4.46273	15.43364	10.38420	10.14300	5.98661
91Q3	14.92725	4.47342	15.43289	10.43750	10.22730	6.01639
91Q4	14.94718	4.48630	15.44242	10.66180	9.94300	6.09522
92Q1	14.96267	4.49569	15.45411	10.78460	9.60010	6.28848
92Q2	14.98595	4.50469	15.45031	10.92070	9.72340	6.33965
92Q3	15.00597	4.51298	15.44668	11.86370	10.09620	6.61070
92Q4	15.02369	4.52012	15.44563	11.33430	9.66600	6.47127
93Q1	15.03936	4.53065	15.43959	10.59870	9.02290	6.24240
93Q2	15.05628	4.53964	15.44024	9.01880	8.64060	5.63604
93Q3	15.06671	4.54652	15.44094	8.07800	7.60290	5.07219
93Q4	15.08373	4.55286	15.44504	7.37750	6.95190	4.57840
94Q1	15.09771	4.55982	15.45361	6.80690	7.00770	4.25262
94Q2	15.10435	4.56540	15.45917	6.33650	7.95310	3.92566
94Q3	15.10982	4.57160	15.46584	6.35560	8.80680	3.84024
94Q4	15.11416	4.57823	15.47374	6.48740	9.20860	3.90580
95Q1	15.12116	4.58475	15.48109	6.94510	9.33330	4.10904
95Q2	15.13135	4.59276	15.48566	7.14530	8.95210	4.10016
95Q3	15.14549	4.60072	15.48676	6.68970	8.55860	3.96883
95Q4	15.16188	4.60505	15.48912	6.49540	8.13150	3.84517
96Q1	15.17852	4.61114	15.49164	5.62600	7.68100	3.52459
96Q2	15.18688	4.61503	15.49690	5.13200	7.53720	3.24352
96Q3	15.19723	4.61859	15.50280	4.99690	7.27070	3.08304
96Q4	15.20632	4.62237	15.50591	4.58100	6.46150	2.85473
97Q1	15.21500	4.62549	15.50733	4.43260	6.18770	2.70237
97Q2	15.22612	4.62941	15.51960	4.32090	6.19120	2.60717
97Q3	15.23914	4.63380	15.52592	4.31620	5.82450	2.52247
97Q4	15.25039	4.63810	15.53399	4.42610	5.65990	2.52401
98Q1	15.26141	4.64180	15.54184	4.19090	5.11270	2.43920
98Q2	15.27622	4.64561	15.54626	4.04420	5.00800	2.32553
98Q3	15.28660	4.64970	15.55088	3.92720	4.55100	2.24206
98Q4	15.29758	4.65218	15.55356	3.61490	4.15240	2.07166
99Q1	15.31487	4.65652	15.55963	3.08990	3.97420	1.80581
99Q2	15.32889	4.65763	15.56510	2.63340	4.22650	1.62408
99Q3	15.34282	4.66056	15.57493	2.69900	5.06140	1.56939
99Q4	15.35589	4.66280	15.58349	3.42960	5.35160	1.69905

Note: Nominal M3, real GDP and the price level are in logs; short-term interest rate, long-term government bond yield and own rate of M3 in percentages per annum.
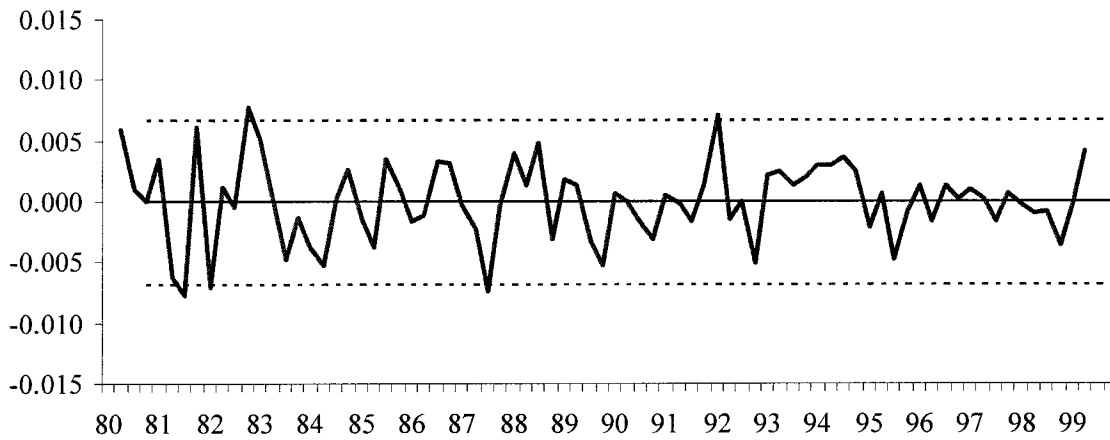
Appendix Figure 1. The Data (quarterly data)
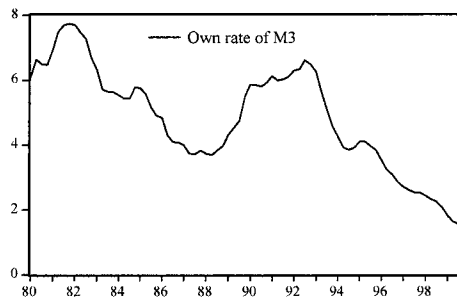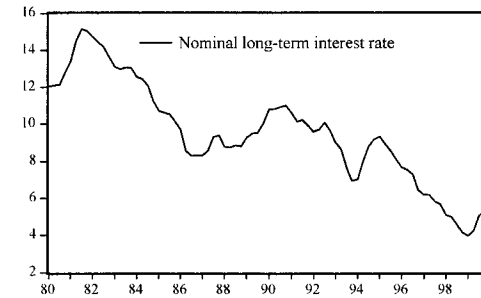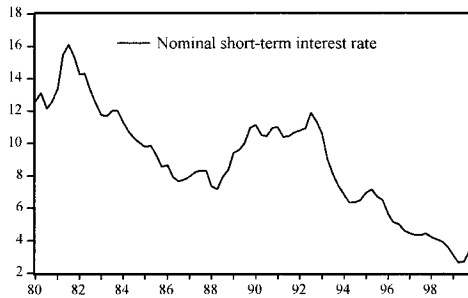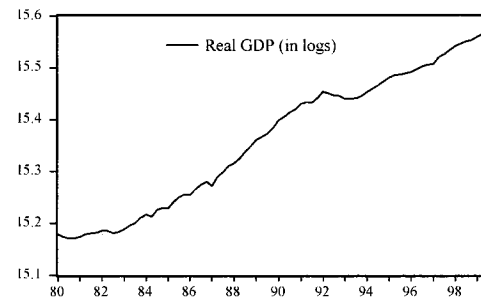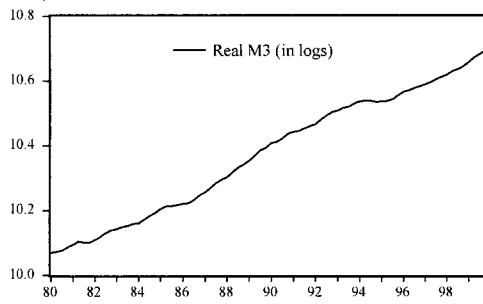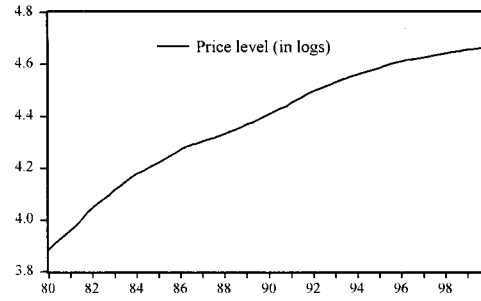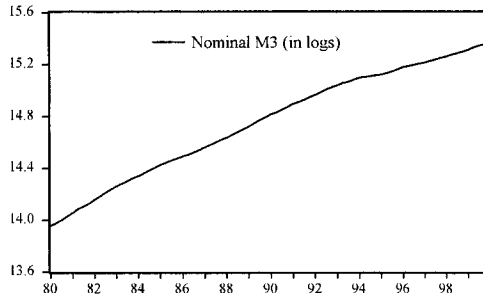
Appendix Figure 2. Residuals of the Single Equations (dotted lines represent ± 2*standard errors)
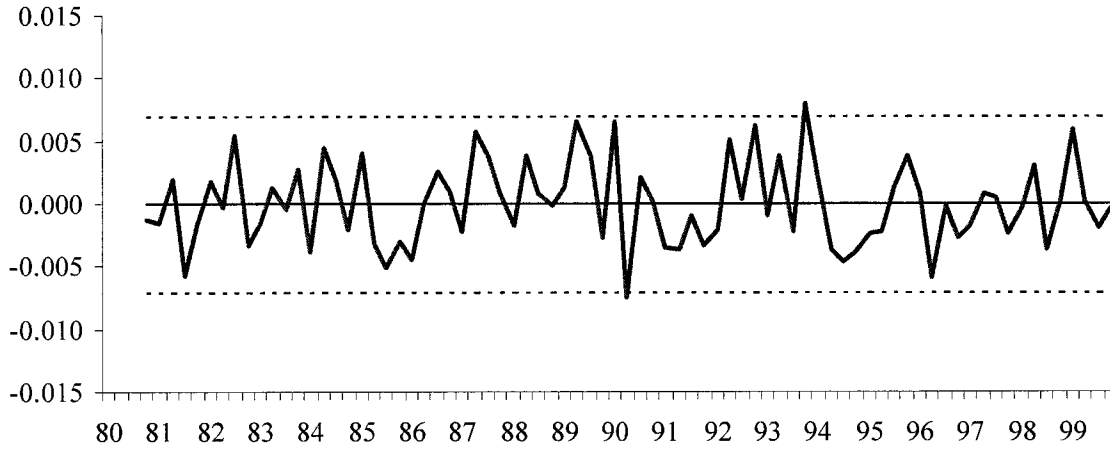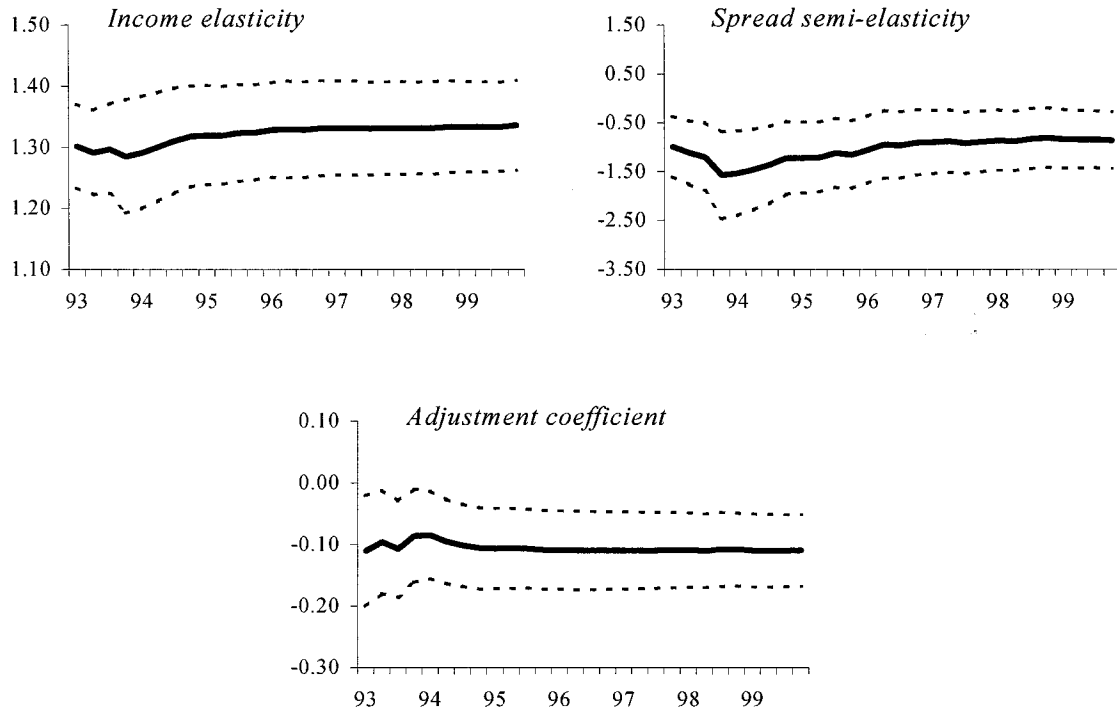
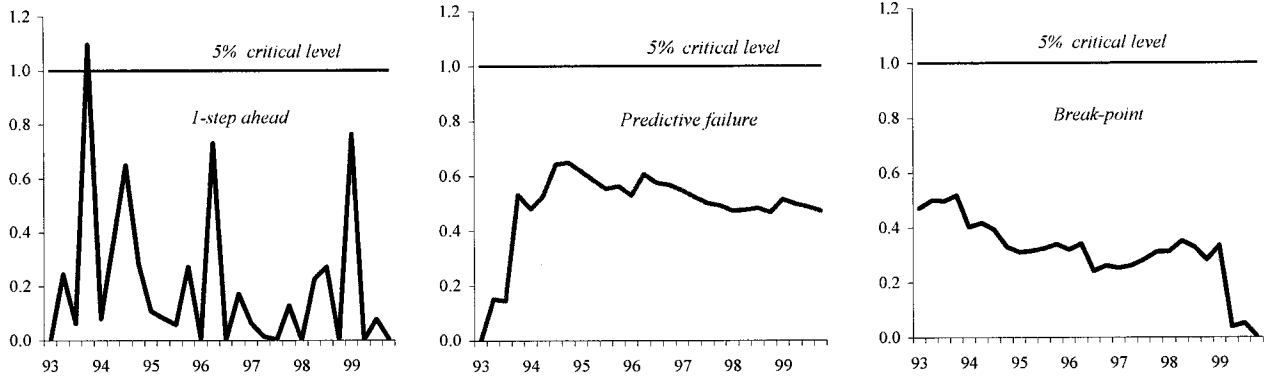*Equation $\Delta(m\text{-}p)$*

Equation $\Delta(ST\text{-}OWN)$

Appendix Figure 3. Recursive Estimates of the Long Run Coefficients of the Money Demand Equation
(dotted lines represent ± 2*standard errors)

Income elasticity

Spread semi-elasticity
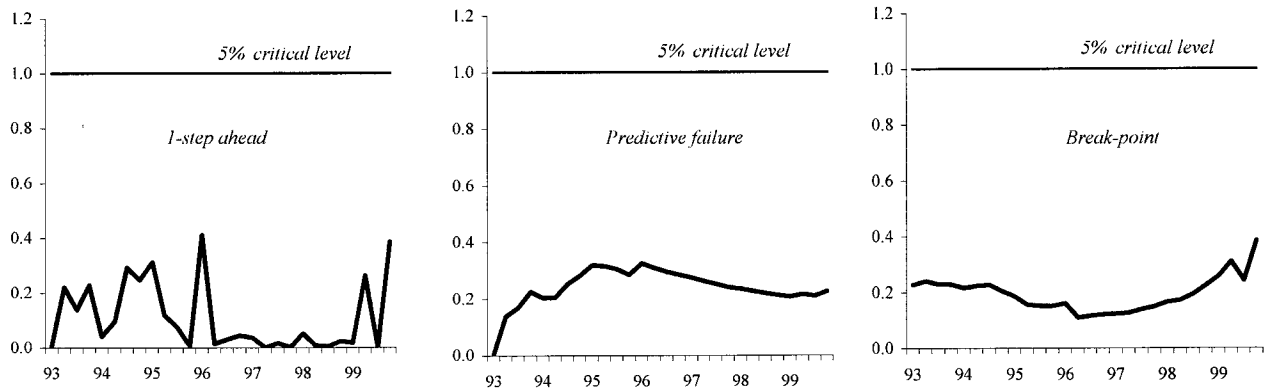

Adjustment coefficient

Appendix Figure 4. Chow's 1-Step Ahead, Predictive Failure and Break-Point Tests for Parameter Constancy (values above the 5% critical value level may signal instability of the parameters).
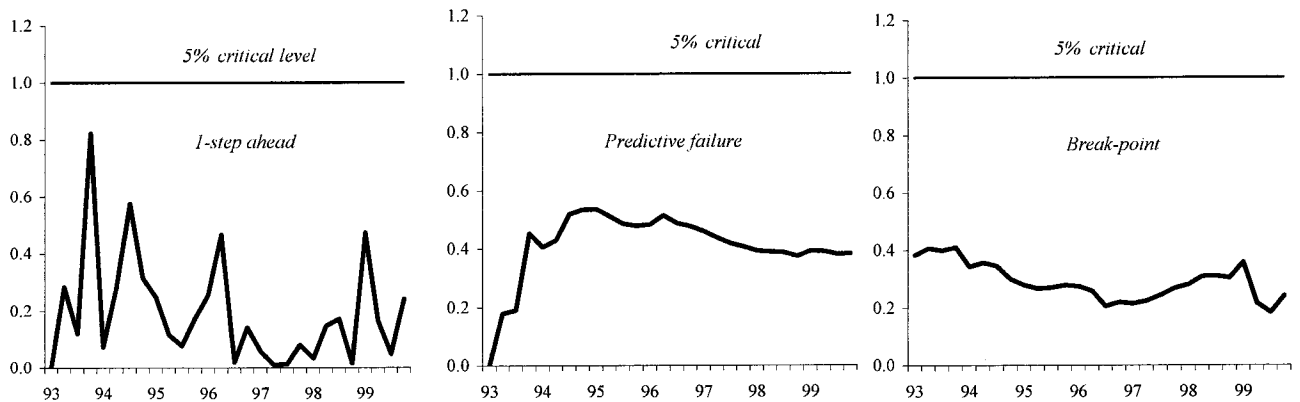
Equation $\Delta(m\text{-}p)$
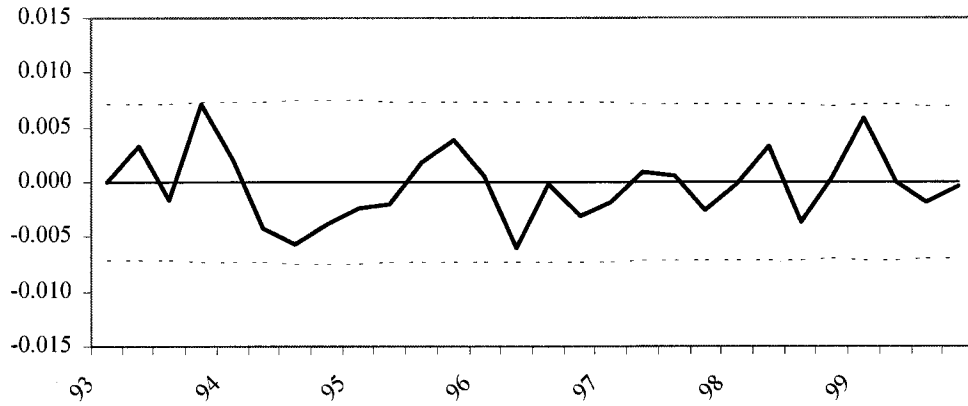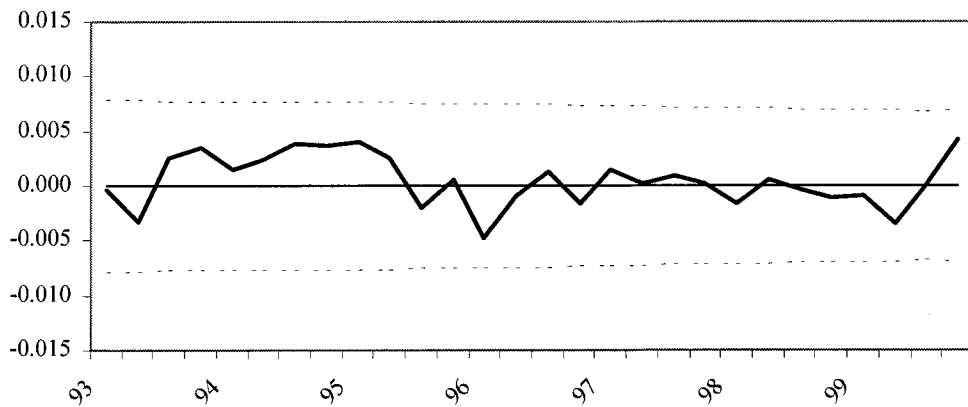

Equation $\Delta(ST\text{-}OWN)$

System

Note: Chow test statistics normalised by their 5% critical values.

Appendix Figure 5. One-Step Recursive Residuals
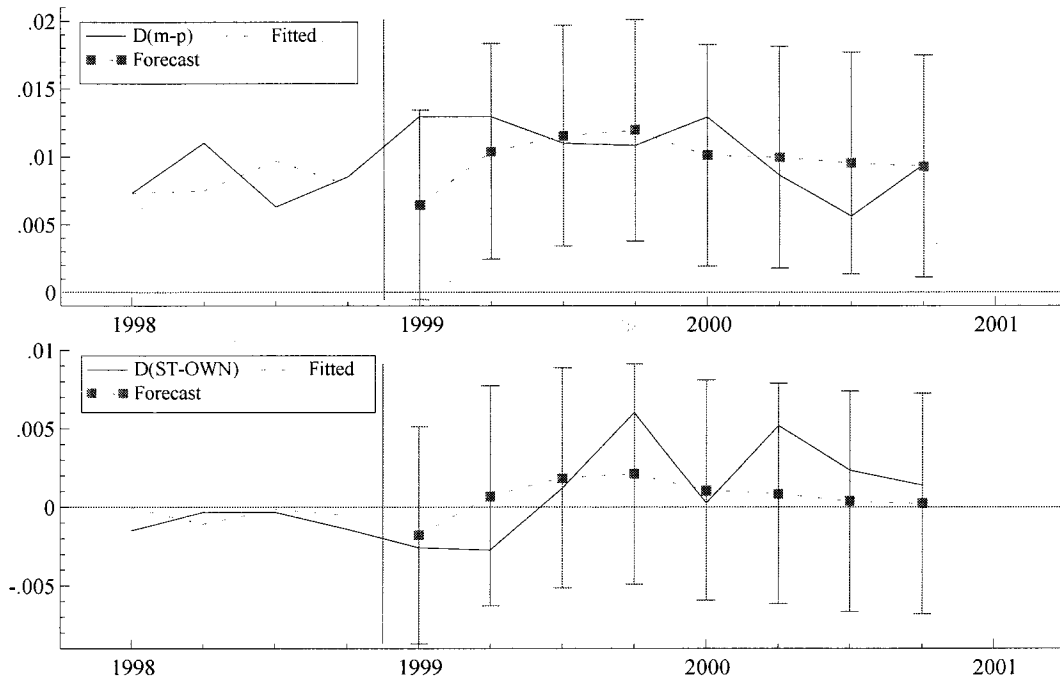(dotted lines represent $\pm$ 2*standard errors)

Equation $\Delta(m\text{-}p)$

Equation $\Delta(ST\text{-}OWN)$

Appendix Figure 6. Out-of-Sample Forecast for Quarter-on-Quarter Changes in Euro Area Me
and the Spread

Appendix Table 1. Unit Root Tests

Variable	Null hypothesis	Alternative	DF[a]		ADF[a]		PP[a]	
			Test statistics b	Test statistics c	Test statistics b	Test statistics c	Test statistics b	Test statistics c
(m-p)	I(1)	Stationary	0.446	-1.234	-0.007	-1.748	0.244	-1.600
	I(2)	I(1)	-5.244**	-5.212**	-5.244**	-5.212**	-5.269**	-5.239**
gdp	I(1)	Stationary	0.957	-2.114	-0.316	-2.295	0.708	-2.114
	I(2)	I(1)	-7.229**	-7.231**	-3.909**	-3.871**	-7.229**	-7.231**
(ST-OWN)	I(1)	Stationary	-1.109	-2.318	-1.015	-2.318	-1.242	-2.657
	I(2)	I(1)	-6.434**	-6.385**	-6.052**	-5.952**	-6.289**	-6.237**
(LT-OWN)	I(1)	Stationary	-1.207	-2.161	-1.862	-2.161	-1.547	-2.783
	I(2)	I(1)	-5.474**	-5.441**	-4.949**	-4.844**	-5.468**	-5.435**

[a]   *DF is the Dickey Fuller test, ADF the Augmented Dickey Fuller test (with lags up to and including the highest lag statistically significant at least at the 5% level, if no lag results statistically significant the DF statistics is reproduced), PP is the Phillips Perron test (with 3 truncation lags, as dictated by the Newey West criterion).*

[b]   *Constant included in the auxiliary test regression.*

[c]   *Constant and deterministic trend included in the auxiliary test regression.*

**   *Rejection of null at 1% significance level; * at 5% significance level; [†] at 10% significance level based on critical values in MacKinnon (1991).*

Appendix Table 2. Stationarity Test

Variable	*Null hypothesis*	*Alternative hypothesis*	KPSS test statistic (l=8)[a]	
			Constant, no trend	Constant and trend
M-P	Stationary	I(1)	0.995**	0.136[†]
	I(1)	I(2)	0.116	0.117
gdp	Stationary	I(1)	0.983**	0.119[†]
	I(1)	I(2)	0.163	0.133[†]
(ST-OWN)	Stationary	I(1)	0.822**	0.093
	I(1)	I(2)	0.071	0.072
(LT-OWN)	Stationary	I(1)	0.792**	0. 063
	I(1)	I(2)	0.058	0.057

[a]   *KPSS is the stationarity test proposed by Kwiatkowski et al. (1992); l represents the parameter of the Bartlett window and has been set at a value close to the square of the number of observations; the test has been run in EViews using a program kindly provided by H. Hansen from Deutsche Bundesbank.*

**   *Rejection of null at 1% significance level based on critical values in Kwiatlowski et al., cit.; * at 5% significance level; [†] at 10% significance level.*

Appendix Table 3. Johansen Test for Cointegration

H_0: rank = p	Eigenvalue	Trace test-statistic	95% critical value	Maximum eigenvalue test-statistic	95% critical value
$p = 0$	0.298762	48.2*	47.2	27.3*	27.1
$p \leq 1$	0.131386	20.9	29.7	10.8	21.0
$p \leq 2$	0.121804	10.0	15.4	10.0	14.1
$p \leq 3$	0.000323	0.0	3.8	0.0	3.8

*Note: * Rejection of null hypothesis at 5% significance level based on Osterwald-Lenum (1992) critical values.*

Appendix Table 4. Test for Exclusion of Long-Run Coefficients

	gdp	*(ST-OWN)*	*(LT-OWN)*
Test statistic [a]	16.125**	4.674*	0.000

Note: [a] LR Chi-square(1) test on zero restriction conditional on rank=1.
*** Rejection of null hypothesis of exclusion at 1% significance level; * at 5% significance level.*

Appendix Table 5. Tests for Irreducible Cointegrating Relationships Including Real M3

Variables included	Rank=0	Rank≤1	Rank≤2	Rank≤3	Cointegration
(m-p), gdp	12.17	0.02	(-)	(-)	No
(m-p), (ST-OWN)	7.34	0.01	(-)	(-)	No
(m-p), (LT-OWN)	9.18	0.01	(-)	(-)	No
(m-p), gdp, (ST-OWN)	31.10*	10.24	0.08	(-)	Yes
(m-p), gdp, (LT-OWN)	22.99	10.08	0.01	(-)	No
(m-p), gdp, (ST-OWN) (LT-OWN)	48.19*	20.87	10.02	0.02	Yes

Note: Figures rounded, VARs include two lags.

Appendix Table 6. Results of Different Estimation Procedures for the Long-Run Relationship

Variable	Method			
	JOH	EG	ARDL	FMOLS
Income elasticity	1.34	1.36	1.36	1.37
Interest rate (semi-) elasticity	-0.86	-0.71	-0.67	-0.62

Note: JOH denotes the Johansen procedure, EG the first step of the Engle-Granger approach, ARDL an Autoregressive distributed model with two lags, FMOLS the fully-modified OLS.

Appendix Table 7. Weak Exogeneity Test

	(m-p)	*gdp*	*(ST-OWN)*
Test statistic [a]	14.030**	0.586	5.291*

Note: [a] Lagrange-multiplier test for exclusion of the cointegrating vector from the individual equation conditional on rank=1 (see Boswijk, 1997) distributed as Chi-square(1).
** Rejection of null hypothesis of weak exogeneity at 1% significance level; * at 5% significance level.

Appendix Table 8. Estimating the VECM

(a) Cointegrating Equation

(m-p)	gdp	(ST-OWN)
1.000	-1.336 [36.3]	0. 863 [2.96]

(b) Dynamic equation estimates

	Δ(m-p)	Δ(ST-OWN)
ECT (-1)	-0.116 [-4.17]	-0.080 [-2.93]
Δ(gdp)	0.083 [1.02]	0.167 [2.09]
Δ(m-p(-1))	0.453 [4.95]	0.075 [0.83]
Δ(ST-OWN(-1))	-0.270 [-2.77]	0.152 [1.58]
Δ(oilp(-1))	0.006 [2.69]	0.005 [2.01]
DUM81Q2	(-)	0.016 [4.48]
C	0.004 [4.20]	-0.002 [-2.34]
R-squared	0.447	0.394
Adjusted R-squared	0.409	0.342
Sum sq. Residuals	0.001	0.001
Durbin-Watson	2.084	1.830
F-statistic	11.498	7.598
S.E. of Regression	0.00348	0.00342

Note: t-statistics in square brackets.

Appendix Table 9. Misspecification Tests

(a) Single equation test statistics

	Autocorrelation [a] (1st order)	Autocorrelation [a] (1st to 5th order)	Normality [b]	ARCH(4) effects [c]	Heteroscedasticity [d]
$\Delta(m\text{-}p)$	0.683 [0.41]	0.516 [0.76]	2.243 [0.33]	1.572 [0.19]	0.745 [0.69]
$\Delta(ST\text{-}OWN)$	0.581 [0.45]	0.781 [0.57]	0.646 [0.72]	1.038 [0.39]	0.940 [0.51]
test distribution	*F(1, 69)*	*F(5, 65)*	*Chi-square(2)*	*F(4, 62)*	*F(11, 58)*

(b) Multivariate test statistics and their distribution

Autocorrelation [a] (1st order)	Autocorrelation [a] (1st to 5th order)	Normality [b]	Heteroscedasticity [e]
1.300 [0.27]	0.931 [0.55]	2.590 [0.63]	1.074 [0.37]
F(4, 136)	*F(20, 120)*	*Chi-square(4)*	*F(33, 168)*

Note: [a] *Lagrange-multiplier test for autocorrelation by Godfrey (1978);* [b] *Normality test by Doornik and Hansen (1994);* [c] *Test for ARCH effects based on Engle (1982);* [d] *Heteroscedasticity test suggested by White (1980);* [e] *Vector test suggested in Doornik and Hendry (1994).*
p-value in square brackets: a p-value lower than 0.05 (0.01) would imply the failure of the test at the 5% (1%) significance level.

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