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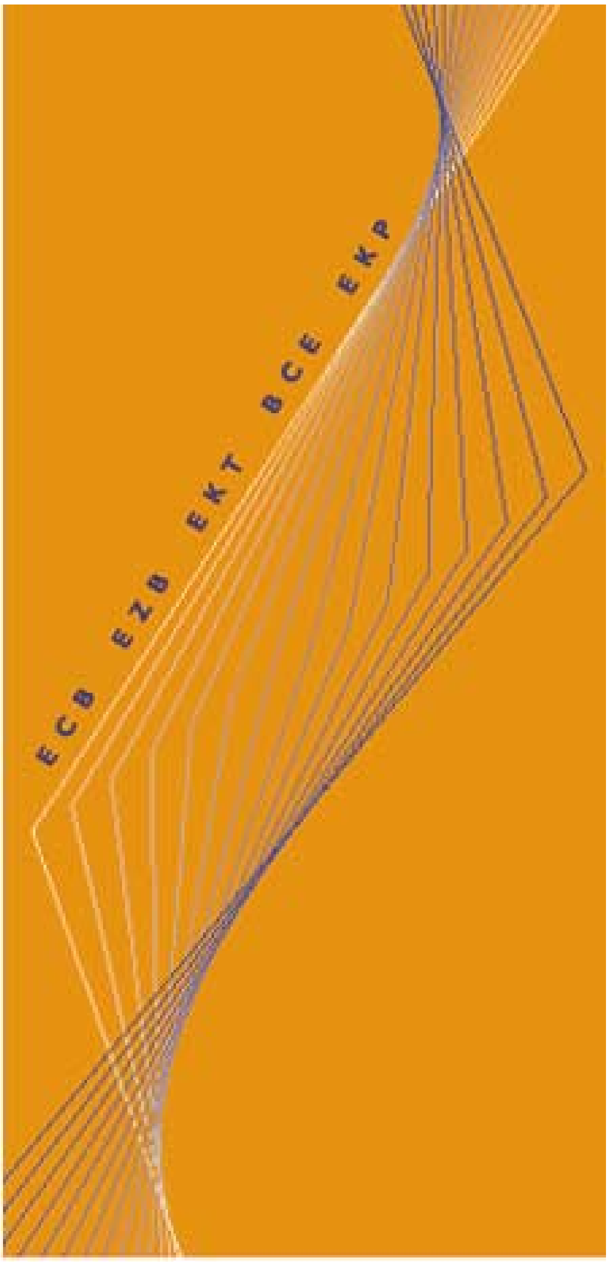

WORKING PAPER NO. 51

THE FUNCTIONAL FORM OF THE DEMAND FOR EURO AREA M1

BY LIVIO STRACCA

March 2001

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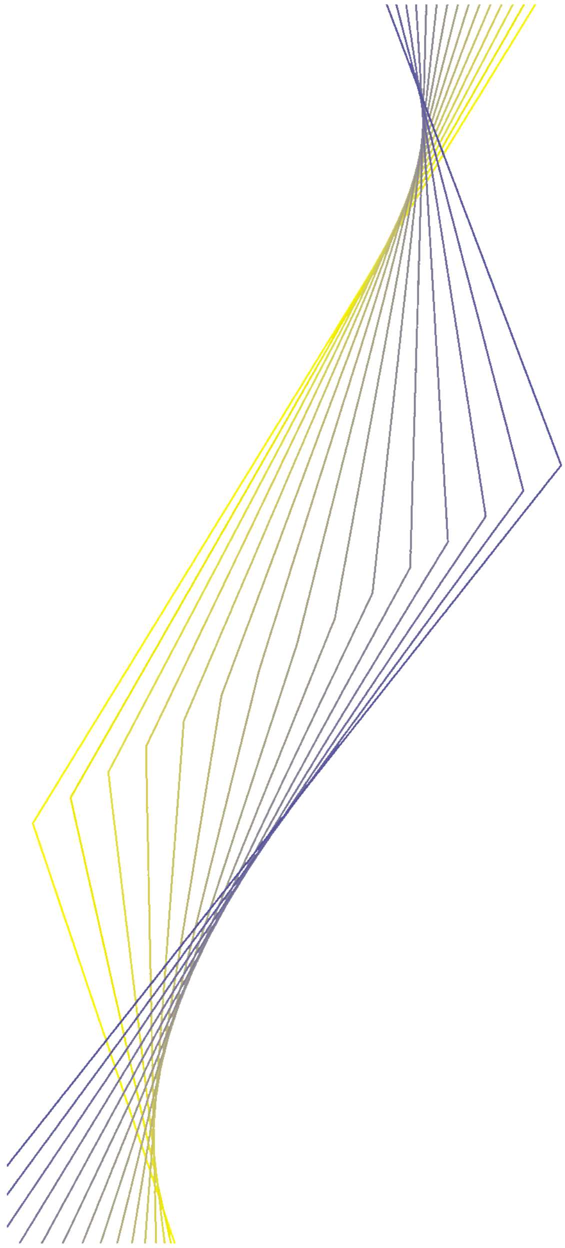

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THE FUNCTIONAL FORM OF THE DEMAND FOR EURO AREA M1

BY LIVIO STRACCA*

March 2001

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Address	**Kaiserstrasse 29**
	D-60311 Frankfurt am Main
	Germany
Postal address	**Postfach 16 03 19**
	D-60066 Frankfurt am Main
	Germany
Telephone	**+49 69 1344 0**
Internet	**http://www.ecb.int**
Fax	**+49 69 1344 6000**
Telex	**411 144 ecb d**

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Contents

Abstract

A remarkable development seen in recent years is the pronounced decline in euro area M1 velocity vis-a-vis a moderate decline in short-term interest rates, which represent the most natural opportunity cost for M1. This paper endeavous to estimate a demand function for euro area M1, in particular by investigating its functional form. While the double log function is found to be very close to the true "deep" functional form of M1 demand in the euro area for most of the sample period, consistent with the findings of Chadha, Haldane and Janssen (1998) for the United Kingdom and of Lucas (2000) for the United States, there is also evidence of an increased interest rate elasticity in M1 demand in the most recent years, presumably owing to the transition to the new policy environment prevailing from the start of Stage Three of EMU and the associated decline in nominal short-term interest rates.

JEL classification system: E41, E52
Keywords: M1, money demand, interest rate elasticity, cointegration, Kalman filter

1 Introduction

Modelling the behaviour of monetary aggregates in Europe has been object of considerable interest over recent years, not least due to the prominence given by the European Central Bank (ECB) to the euro area M3 indicator, which is the "first pillar" of its monetary policy strategy (ECB, 1999a). Coenen and Vega (1999) and Brand and Cassola (2000) have found that the demand for broad money M3 in the euro area is stable. The evidence reported so far in the literature also suggests that euro area M3 tends to display better econometric properties than comparable aggregates at national level (Fagan and Henry, 1998).

The demand for narrow money M1 in the euro area has, however, received far less attention in the recent literature.[1] In part, this appears to be justified, as financial innovation tends to push forward the ideal border between monetary and non-monetary assets, making narrow aggregates less relevant for monetary policy. Nonetheless, the analysis of the demand for narrow money in the euro area may still be interesting for at least three important reasons. First, instruments included in narrow money, owing to their high degree of liquidity, may have a tighter and more timely correlation with aggregated spending than comparatively less liquid financial instruments held also for saving purposes. Narrow money may therefore be an important indicator of impending inflationary pressures. Second, M1 is an important component of M3 and its analysis is therefore useful to understand the behaviour of broad money in the euro area. Third, an important feature of the instruments included in M1 is that no or little interest is paid on them. Just for this reason, as recently highlighted by Lucas (200), the analysis of the demand for narrow money may give important indications on the welfare costs of inflation. In particular, Chadha, Haldane and Janssen (1998) and Lucas (2000) recently stressed that money-holding behaviour is very important to assess the welfare costs of inflation. Moreover, the welfare gains of a move to price stability (measured as the possibility of economising in shoe-leather costs) may be significant even at low levels of interest rates (of inflation). In turn, the quantification of the welfare costs of inflation when the latter is at low levels depends crucially on the functional form of money demand. With the double log specification used by Lucas, welfare costs remain significant even if inflation is at low levels; conversely, with the standard Cagan (semi-log) specification, welfare costs tend to become negligible as nominal interest rates approach zero and inflation turns into deflation. Developments seen in the euro area over recent years provide an interesting opportunity to further test the conclusions of Lucas, as the inflation rate and nominal interest rates declined significantly from levels, which were already relatively low by historical standards. This provides an additional rationale to modelling the demand for M1 in the euro area, and in particular to investigating its functional form.[2]

This paper thus aims at modelling the demand for M1 in the euro area with a view to explaining the pronounced decline in M1 velocity observed in recent years (see Chart 1). Such prolonged and significant drop appears to be hardly explained by the gradual and moderate decline of short-term interest rates, traditionally regarded as the most relevant opportunity cost in the demand for narrow money. This apparently stands in contrast with the findings especially of Hoffman and Rasche (1996), Fagan and Henry (1998) and Bruggeman (2000) that the demand for M1 in the euro area (or close proxies thereof) is stable up to the mid nineties.[3] It also suggests that

1 *Relatively recent papers estimating a M1 demand equation in the EU or in the euro area include Falk and Funke (1995), Monticelli and Papi (1996), Fagan and Henry (1998), Clausen (1998) and Bruggeman (2000).*

2 *It may also be remarked that Bruggeman (2000), in evaluating the properties of different monetary aggregates for the euro area, held the view that M1 scored best in three out of six criteria (namely, measure of liquidity, controllability and definitional consistency). Clausen (1998) even argued in favour of a monetary policy strategy by the ECB focused on M1. On the other hand, according to Bruggeman (2000), a main drawback of M1 lies in its instability, due to possible portfolio shifts.*

3 *The only exception in the literature is Clausen (1998) who estimated an M1 demand function in the euro area up to 1996:4, finding evidence of an increase in the interest rate elasticity in the last part of the sample period. Interestingly, Clausen (1998) also finds some evidence of mis-specification of the semi-logarithmic functional form.*

something new – and worth investigating – has happened in the second part of the decade. A working hypothesis is that the interest rate elasticity of M1 may have increased in recent years, either due to a structural shift associated with the transition to a new monetary regime in Stage Three of EMU or reflecting agents' "underlying" liquidity preference at historically low levels of interest rates.[4] Broadly following the approach of Chadha, Haldane and Janssen (1998), a relatively general functional form for the demand for M1 is specified and three interesting special cases are investigated empirically. These three special cases include the semi-log functional form, which is the most popular in the recent literature on money demand (see Ericsson, 1998); the double log model supported by Lucas (2000); and finally a model put forward by Ashworth and Evans (1998), where the size of the interest elasticity of money demand is a decreasing function of the level of the interest rate. Within each specification, the standard procedure using the Johansen cointegration technique is followed and the estimation of a fully-fledged money demand model is attempted. The outcome of this econometric exercise is that only with the Ashworth-Evans specification it is possible to estimate a theoretically reasonable and stable demand for euro area M1, suggesting that M1 holdings have been very reactive to movements in the interest rate at low levels. However, this model is not able to shed light on whether this finding reflects an immutable trait of agents' preferences, or rather a structural change in liquidity preference brought about by the transition to Stage Three of EMU. To discriminate between these two competing hypotheses, and departing from Chadha, Haldane and Janssen (1998), a time-varying parameters model is estimated similar to that developed by Bomhoff (1991). This model is able to test *simultaneously* the functional form of M1 demand and the stability of the parameters in the money demand relationship. These estimates clearly point to a structural change in the interest rate elasticity of M1 demand in the years preceding and around the start of Stage Three of EMU, while agents' "deep" degree of preference for liquidity appears to be relatively independent of the level of the interest rate (namely, a functional form of money demand very close to the double-log is supported). These results also suggest that the welfare gains implied by the move toward price stability in the euro area over the most recent years should have been significant.[5]

The paper is organised as follows. The theoretical background on the functional form of money demand is outlined in Section 2. In Section 3, the Johansen approach is employed to derive theoretically sound and statistically fit M1 demand models based on the three considered functional forms (the semi-log, double log and AE models). Thereafter, the time-varying parameters model on the velocity of M1 is estimated. Finally, Section 4 contains some concluding remarks.

2 The functional form of money demand: some theoretical background

It is traditional to study the functional form of the demand for money in a general equilibrium framework, as put forward by Sidrauski (1967). This implies the specification of a leisure function (M/P), where the variable M/P represents holdings of real balances by a representative agent (M represents nominal balances and P is the price level). Agents maximise at time t the expected value of an inter-temporal consumption-leisure utility function V defined as:

$$V(C,L) = \sum_{j=t}^{\infty} U(C_j, L_j)\beta^{j-t} \tag{1}$$

4 *This latter interpretation may find confirmation, prima facie, from the high annual growth rate of real M1 in Japan - which experienced no major change in monetary regime in the nineties - in recent years (e.g., above 12% at the end of 1999), against the background of short-term interest rates close to zero. This compares with an annual rate of growth of real GDP of only 0.3% at the end of 1999. On the demand for M1 in Japan, see Rasche (1990).*

5 *For a detailed analysis of the relation between the functional form of money demand and consumer surplus, see Lucas (2000).*

where U is a concave (and normally time separable) instantaneous utility function and β a discount factor, $0<\beta<1$; real consumption C_t and real balances M_t/P_t enter with a positive sign. Following Holman (1998), we postulate the existence of two kinds of financial assets, the first labelled as "money" M_t yielding a nominal rate of return $R_t^M>0$ and the second as an "alternative asset" W_t yielding a nominal rate of return $R_t^W>R_t^M$. The budget constraint defined for total wealth W_t+M_t in each period is given by:

$$W_t+M_t=(1+R_{t-1}{}^W)W_{t-1}+(1+R_{t-1}{}^M)M_{t-1}-P_tC_t \tag{2}$$

Within this framework, the demand for real money is a by-product of the maximisation of the expected value of the utility function V in (1) under the constraint in (2) and some initial endowment of resources (a transversality condition is omitted for brevity). In general, the functional form of money demand depends on the functional forms of both the leisure function L and of the instantaneous utility U. As in Holman (1998), we assume that L is a function of real balances only; under these conditions, and assuming that the utility function is well behaved (i.e., it is increasing in its arguments at a decreasing rate), the Euler equation for real balances is as follows:

$$E_t\{\beta\frac{\partial U_{t+1}/\partial C_{t+1}}{\partial U_t/\partial\frac{M_t}{P_t}}\frac{R_t{}^W-R_t{}^M}{1+\pi_{t+1}}-1\}=0\,, \tag{3}$$

where π_{t+1} is the inflation rate on period ahead ($\pi_{t+1}=P_{t+1}/P_t-1$). Equation (3) identifies a money demand function. Chadha, Haldane and Janssen (1998) showed that if the utility function V is well behaved, a double log functional form of money demand arises naturally. It is easy to show that this is also valid in the Holman (1998) context, where monetary instruments are interest bearing. For instance, we consider a CES instantaneous utility function, which is fairly general and widely used in empirical applications:

$$U_t=[\omega C_t{}^\delta+(1-\omega)(M_t/P_t)^{1-\delta}]^{\frac{1}{\delta}}\,, \tag{4}$$

with $\delta<1$ and $\delta\neq 0$. Consumption and real money holdings have decreasing marginal utility and are separable. It is shown in Holman (1998) (see equation 4'b) that with a CES utility function the Euler equation (dropping the expectation operator for simplicity) is the following:

$$\beta\frac{\omega}{1-\omega}(\frac{\omega C_{t+1}{}^\delta+(1-\omega)(M_{t+1}/P_{t+1})^\delta}{\omega C_t{}^\delta+(1-\omega)(M_t/P_t)^\delta})^{\frac{1-\delta}{\delta}}(\frac{M_t}{P_tC_{t+1}})^{1-\delta}\frac{R_t{}^W-R_t{}^M}{1+\pi_{t+1}}=1\,, \tag{5}$$

which can be log-linearised around the steady state as follows (with $m_t=\ln(M_t)$, $p_t=\ln(P_t)$ and $c_t=\ln(C_t)$, and then dropping the time subscript to all variables in (5)):

$$\ln(\beta\frac{\omega}{1-\omega})+(1-\delta)(m-p-c)=-\ln(\frac{R^W-R^M}{1+\pi}) \tag{6}$$

For moderate inflation rates, the term $1+\pi$ will not significantly deviate from 1 and will therefore be left out in the continuation. Rearranging terms in (6), a double log long run money demand very similar to that shown in Chadha, Haldane and Janssen (1998) is obtained:

$$\ln(\frac{M_t}{P_t})=\ln(1-\delta)-\ln\beta\frac{\omega}{1-\omega}+\ln(C_t)-\gamma\ln(R_t{}^W-R_t{}^M)\,, \tag{7}$$

where $\gamma = 1/(1-\delta) > 0$. In practice, however, financial innovation is likely to affect, and in particular to lower over time, the consumption (or income[6]) elasticity of money demand. Thus, in an empirical setting equation (7) is often estimated in the slightly more general form:

$$\ln(\frac{M_t}{P_t}) = \ln(1-\delta) - \ln\beta\frac{\omega}{1-\omega} + \phi\ln(C_t) - \gamma\ln(R_t^W - R_t^M) , \tag{8}$$

the parameter ϕ being the income elasticity which can be expected to be smaller than one, at least for a narrowly defined monetary aggregate.

It is important to stress that with the double log functional form, the interest rate elasticity of money demand is independent of the level of the spread itself. This elasticity is in fact given by $-\gamma$, irrespective of the spread and thus of the monetary policy regime in place.[7,8]

Being derived from the maximisation of standard diminishing marginal utility preferences, equation (8) and the double log functional form represent a natural "benchmark" money demand specification against which different functional forms may be evaluated (see also Lucas, 2000). At the same time, however, agents' degree of preference for liquidity may be also made dependent on the monetary regime in place, and this is the main area of investigation of the present study. The link between preference for liquidity and the prevailing monetary regime – i.e., the level of the inflation rate and therefore of nominal interest rates – is still an unsettled issue in the literature. On the one hand, arguments have been proposed in the literature to suggest a *negative* relationship between the level of the inflation rate and agents' degree of preference for liquidity. Among others, English (1996), Ayiagari, Braun and Eckstein (1998) and Frenkel and Mehrez (2000) reported empirical evidence and theoretical arguments in support of the fact that the higher the inflation rate, the higher the incentives for agents to shift resources from the manufacturing to the financial sector in order to economise in money holdings. As Ayiagari, Braun and Eckstein (1998) suggested, the semi-log functional form popular in empirical studies on money demand (see Ericsson, 1998) well captures the existence of this phenomenon, as the size of the interest rate elasticity is an *increasing* function of the level of the interest rate (spread). In fact, the semi-log function postulates:

$$\ln(\frac{M_t}{P_t}) = k + \phi\ln(C_t) - \gamma(R_t^W - R_t^M) , \tag{9}$$

with the interest rate elasticity of money demand η given by $\eta = -\gamma(R_t^W - R_t^M)$. This in turn implies that agents' degree of preference for liquidity is a *decreasing* function of the level of nominal interest rates.

On the other hand, Mullighan and Sala-i-Martin (1996), working on cross-sectional data, put forward the idea that the demand for money for any individual agent may have a discontinuity at a certain (low) level of the nominal interest rate where the interest rate income does not compensate for the fixed transaction and learning costs associated to investing in interest-bearing assets. This results in a boost to liquidity holdings when the interest rate spread falls below a certain threshold. Below this threshold, money demand becomes insensitive to movements in the

6 *In the remainder of this paper it will be always assumed that consumption and income move together in the long run, as most general equilibrium models predict. Therefore, for simplicity it will be always referred to "income" elasticity.*

7 *As noted above, this result does not depend on the assumption of a CES utility function, and it is common to a large number of well-behaved utility functions (see Chadha, Haldane and Janssen, 1998).*

8 *In the following we will always assume, conveniently but also realistically, that the spread between the nominal interest rate R_t^W and the rate of return on monetary instruments R_t^M depends on the level of R_t^W (i.e., the higher the latter, the higher the spread). Therefore, in a monetary regime with high inflation we assume that the opportunity cost of holding monetary instruments is high in relative terms.*

nominal interest rate spread. However, it is reasonable to assume that the level of this threshold varies across individuals. At the *aggregate level*, it is plausible to observe a generalised increase in the interest rate elasticity of money demand when nominal interest rates fall and the inflation rate approaches zero, without noting a discontinuity at a particular level of the interest rate spread.[9] This would result in a functional form where the size of the interest rate elasticity is a *decreasing* function of the level of the interest rate spread (in particular, the elasticity increases when the interest rate spread falls). We use a functional form as in Ashworth and Evans (1998) – hereafter AE – to capture this idea. The specification of money demand is as follows:

$$\ln(\frac{M_t}{P_t}) = k + \phi \ln(C_t) + \frac{\gamma}{R_t^W - R_t^M}\ , \qquad (10)$$

where the interest rate elasticity of money demand is given by $\eta = -\gamma/(R_t^W - R_t^M)$.

Which one of the functional forms in (8), (9) or (10) is the most appropriate is thus largely an empirical question. Clearly, a larger number of functional forms may be conceived and, in practice, estimated (see Chowdhury, 1992). In this paper we follow an approach similar to, but also departing from, that developed in Chadha, Haldane and Janssen (1998). First, a fixed parameters model is estimated by means of a cointegrated VAR technique with the Johansen approach to check if theoretically plausible and statistically fit models of the demand for M1 in the euro area can be found within each of the three considered functional forms (i.e., as in (8), (9) and (10)). Thereafter, a time-varying parameters model is estimated with Kalman filter to test simultaneously the functional form of the demand for M1 and detect the possible presence of changes over time of its parameters, in a period (1980-2000) dense of structural changes such as the establishment of EMU. The time-varying parameters model represents an innovation compared to the approach followed by Chadha, Haldane and Janssen (1998). In fact, in addition to a grid search within the cointegrated VAR methodology, these authors applied a non-linear least squares estimate of the parameter driving the functional form of money demand, without explicitly allowing for the possibility of changes in the interest rate elasticity over time.

3 The empirical analysis

As in Chadha, Haldane and Janssen (1998), it is useful to write down the three considered functional forms via a standard Box-Cox transformation, as follows:

$$\ln(\frac{M_t}{P_t}) = k + \phi \ln(C_t) - \gamma \frac{(R_t^W - R_t^M)^\lambda}{\lambda}\ , \qquad (11)$$

where $\lambda = 0$, 1 and -1 identify respectively the double log, semi-log and AE functional forms. It is useful to recall that in this general form the interest rate elasticity of money demand can be written as:

$$\eta = -\gamma (R_t^W - R_t^M)^\lambda \qquad (12)$$

In the continuation, we first describe the database, and then move to the estimation of a fixed parameters model with a cointegrated VAR approach and thereafter to estimate a time-varying parameters model by means of the Kalman filter.

9 *More precisely, Mullighan and Sala-i-Martin (1996) refer to a "hill-shaped" form of the interest rate elasticity. When the nominal interest rate falls to really low levels, the interest rate elasticity starts to decrease in size.*

3.1 The data

Quarterly area wide harmonised data for M1 holdings in the eleven countries of the euro area from 1980:1 to 2000:3 are used in this study (all data are reported in Table 1). The monetary aggregate M1 in the euro area includes currency in circulation (notes and coins) and overnight deposits held by the private sector and by the general government excluding central government (i.e., local authorities and social security funds). Overnight deposits are held with euro area Monetary and Financial Institutions (see ECB, 1999b) and, in some euro area countries, also with the central government. M1 balances also include deposits denominated in foreign currency. Quarterly data are computed as averages of monthly data.

For the period before the monetary union (1980:1 to 1998:4), M1 figures for individual countries are aggregated on the basis of GDP weights at PPP exchange rates of 1995.[10] While no uncontroversial aggregation method exists, GDP weights at PPP exchange rates are deemed to be the most appropriate, as they reflect the true purchasing power available to agents in individual countries. Moreover, it is advisable that the aggregation method used for M1 data is the same used for the right hand side variables in the empirical analysis (see Coenen and Vega, 1999).[11] M1 holdings are in levels and seasonally adjusted, with the procedure X-11 ARIMA; the effect of German reunification is also controlled for. As from September 1997, figures are also adjusted for statistical reclassifications and for revaluation effects. Quarterly seasonally adjusted series for real GDP and for the GDP deflator in the euro area are also used in this paper. Real GDP is calculated based on the ESA79 system of national accounts (controlling for the effect of German reunification) and extended after 1995:1 using ESA95 quarter-on-quarter growth rates. Real GDP and the GDP deflator are aggregated across countries using GDP weights at PPP exchange rates of 1995, the same procedure used for M1 data. The velocity of circulation of M1 calculated as a share of real GDP on real M1 in the euro area is reported in Chart 1.

Regarding interest rates, a weighed average of 3-month money market interest rates is considered to be a representative short-term market interest rate in the euro area. GDP weights at PPP exchange rates of 1995 are used also for aggregating the short-term interest rate. Coming to the own rate of return on M1 in the euro area, a plausible estimate based on data available internally in the ECB and drawn from the Bank for International Settlements databank turns out to be possible. The retail rates paid by banks to customers on overnight deposits, or similar definitions thereof before the start of Stage Three of EMU, are aggregated using GDP weights at PPP exchange rates of 1995.[12] Thereafter, the rate of return on M1 is computed as a weighted sum of the rate of return on currency in circulation (namely, zero) and on overnight deposits. Chart 2 depicts the 3-month interest rate, the own rate on M1 and the spread between the two rates as from 1980:1. It is interesting to notice a tendency for the spread to shrink over time, possibly also due to the fact that increasing banking competition and financial innovation has led financial intermediaries to increasingly remunerate sight deposits.[13]

10 The weights are the following (in percentage): Belgium 3.9%, Germany 30.5%, Spain 10.2%, France 21.0%, Ireland 1.1%, Italy 20.3%, Luxembourg 0.2%, the Netherlands 5.6%, Austria 3.0%, Portugal 2.4% and Finland 1.7%.

11 GDP weights at the PPP exchange rates of 1995 are also used in the ECB's area wide model (see Fagan, Henry and Mestre, 2001). A drawback of this aggregation method is that balance sheet identities are no more satisfied at euro area level and data do not correspond strictly to those officially published by the ECB.

12 Data for Austria, Belgium, Luxembourg and Portugal are not available. However, the contributions of these countries to euro area GDP amount to less than 10%. Therefore, their exclusion is unlikely to lead to a significant bias in the estimate. Moreover, the series for rate of return on overnight deposits in Spain undergoes a discontinuity in August 1987, when the administrative maximum rate for tax-exempt transaction accounts was abolished. This causes a significant jump in the series in 1987:3, which has nevertheless a relatively little effect on the euro area aggregate.

13 This is certainly the case in Germany, where no remuneration was given on current account deposits until recent years.

3.2 A cointegrated VAR approach

The log of real M1 holdings, the log of real output and the spread between the nominal 3-month interest rate in the euro area are I(1) variables over the sample 1980:1 – 2000:3, according to standard ADF and Phillips-Perron tests. The same holds true for the log and the reciprocal of the spread between the 3-month interest rate and the own rate on M1.[14] Therefore, the Johansen approach to test for cointegration is followed. This implies estimating a VAR model on the vector $x_t = \{m_t - p_t, y_t, R_t^{\lambda}/\lambda\}$, where m_t denotes the log of seasonally adjusted nominal M1 balances at time t, y_t is the log of seasonally adjusted real output, p_t is the log of the seasonally adjusted GDP deflator, and R_t denotes the spread between the 3-month market interest rate and the own rate of return on M1. The VAR model is specified as follows:

$$\Delta x_t = \Pi x_{t-1} + \sum_{i=1}^{p} A_i \Delta x_{t-i} + \psi \Delta DUM99Q1 + \varepsilon_t \qquad (13)$$

Where Δ stands for quarter-on-quarter change, Π and A_i are coefficient matrices and ε_t is a vector of disturbance terms.[15] We introduce a dummy variable $DUM99Q1$, taking values 1 after the first quarter of 1999 and zero otherwise. The introduction of this dummy variable is motivated by the observation that the aggregation method used up to 1998:4 (GDP weights at 1995 PPP exchange rates) differs from that from 1999:1 onwards (irrevocable parities of 31 December 1998). Moreover, an exceptionally large jump in M1 holdings (and in overnight deposits in particular) was recorded in the first quarter of 1999, possibly reflecting the novelties associated with the transition to Stage Three of EMU (for example, the establishment of a new reserve requirement regime; see ECB, 1999c). The one-off nature of the changes in both the aggregation method and the institutional setting at the start of Stage Three of EMU appears to justify the inclusion of a step dummy in the VAR models in (13). Conversely, inserting a dummy controlling for the disturbances brought about by the uncertainties related to the millennium change (Y2K) is not strictly necessary, given that the overall effect on euro area M1 should have been of temporary nature.

According to the Schwartz and Akaike criteria, a lag order *p* of 2 is appropriate in estimating the VAR model above. Diagnostic tests give satisfactory results, and no presence of serial correlation may be detected for any of the three considered functional forms. Hence, the Johansen likelihood ratio test is run on the rank of the matrix Π , allowing for an intercept in the cointegrating vector and for a linear trend in the VAR. The results of the Johansen test for the three considered functional forms are reported in Table 2. In each case, the Johansen test signals the presence of one cointegrating relationship at the 5% significance level. It should be noted that the outcome of the Johansen test does not depend on the inclusion of the dummy variable for 1999:1; when this is dropped from the VAR model, the same result is obtained.

With the results of the Johansen test at hand, VECM models imposing a single cointegrating vector are estimated. The results of the VECM estimation are reported in Tables 3 to 5 separately for each of the considered functional forms.

Clearly, the identification of one cointegrating vector for each functional form does not necessarily imply that such vector may be interpreted as a long run money demand function, as nothing allows this structural interpretation. A minimum requirement for such cointegrating vector to be

14 See Granger and Hallman (1991) on the assessment of the integration properties of non-linear transformations of I(1) series.

15 Theoretically, a number of other short-term interest rates might be included; for instance the rate of return on time and savings deposits. However, this is not possible for the demand for euro area M1, as area wide data for these rates of return are not available for the whole sample period 1980:1 - 2000:3. Moreover, no long-term interest rate (e.g. 10-year) is considered, on the basis of theoretical a priori and because it is highly collinear with the short-term rate. The inflation rate also turns out to be strongly correlated with the nominal short-term market interest rate and it is therefore left out of the equation.

interpreted as a money demand function is that changes in M1 holdings should react to it (and with a negative sign). An additional desirable property is that output and the interest rate spread should be weakly exogenous to the long run relation of interest, and therefore the error correction term in the corresponding equations should be insignificant. A further identifying condition is the theoretical plausibility of the parameters in the long run relationship. This analysis clearly reveals that for the semi-log functional form the cointegrating relationship cannot be interpreted as a long run money demand function (see Table 3), whereas the double-log and AE specifications turn out to be plausible candidates (see Tables 4 and 5). For the latter functional forms, there is no feedback from money holdings to real GDP and to (the log or the reciprocal of) the interest rate spread, signalling that nothing is lost if a single equation for M1 holdings is estimated individually.

While both the double-log and the AE functional forms are possible candidates theoretically, the former specification turns out to be problematic and should be discarded as a satisfactory fixed parameters model of the demand for euro area M1. First, the estimate of income elasticity under this functional form is implausibly low (0.39). Second, the equation performs badly in the last part of the sample, and all stability tests fail in this period. Therefore, only under the AE functional form a theoretically plausible and statistically fit demand for euro area M1 can be estimated in a fixed parameters context.

Following a general-to-specific approach, a set of restrictions on the equation for real M1 holdings under the AE functional form is introduced and tested via a Wald test. In particular, the restriction is tested that all exogenous variables except the error correction term, the dummy for the first quarter of 1999 and two lags of the endogenous can be excluded from the equation. The Wald test cannot reject these restrictions. In addition, the model now includes a dummy variable capturing the effect of the uncertainties related to the millennium change (Y2K). This variable (*DUMY2K*) takes values 1 in 1999:4 and 2000:1, and zero elsewhere. It is consistent with the idea of a temporary build up of liquidity in 1999:4 due to the fears associated with the century change, which may have lingered for a while in the first quarter of 2000. Theoretically, the effect of the millennium should be temporary and therefore be modelled via an impact, rather than a step dummy. Unfortunately, the paucity of the data *after* the millennium change does not allow to discriminate between the hypothesis of a temporary vis-à-vis a permanent change.

This leads to the following parsimonious model of the demand for real M1 in the euro area: [16]

$$\Delta(m-p)_t = k + \underset{2.16}{0.21}\Delta(m-p)_{t-1} + \underset{2.25}{0.22}\Delta(m-p)_{t-2} - \underset{4.14}{0.08}(m_{t-1} - p_{t-1} - 0.76y_{t-1} + \frac{0.81}{R_t}) + \quad (14)$$
$$+ \underset{7.09}{0.05}\Delta DUM99Q1 + + \underset{2.32}{0.01}DUMY2K$$

Sample 1980:1 to 2000:3 (T=80); R-squared (adjusted): 0.65; S.E. of regression 0.01; serial correlation test LM(1) 0.12 [0.73], LM(1-4) 1.06 [0.38]; ARCH(1) 1.98 [0.16]; Jarque-Bera 0.09 [0.96].

Overall, diagnostic tests suggest that the model in (14) is well specified, and no sign of serial correlation, heteroscedasticity and mis-specification can be found. It is remarkable that despite its being extremely parsimonious, the equation has still an adjusted R-squared of 0.65, which is of the same order of magnitude of the unrestricted model. Given the relatively high value of the R-squared, no insertion of additional (possibly contemporaneous) dynamic terms is attempted. The

16 *It may be useful to add that the model is consistent with a "real partial adjustment" mechanism (see Goldfeld, 1973), where the assumption of price homogeneity is maintained both in the short and in the long run.*

relatively low absolute level of the error correction coefficient (-0.08) suggests that the costs of remaining out of the equilibrium are small, as also found by Coenen and Vega (1999) for euro area M3. The long run income elasticity of 0.76 signals a tendency for M1 velocity to increase over time, a common finding when modelling the demand for narrow monetary aggregates.[17] It is interesting to notice the striking difference with the income elasticity well above 1 found for euro area M3 by Coenen and Vega (1999) and Brand and Cassola (2000). This appears to confirm that a broad monetary aggregate such as M3 is held also for savings purposes, whereas the liquid instruments in M1 are held primarily for transactions and therefore should not be affected by a wealth effect.

Apart from the aforementioned special factors in 1999:1 and the two quarters covering the millennium change, the model in (14) displays favourable stability properties. When estimated up to the fourth quarter of 1998 (thus without any dummy variable), recursive residuals and the CUSUM test (see Chart 3) give no evidence of major instability episodes. Moreover, the recursive estimation of the coefficients signals no major instability over the sample period (Chart 3). When estimated up to 2000:3 with the dummy variables, the equation appears to be stable also in the last part of the sample.

While on the basis of the reported evidence equation (14) should be regarded as a statistically fit and theoretically sound demand for M1 in the euro area, it is nevertheless not entirely satisfactory for a number of reasons. Most notably, the AE functional form is relatively uncommon in the literature and attributes a disproportionately large weight to movements in the interest rate at very low levels. This is confirmed by looking at the development over time of the error correction term (see Chart 4), which displays some instability towards the end of the sample period, when the 3-month interest rate in the euro area falls to around 2.5%. Moreover, in the sample period under investigation (1980-2000) a number of institutional and structural changes have come about in the euro area. Notably, a change in monetary regime and, for some euro area countries, a move to an environment of price stability took place with the transition to Stage Three of EMU. It is highly plausible that such changes have a significant bearing on the parameters of the demand for narrow money. Clearly, a fixed parameters model does not appear suited to deal with a non-stationary environment; therefore, a time-varying parameters model explicitly allowing for the unfolding of structural changes is estimated in the ensuing section.

3.3 A state space model of the demand for euro area M1

In this section a state space (time-varying parameters) model is estimated on the demand for euro area M1 following an approach similar to Bomhoff (1991). As mentioned above, the time-varying parameters model may both assess possible changes over time of the parameters of interest as well as be a discriminating device among possible functional forms. From a methodological perspective, it may represent a step forward compared with the fixed parameters non-linear least squares estimate of the functional form of money demand in Chadha, Haldane and Janssen (1998). Moreover, the estimation through the Kalman filter makes it possible to consider a general, non-linear specification of the demand for M1, which cannot be dealt with within a cointegrated VAR approach. An interesting by-product of this analysis is also the possibility of evaluate the impact of plausible forms of financial innovation onto M1 holdings in the euro area. In particular, as pointed out by Bomhoff (1991), the state space approach proposed below is able to model the effect of some types of financial innovation separately, thereby increasing the explanatory power of the analysis.

17 The restriction of unit long run income elasticity is rejected by the data.

As a preliminary step in the analysis, we follow the same approach as in Chadha, Haldane and Janssen (1998) to run a non-linear least squares estimate of the long run demand for M1, in order to draw a direct estimate of the parameter λ. Hence, the following regression was run on the sample period from 1980:1 to 2000:3:[18]

$$m_t - p_t = k + \phi y_t - \gamma \frac{R_t^{\lambda}}{\lambda} + \psi DUM99Q1 \tag{15}$$

The results of this preliminary analysis, not reported here for reasons of brevity, confirm the finding of Chadha, Haldane and Janssen (1998) that the parameter λ can be very imprecisely estimated using this methodology.[19] In fact, while the point estimate of 0.02 would suggest a double log functional form, the standard error is such that none of the three considered functional forms could be rejected by the data. In addition, the model in (15) clearly suffers from instability problems. An inspection at the recursive estimates (see Chart 5) suggests that (i) the model performs badly in the last part of the sample and (ii) the instability appears to be concentrated in the parameter γ determining the interest rate elasticity, while the income elasticity is estimated precisely and without much variation over time, at 0.75.

Based on the results of this preliminary analysis, we move to specify a time-varying parameters model where the possibility of time variation in the interest rate elasticity of money demand is explicitly allowed. The specification of the model is somewhat different from, and slightly more general than, that put forward by Bomhoff (1991). The model is specified as:

$$m_t - p_t = k + \phi y_t - \gamma_t \frac{R_t^{\lambda}}{\lambda} + \psi DUM99Q1 + \varepsilon_t \tag{16}$$

$$\gamma_t = \gamma_0 + \gamma_1 \gamma_{t-1} + u_t^{\gamma} \tag{17}$$

In this specification, a new type of shock is introduced compared with the specification of Bomhoff (1991) to the interest rate elasticity of money demand (namely, the parameter driving the interest rate elasticity is now a state series γ_t). This inclusion looks reasonable also because theoretical research (see among others Ireland, 1995, and Glennon and Lane, 1996) has shown that the influence of financial innovation, such as the introduction of new monetary instruments by financial intermediaries, may have significant effects on the interest rate elasticity of the demand for existing monetary assets.[20] Theoretically, the parameter ϕ may be estimated freely, implying that the model may also implicitly contain a time trend for velocity as in Bomhoff (1991). In practice, the income elasticity is kept fixed at 0.75 in the estimate in order to gain degrees of freedom.[21] The state series γ_t is modelled as an auto-regressive process with a constant term (with parameters γ_0 and γ_1); the auto-regressive coefficient γ_1 is estimated freely. In practice, however, the state series γ_t turns out to be indistinguishable from a random walk and the estimation is then subsequently carried out under this assumption. u_t^{γ} is a disturbance term, with zero mean and constant variance. The disturbance term to the money demand equation (16), ε_t, captures the influence of transitory shocks, and it is also assumed to have a zero mean, constant variance and to be uncorrelated at all leads and lags with u_t^{γ}. An attractive feature of the model in (16)-(17) is that it nests the three functional forms taken into consideration in the previous section as special cases (depending on the value assumed by λ, which is estimated freely). It is therefore able to provide a

18 No dummy variable for the millennium change was included, on the basis of the assumption that the uncertainties related to the Y2K had only a temporary effect on M1 demand, while the focus here is on the long run properties of M1 demand. Results do not change anyway when including the dummy variable DUMY2K.

19 Estimating the parameter in equation (15) in a dynamic error-correction specification does not qualitatively change the results.

20 Better accessibility to banking services (e.g. through the Internet) may also tend to change the interest rate elasticity of money holdings (and in particular, to increase it over time), as agents might find it less costly to adjust their portfolio holdings following changes in market conditions.

21 Moreover, the free estimation of this parameter tends to give a value close to 0.75. This is also very close to the value of 0.76 estimated in equation (14).

direct test of the relative performance of the three functional forms, while at the same time modelling the variation of parameters over time.[22]

The time-varying parameters model in (16)-(17) is estimated by means of a Kalman filter over the full sample period from 1980:1 up to 2000:3. This requires maximising the likelihood function using an optimisation algorithm (in particular, the BHHH algorithm). The fact that real M1 is a I(1) variable over the considered sample period does not represent a problem, as time-varying parameters models are well designed to deal with non-stationary (non-ergodic) data, because states are always taken conditional on their last realisation.

The results of the estimation of the model in (16) and (17) are reported in Table 6. Overall, the model appears to be well specified, and residuals (see the chart in the lower panel) appear to be stationary, well behaved and approximately Normal (see Chart 6). Clearly, being the model in (16)-(17) specified in terms of the long run relationship, the residuals have some positive autocorrelation, reflecting the existence of adjustment costs in bringing monetary holdings to the desired equilibrium value.

The most striking result arising from this analysis is that the parameter λ, which identifies the functional form of M1 demand, can be now estimated very precisely at 0.02 with a standard error of 0.01. This is in sharp contrast with the very imprecise estimate of the non-linear least squares model. Chi-squared tests reject λ to be equal to –1 (AE functional form), 0 (double-log) or 1 (semi-log). Hence, this econometric exercise suggests that none of the three considered specifications mirrors the "true" preferences of agents and the "deep" functional form of money demand. At the same time, among the three functional forms considered in the fixed parameters estimation the double-log function is by far the closest to the "true" model. Equally important, a small but noticeable increase in the absolute value of the interest rate elasticity of M1 (i.e., the series $\eta_t = -\gamma_t R_t^{\lambda}$) is clearly visible as from the beginning of 1996 (Chart 7). It is interesting to notice that such increase can be straightforwardly associated, due to its timing, to the run-up and the establishment of Stage Three of EMU. To paraphrase, the results suggest that the transition to a new monetary regime and, for some euro area countries, to an environment of low and predictable inflation, and therefore low and predictable nominal interest rates for the foreseeable future, brought about an increase in agents' degree of preference for liquidity. It is clear from Chart 7 that the absolute increase of the interest rate elasticity of M1 during the period 1996-1999 is far from dramatic. However, it should also be noted that it is sufficient to relieve the equation from the stability problems encountered with the fixed parameters non-linear least squares estimate.

That the variation over time of the parameter γ_t is decisive to ensure the stability of the estimated M1 demand relationship is demonstrated by the simple exercise as shown in the lower panel of Chart 8. When the parameter γ_t is constrained to be equal to its average between 1980:1 and 1995:4 over the full sample up to 2000:3, the time-varying parameters (now indeed a fixed parameters) model is not able any more to give account of the pronounced fall in M1 velocity in the period 1996-1999. Actually, the model even predicts a further *increase* in M1 velocity, in line with the historical trend until 1995.

Overall, the conclusion may be drawn that the demand for euro area M1 has a functional form, which closely resembles, although it is not exactly equal to, the outcome of a textbook

22 *The long run demand for M1 identified in the cointegrated VAR approach (i.e., the cointegrating vector stemming from (14)) might be seen as a particular case of the time-varying parameters specification in (16)-(17), where the state displays no variation over time (namely, the disturbance term of the states have zero variance) and =-1. It should also be stressed that there is no guarantee that the time-varying parameters model really captures a money demand relationship, i.e. the structural interpretation cannot be tested. However, given the theoretical a priori and the similarity with the fixed parameters specification for which a test of the structural interpretation exists, it is very likely that the model actually captures a money demand relationship.*

optimisation, namely a double-log specification. According to this specification, the size of the interest rate elasticity of M1 demand varies little with the level of the spread between the nominal short-term interest rate and the own rate on M1. This in turn implies that changes in monetary regime have in the steady state little effect on the functional form of M1 demand. However, estimates clearly show that the establishment of EMU did have a significant effect, albeit moderate in size, on the interest rate elasticity of M1 demand.

The differences in the outcome of the time-varying parameters and fixed parameters models should not be overemphasised as they buttress the same argument, namely an increase in the size of the interest rate elasticity of M1 demand in the run-up to Stage Three of EMU. In the light of the results of the time-varying parameters estimate it is not surprising that the AE specification – where the interest rate elasticity is a decreasing function of the interest rate – did well over the sample up to 2000:3 due to the transition to Stage Three of EMU. This appears to be due to the strong correlation between the increase in interest rate elasticity and the decrease in short-term interest rates in the euro area, which took place almost contemporaneously.

4 Conclusions

This paper has dealt with the properties of the demand for M1 in the euro area, on the basis of area wide quarterly data over the sample period from 1980:1 to 2000:3, taking a close look at the fall in M1 velocity experienced in the most recent years. To do so, it focussed on the functional form of the demand for M1 considering three specifications, namely the semi-log popular in the empirical literature, the double-log and the AE models. Theoretical considerations seem to suggest that a double log model should be the "true" functional form, but it is not necessarily the case if the interest rate elasticity (and therefore agents' degree of preference for liquidity) is a function of the monetary regime in place. Indeed, according to the semi-log function, the interest rate elasticity of money demand *increases* with the level of the nominal interest rate, so that shoe-leather costs become comparatively less important in a high-inflation environment. Conversely, the AE model foresees that the interest rate elasticity is *stronger* the *lower* the interest rate, for instance because under a certain threshold the forgone interest rate income does not adequately compensate for the learning and transactions costs associated to investing in securities (see Mullighan and Sala-i-Martin, 1996).

The main finding of this paper is that it is possible to estimate a statistically fit and theoretically sound demand for euro area M1 if functional forms alternative to the traditional semi-log function are employed. In particular, a fixed parameters estimate based on the Ashworth-Evans functional form provides satisfactory results. Moreover, it is found that a time-varying parameters model, allowing for a modest increase in the interest rate elasticity of M1 demand in the period up to and around the establishment of EMU, is able to give account of recent M1 developments on the basis of a textbook double log functional form. In this respect, the results in this paper tend to confirm those in Chadha, Haldane and Janssen (1998) and Lucas (2000) and corroborate the evidence in favour of the double log functional form.

The increase in interest rate elasticity in the period up to and around the start of Stage Three of EMU, which albeit of limited size has important consequences for the stability of the demand for M1, likely reflected the establishment of a new monetary regime. About the economic mechanism exactly driving this phenomenon, more research is warranted and only tentative speculations may be provided here. Transaction costs as emphasised in Mullighan and Sala-i-Martin (1996) should have played an important role. Moreover, the decline in nominal interest rates and inflation might have been perceived as *permanent* on the eve of Stage Three of EMU. This may have brought about a permanent change in agents' accounting of costs and benefits of alternative investment strategies.

Further research is needed in several directions. One important avenue for future work is reconciling the findings in this paper with those on euro area M3 in Coenen and Vega (1999) and Brand and Cassola (2000), which requires an analysis of the properties of the aggregate M3-M1. For instance, the fact that the long run income elasticity of M1 and M3 are respectively clearly below and clearly above one implies that the instruments in M3-M1 should display income elasticity well above one. This would be consistent with the idea that the instruments in M3-M1 (mainly time and savings deposits and short-term securities) are mainly held for savings purposes, whereas those in narrow money are mainly held for transactions.

Table 1

The data

Date	Log of M1 (s.a.)	Log of GDP deflator (s.a)	Log of real GDP (s.a.)	3-month interest rate (in %)	Own rate of return on M1 (in %)
1980:1	13.08509	3.780700	15.17450	12.60730	2.735192
1980:2	13.10248	3.802300	15.16680	13.09870	2.779242
1980:3	13.12524	3.824400	15.16210	12.13230	2.838434
1980:4	13.14039	3.844900	15.16290	12.56590	2.884472
1981:1	13.14987	3.870700	15.16530	13.36850	3.112469
1981:2	13.16313	3.894300	15.17190	15.47680	3.239622
1981:3	13.17072	3.922600	15.17330	16.08140	3.293264
1981:4	13.18543	3.949100	15.17550	15.35320	3.331698
1982:1	13.21031	3.976700	15.17910	14.25510	3.507080
1982:2	13.22875	3.997900	15.17980	14.30210	3.530863
1982:3	13.25222	4.016100	15.17530	13.25180	3.246812
1982:4	13.27654	4.034900	15.17790	12.49140	3.513033
1983:1	13.30392	4.060500	15.18260	11.75690	3.443696
1983:2	13.32694	4.076600	15.18880	11.66310	3.272768
1983:3	13.34808	4.097300	15.19300	12.01080	3.254266
1983:4	13.36598	4.114100	15.20530	12.00270	3.318737
1984:1	13.37976	4.135800	15.21220	11.28900	3.132193
1984:2	13.39376	4.147200	15.20580	10.74570	3.038922
1984:3	13.41153	4.158600	15.21900	10.31640	3.017352
1984:4	13.43200	4.168800	15.22370	10.03480	3.087772
1985:1	13.45798	4.185500	15.22340	9.769100	2.979314
1985:2	13.46306	4.197600	15.23500	9.859000	2.823629
1985:3	13.48236	4.212200	15.24540	9.244600	2.639306
1985:4	13.50299	4.225000	15.25110	8.553300	2.730874
1986:1	13.52471	4.242100	15.25020	8.642500	2.704175
1986:2	13.55042	4.255800	15.26200	7.919700	2.203151
1986:3	13.57323	4.264800	15.26900	7.642900	2.098014

Table 1 (continued)

1986:4	13.58901	4.271700	15.27530	7.755000	2.100156
1987:1	13.60703	4.279800	15.26940	7.957600	1.928362
1987:2	13.63323	4.288900	15.28760	8.222200	1.842891
1987:3	13.64758	4.294100	15.29590	8.315300	1.857513
1987:4	13.66216	4.304700	15.30860	8.292200	2.567012
1988:1	13.68032	4.314000	15.31550	7.345000	2.552320
1988:2	13.70247	4.323300	15.32390	7.171600	2.498653
1988:3	13.72175	4.331900	15.33540	7.902500	2.501390
1988:4	13.73941	4.343600	15.34660	8.378700	2.545407
1989:1	13.75740	4.354200	15.35900	9.411900	2.618188
1989:2	13.77111	4.362800	15.36420	9.581400	2.616158
1989:3	13.79363	4.373600	15.37110	9.991000	2.623874
1989:4	13.81344	4.387200	15.38240	10.96510	2.663445
1990:1	13.82805	4.397900	15.39600	11.11330	2.777908
1990:2	13.83661	4.411000	15.40240	10.51270	2.742456
1990:3	13.85516	4.422100	15.40980	10.43380	2.775911
1990:4	13.86713	4.429900	15.41760	10.94850	2.799933
1991:1	13.87803	4.442400	15.42740	11.00220	2.852942
1991:2	13.88616	4.455800	15.43070	10.38420	2.716430
1991:3	13.89304	4.467700	15.43090	10.43750	2.655322
1991:4	13.89758	4.481100	15.44030	10.66180	2.635896
1992:1	13.90102	4.490600	15.45170	10.78460	2.681731
1992:2	13.91840	4.499600	15.44730	10.92070	2.671572
1992:3	13.92292	4.507900	15.44310	11.86370	2.798124
1992:4	13.94150	4.514600	15.44130	11.33430	2.731396
1993:1	13.94667	4.525400	15.43460	10.59870	2.651525
1993:2	13.95777	4.534700	15.43560	9.018800	2.475613
1993:3	13.97250	4.541700	15.43710	8.078000	2.212134
1993:4	13.99827	4.548600	15.44250	7.377500	2.135318
1994:1	14.02852	4.555400	15.45090	6.806900	1.940066
1994:2	14.03758	4.561100	15.45670	6.336500	1.817757
1994:3	14.04583	4.567900	15.46350	6.355600	1.799320
1994:4	14.04935	4.574700	15.47180	6.487400	1.806700
1995:1	14.05554	4.581900	15.47920	6.945100	1.879514
1995:2	14.06466	4.590200	15.48410	7.145300	1.974201
1995:3	14.07935	4.598800	15.48470	6.689700	2.006504
1995:4	14.09543	4.603800	15.48780	6.495400	2.042214
1996:1	14.11020	4.609800	15.49100	5.626000	2.043016
1996:2	14.12731	4.614400	15.49610	5.132000	1.957223
1996:3	14.14497	4.618400	15.50130	4.996900	1.819266
1996:4	14.17027	4.622100	15.50390	4.581000	1.728774
1997:1	14.18746	4.625500	15.50660	4.432600	1.554383
1997:2	14.20689	4.629500	15.51910	4.320900	1.473723
1997:3	14.23552	4.634100	15.52510	4.316200	1.349734

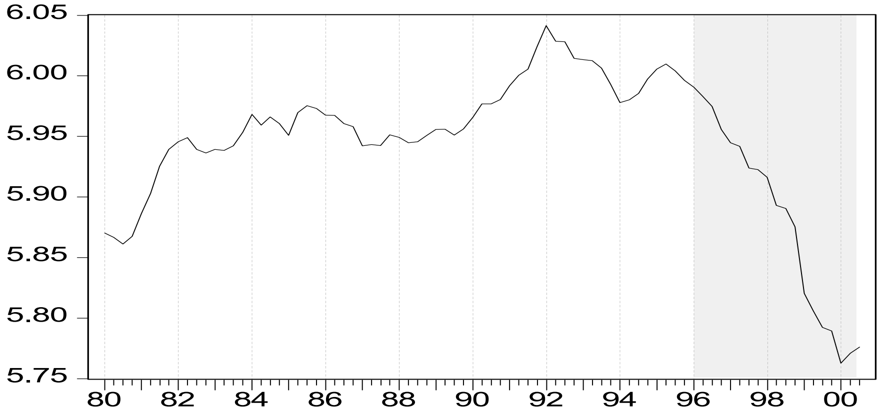
Table 1 (continued)

1997:4	14.24921	4.638200	15.53350	4.426100	1.348806
1998:1	14.26729	4.642600	15.54110	4.190900	1.199757
1998:2	14.29858	4.646200	15.54550	4.044200	1.123684
1998:3	14.30998	4.650200	15.55020	3.927200	1.062107
1998:4	14.33089	4.653600	15.55270	3.614900	0.902900
1999:1	14.39634	4.657300	15.55940	3.089900	0.763868
1999:2	14.41798	4.659000	15.56510	2.633400	0.651080
1999:3	14.44377	4.661400	15.57480	2.699000	0.615130
1999:4	14.45669	4.662900	15.58320	3.429600	0.680699
2000:1	14.49089	4.662900	15.59065	3.542500	0.725363
2000:2	14.50367	4.674000	15.60065	4.270000	0.832270
2000:3	14.51000	4.677400	15.60864	4.500000	0.933744

Chart 1

M1 velocity (1)

Quarterly s.a. data



(1) Shaded area as from 1996:1.

Chart 2

3-month interest rate and own rate on M1 (1)

Quarterly n.s.a. data

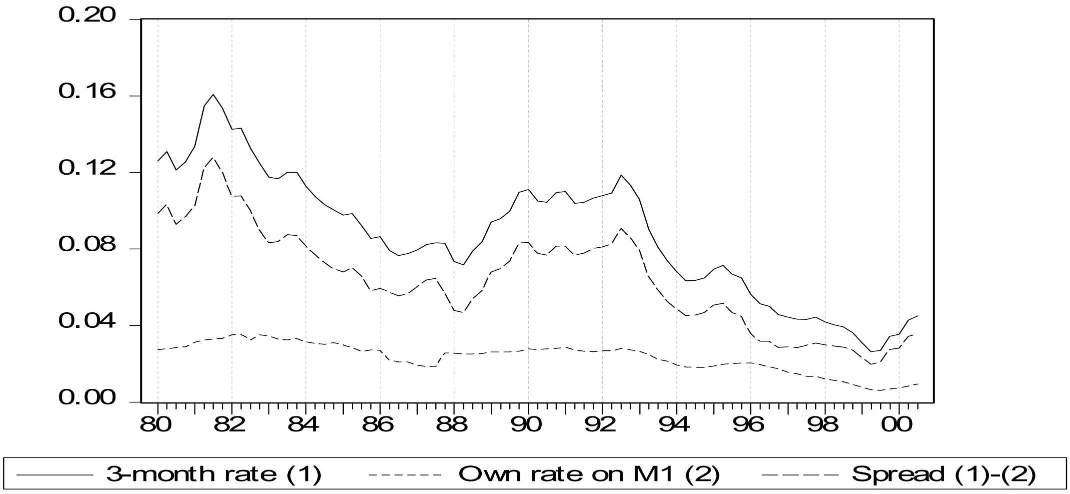


Table 2

Johansen likelihood ratio test (1)

Semi-log functional form ($\lambda = 1$)

Exogenous series: D(DUM99Q1)

Lags interval: 1 to 2

Eigenvalue	Likelihood Ratio	5 Percent Critical Value	1 Percent Critical Value	Hypothesised No. of CE(s)
0.225880	31.57770	29.68	35.65	None *
0.097180	11.09542	15.41	20.04	At most 1
0.035804	2.916879	3.76	6.65	At most 2

*(**) denotes rejection of the hypothesis at 5%(1%) significance level

Double-log functional form ($\lambda = 0$)

Exogenous series: D(DUM99Q1)

Lags interval: 1 to 2

Eigenvalue	Likelihood Ratio	5 Percent Critical Value	1 Percent Critical Value	Hypothesised No. of CE(s)
0.211204	31.49878	29.68	35.65	None *
0.110463	12.51898	15.41	20.04	At most 1
0.038665	3.154611	3.76	6.65	At most 2

*(**) denotes rejection of the hypothesis at 5%(1%) significance level

AE functional form ($\lambda = -1$)

Exogenous series: D(DUM99Q1)

Lags interval: 1 to 2

Eigenvalue	Likelihood Ratio	5 Percent Critical Value	1 Percent Critical Value	Hypothesised No. of CE(s)
0.261057	37.65348	29.68	35.65	None **
0.130667	13.45070	15.41	20.04	At most 1
0.027713	2.248345	3.76	6.65	At most 2

*(**) denotes rejection of the hypothesis at 5%(1%) significance level

(1) Estimated over the sample 1980: 1–2000: 3; see text for further explanations. The test allows for an intercept and in the cointegrating relationship and a linear trend in the VAR.

Table 3

Estimates of the VECM model (semi-log functional form)

(Symbols: $M=m_t-p_t$; $Y=y_t$; $R=R_t$)

Sample(adjusted): 1980:4 2000:3			
Included observations: 80 after adjusting endpoints			
Standard errors & t-statistics in parentheses			
Cointegrating Eq:	CointEq1		
M(-1)	1.000000		
Y(-1)	-3.268577		
	(4.35543)		
	(-0.75046)		
R(-1)	-36.05363		
	(64.2223)		
	(-0.56139)		
C	43.10694		
Error Correction:	D(M)	D(Y)	D(R)
CointEq1	0.006556	0.002036	0.002524
	(0.00206)	(0.00134)	(0.00138)
	(3.17746)	(1.51609)	(1.82726)
D(M(-1))	0.096181	-0.017900	-0.003326
	(0.10083)	(0.06564)	(0.06749)
	(0.95386)	(-0.27269)	(-0.04929)
D(M(-2))	0.117792	0.032779	-0.103464
	(0.10286)	(0.06696)	(0.06885)
	(1.14517)	(0.48954)	(-1.50282)
D(Y(-1))	-0.042162	0.064687	-0.039062
	(0.17952)	(0.11686)	(0.12016)
	(-0.23486)	(0.55353)	(-0.32509)
D(Y(-2))	0.001751	0.021726	0.054138
	(0.16872)	(0.10984)	(0.11293)
	(0.01038)	(0.19780)	(0.47939)
D(R(-1))	-0.195338	0.229229	0.535360
	(0.17192)	(0.11192)	(0.11507)
	(-1.13619)	(2.04819)	(4.65240)
D(R(-2))	-0.070819	-0.048498	-0.121167
	(0.17492)	(0.11387)	(0.11708)
	(-0.40487)	(-0.42591)	(-1.03493)
C	0.004629	0.005180	0.000332
	(0.00188)	(0.00122)	(0.00126)
	(2.46216)	(4.23282)	(0.26416)
D(DUM99Q1)	0.047957	-0.000327	-0.005224
	(0.00750)	(0.00488)	(0.00502)
	(6.39644)	(-0.06703)	(-1.04092)
R-squared	0.652167	0.196737	0.275848
Adj. R-squared	0.612974	0.106228	0.194254
Sum sq. resids	0.003698	0.001567	0.001657
S.E. equation	0.007217	0.004698	0.004830
F-statistic	16.64008	2.173685	3.380719
Log likelihood	285.7678	320.1102	317.8869
Q(1)-statistics on residuals [P-value]	0.06 [0.81]	0.02 [0.89]	0.39 [0.53]
Q(1-4) statistics on residuals [P-value]	2.32 [0.68]	4.50 [0.34]	1.84 [0.76]
Akaike AIC	-6.919196	-7.777755	-7.722172
Schwarz SC	-6.651218	-7.509777	-7.454194
Mean dependent	0.006647	0.005582	-0.000716
S.D. dependent	0.011600	0.004969	0.005381
Determinant Residual Covariance		1.71E-14	
Log Likelihood		927.5512	

Table 4

Estimates of the VECM model (double-log functional form)

(Symbols: $M=m_t-p_t$; $Y=y_t$; $LR=\ln(R_t)$)

Sample(adjusted): 1980:4 2000:3			
Included observations: 80 after adjusting endpoints			
Standard errors & t-statistics in parentheses			
Cointegrating Eq:	CointEq1		
M(-1)	1.000000		
Y(-1)	-0.391456		
	(0.29846)		
	(-1.31160)		
LR(-1)	0.510340		
	(0.23181)		
	(2.20153)		
C	-1.950331		
Error Correction:	D(M)	D(Y)	D(LR)
CointEq1	-0.035197	-0.002227	-0.021668
	(0.00858)	(0.00581)	(0.09767)
	(-4.10364)	(-0.38341)	(-0.22186)
D(M(-1))	0.105741	0.034762	0.889028
	(0.09530)	(0.06453)	(1.08523)
	(1.10951)	(0.53867)	(0.81921)
D(M(-2))	0.111130	0.074101	-0.287150
	(0.09400)	(0.06365)	(1.07039)
	(1.18222)	(1.16421)	(-0.26827)
D(Y(-1))	-0.069524	0.093424	0.116545
	(0.17345)	(0.11744)	(1.97503)
	(-0.40084)	(0.79549)	(0.05901)
D(Y(-2))	-0.031745	0.046023	1.663568
	(0.16459)	(0.11144)	(1.87413)
	(-0.19288)	(0.41298)	(0.88765)
D(LR(-1))	0.001882	0.013859	0.467708
	(0.01081)	(0.00732)	(0.12313)
	(0.17403)	(1.89290)	(3.79851)
D(LR(-2))	-0.001942	-0.004690	-0.080097
	(0.01146)	(0.00776)	(0.13047)
	(-0.16952)	(-0.60448)	(-0.61391)
C	0.005168	0.004224	-0.018381
	(0.00171)	(0.00116)	(0.01951)
	(3.01561)	(3.64045)	(-0.94200)
DDUM99	0.047179	0.001090	-0.136930
	(0.00726)	(0.00492)	(0.08268)
	(6.49782)	(0.22168)	(-1.65621)
R-squared	0.669345	0.173876	0.246374
Adj. R-squared	0.632089	0.080792	0.161459
Sum sq. resids	0.003515	0.001612	0.455772
S.E. equation	0.007036	0.004764	0.080121
F-statistic	17.96570	1.867940	2.901405
Log likelihood	287.7938	318.9877	93.19650
Q(1)-statistics on residuals	0.06 [0.80]	0.09 [0.77]	0.05 [0.82]
Q(1-4) statistics on residuals	3.24 [0.52]	4.16 [0.38]	1.89 [0.76]
Akaike AIC	-6.969845	-7.749692	-2.104913
Schwarz SC	-6.701867	-7.481714	-1.836935
Mean dependent	0.006647	0.005582	-0.011973
S.D. dependent	0.011600	0.004969	0.087495
Determinant Residual Covariance		4.58E-12	
Log Likelihood		703.8246	

Table 5

Estimates of the VECM model (AE functional form)

(Symbols: $M=m_t-p_t$; $Y=y_t$; $IR=\frac{1}{R_t}$

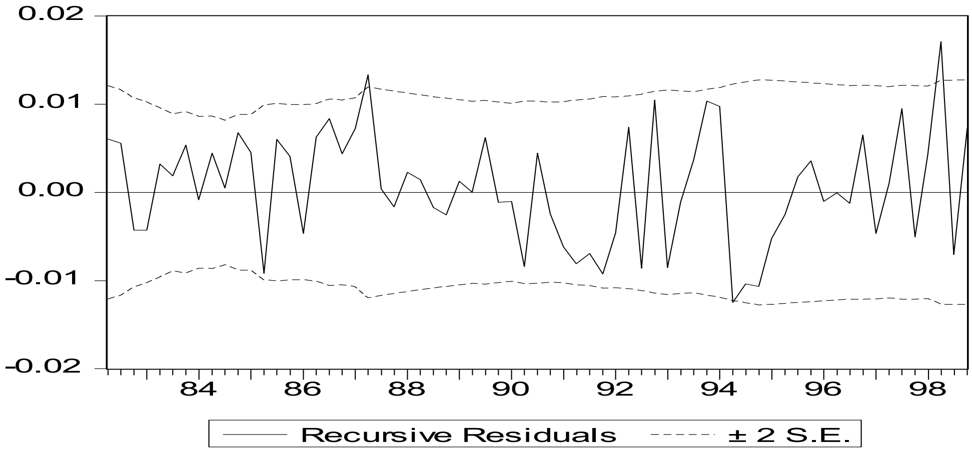
Sample(adjusted): 1980:4 2000:3			
Included observations: 80 after adjusting endpoints			
Standard errors & t-statistics in parentheses			
Cointegrating Eq:	CointEq1		
M(-1)	1.000000		
Y(-1)	-0.650694		
	(0.09177)		
	(-7.09066)		
IR(-1)	-1.158364		
	(0.21856)		
	(-5.30000)		
C	0.803098		
Error Correction:	D(M)	D(Y)	D(IR)
CointEq1	-0.088574	0.006023	-0.007927
	(0.01835)	(0.01292)	(0.05732)
	(-4.82695)	(0.46604)	(-0.13829)
D(M(-1))	0.180288	0.049305	-0.056246
	(0.08879)	(0.06253)	(0.27736)
	(2.03055)	(0.78850)	(-0.20279)
D(M(-2))	0.167619	0.105139	-0.158142
	(0.08554)	(0.06024)	(0.26721)
	(1.95952)	(1.74524)	(-0.59182)
D(Y(-1))	-0.099855	0.117780	-0.170537
	(0.16477)	(0.11604)	(0.51471)
	(-0.60603)	(1.01499)	(-0.33133)
D(Y(-2))	-0.065459	0.060913	-0.388329
	(0.15827)	(0.11147)	(0.49442)
	(-0.41358)	(0.54647)	(-0.78543)
D(IR(-1))	-0.091782	-0.028480	0.356413
	(0.04036)	(0.02842)	(0.12608)
	(-2.27406)	(-1.00196)	(2.82692)
D(IR(-2))	-0.032402	0.012368	-0.089919
	(0.04485)	(0.03159)	(0.14010)
	(-0.72247)	(0.39158)	(-0.64182)
C	0.004951	0.003620	0.005266
	(0.00148)	(0.00104)	(0.00463)
	(3.33954)	(3.46727)	(1.13718)
DDUM99	0.049067	0.001739	0.053370
	(0.00700)	(0.00493)	(0.02186)
	(7.01114)	(0.35289)	(2.44123)
R-squared	0.686560	0.152817	0.231505
Adj. R-squared	0.651242	0.057360	0.144914
Sum sq. resids	0.003332	0.001653	0.032515
S.E. equation	0.006851	0.004825	0.021400
F-statistic	19.43979	1.600895	2.673543
Log likelihood	289.9324	317.9808	198.8085
Q(1)-statistics on residuals	0.03 [0.86]	0.21 [0.65]	1.62 [0.20]
Q(1-4) statistics on residuals	4.06 [0.40]	5.44 [0.25]	8.98 [0.07]
Akaike AIC	-7.023310	-7.724521	-4.745212
Schwarz SC	-6.755332	-7.456543	-4.477234
Mean dependent	0.006647	0.005582	0.002160
S.D. dependent	0.011600	0.004969	0.023142
Determinant Residual Covariance		3.19E-13	
Log Likelihood		810.4553	
Akaike Information Criteria		-19.51138	

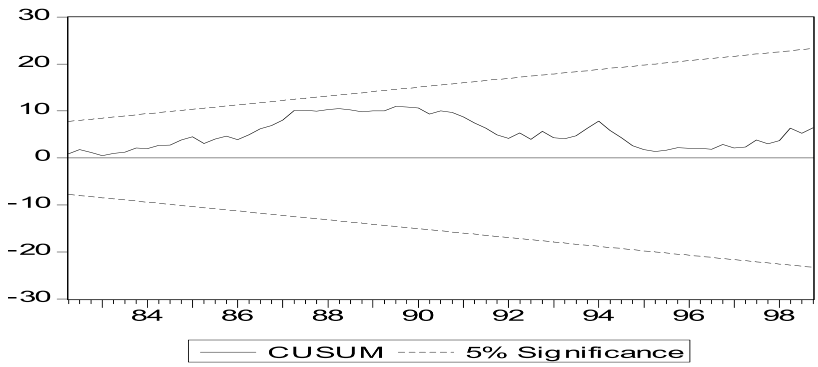
Chart 3

Stability tests on equation (14)

Estimated recursively on the sample period 1980: 1–1998: 4

Recursive residuals





Recursive estimate of the coefficients in equation (14)

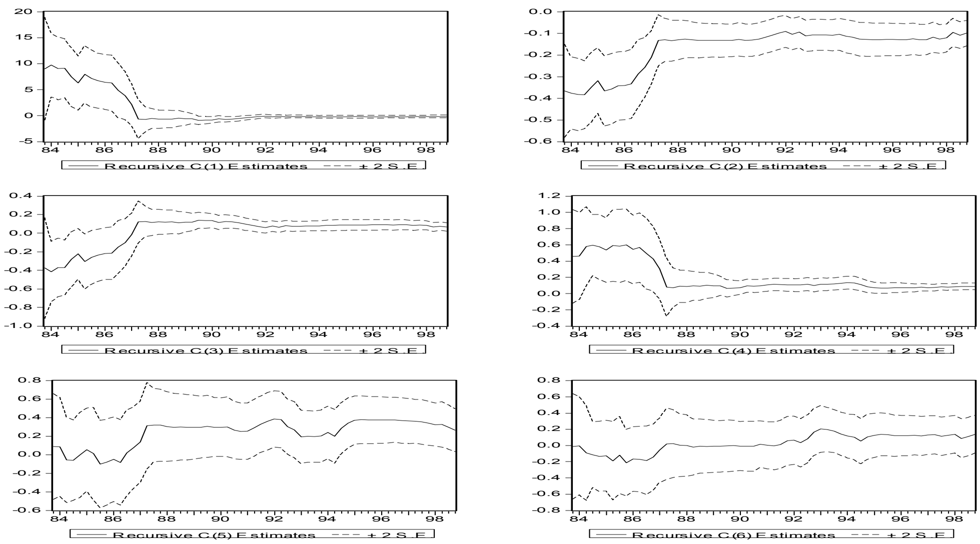


Chart 4

Error correction term stemming from equation (14) in text

Estimated on the sample period 1980: 1–2000:3

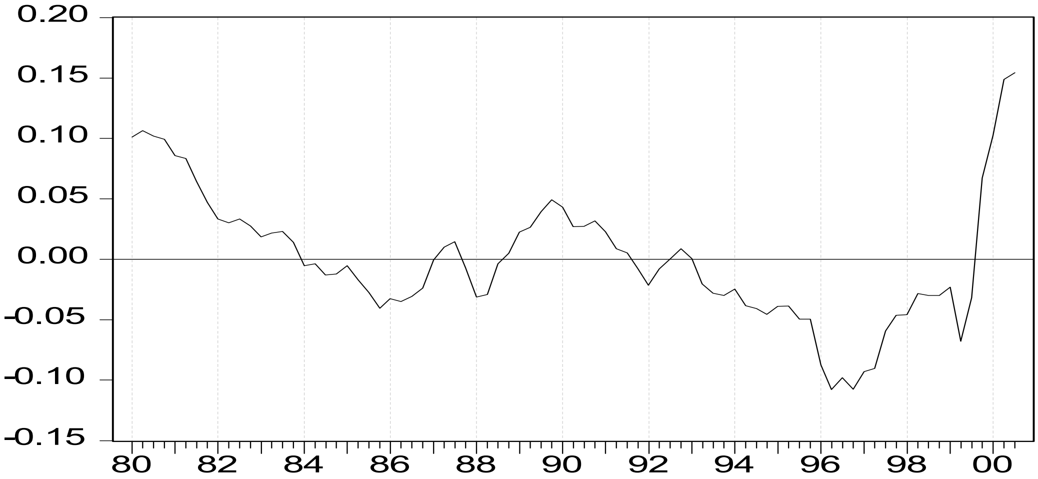


Chart 5

Stability properties of the NLLS estimate

(see paragraph 3.3 for explanations)

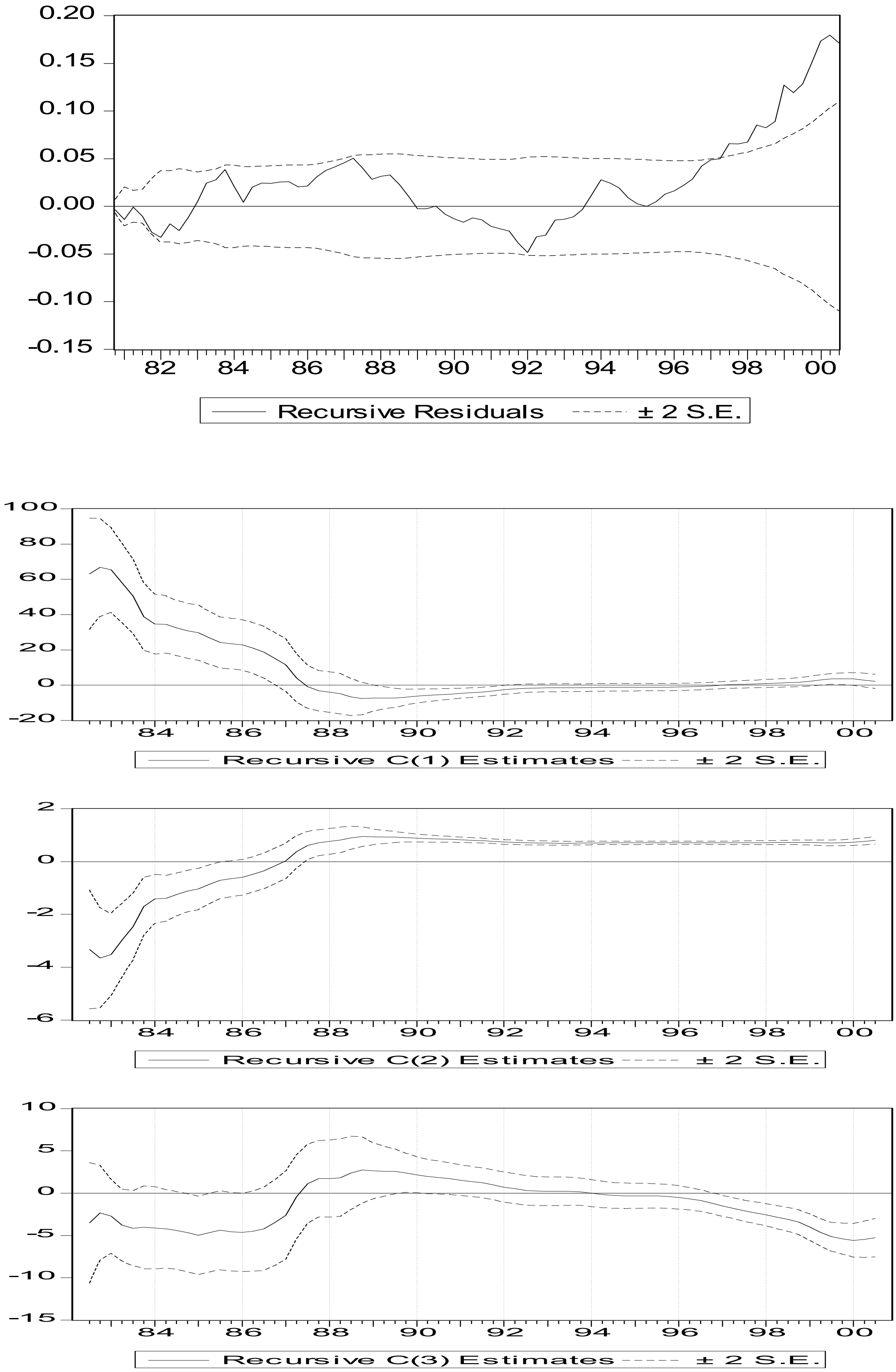


Chart 6

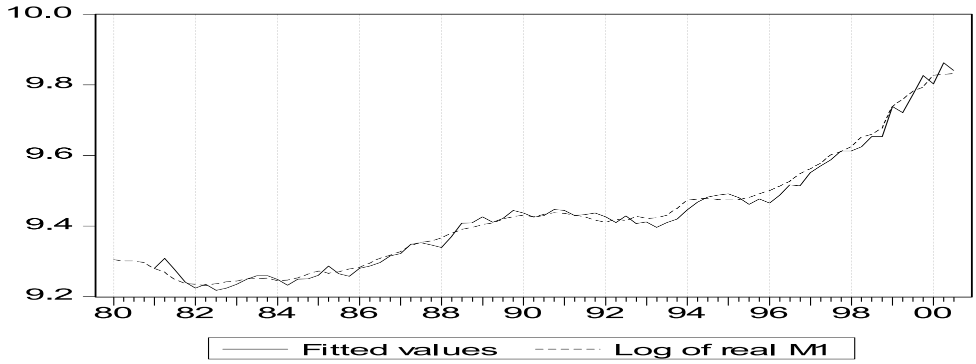
Results of the time-varying parameters model

(Estimation by Kalman filter; see text for further explanations)
Sample period: 1980: 1–2000:3 (78 available observations)

	Estimate (std. Error)	P-value
k	-11.60 (0.23)	0.00
ψ	0.08 (1.35)	0.95
λ	**0.01 (0.00)**	**0.01**

R-squared: 1.00
Durbin-Watson: 2.85
Std. Error of dependent variable: 0.16
Std. Error of regression: 0.00

Fitted values:



Residuals:

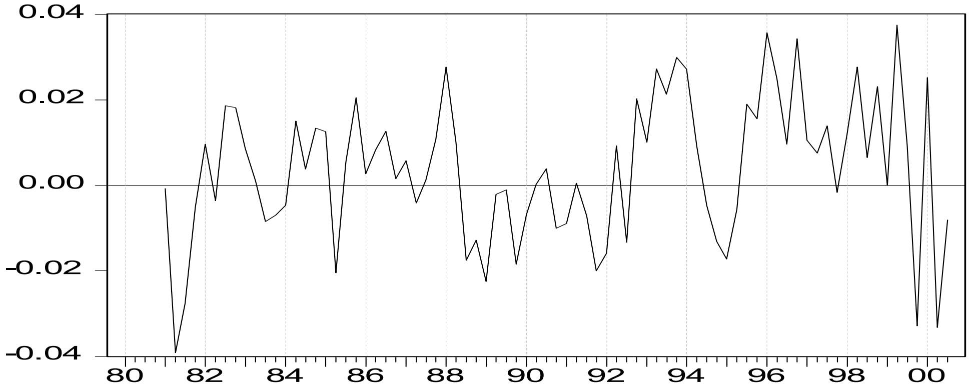


Chart 6 (continuation)

Statistics on residuals

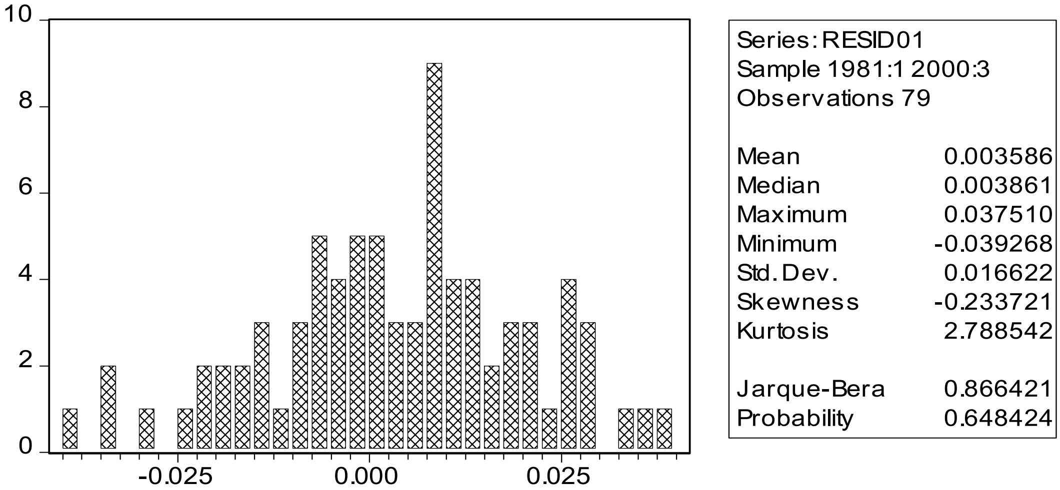


Chart 7

Interest rate elasticity of the demand for euro area M1 (State space model)

(Calculated as $\eta_t = -\gamma_t R_t^{\lambda}$)

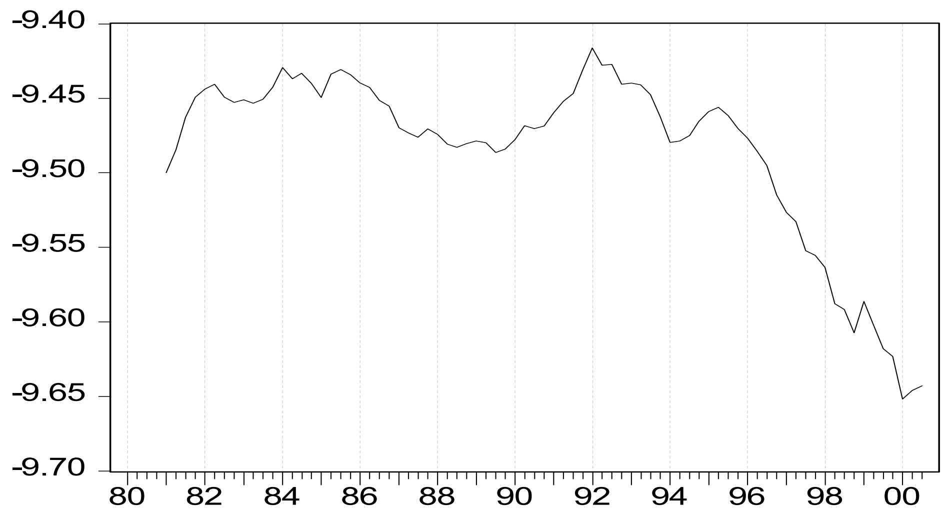
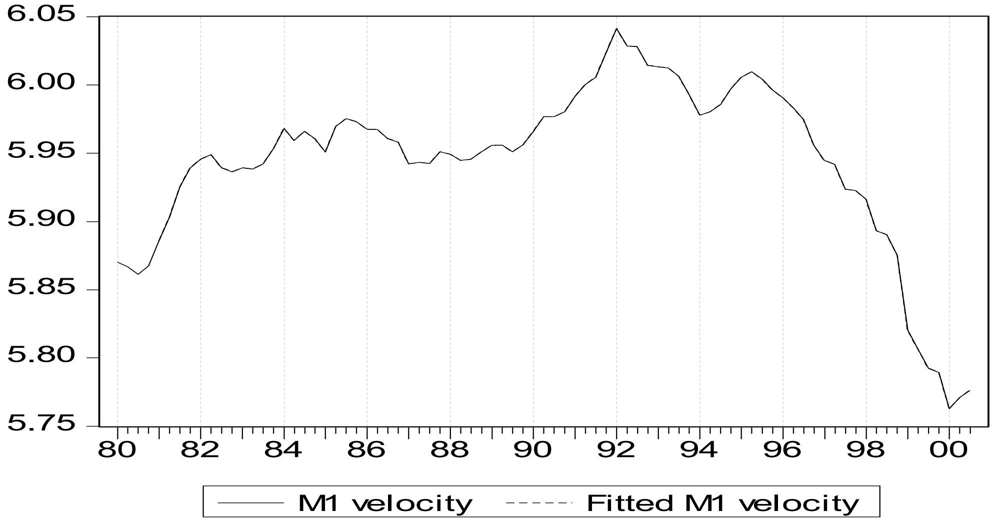
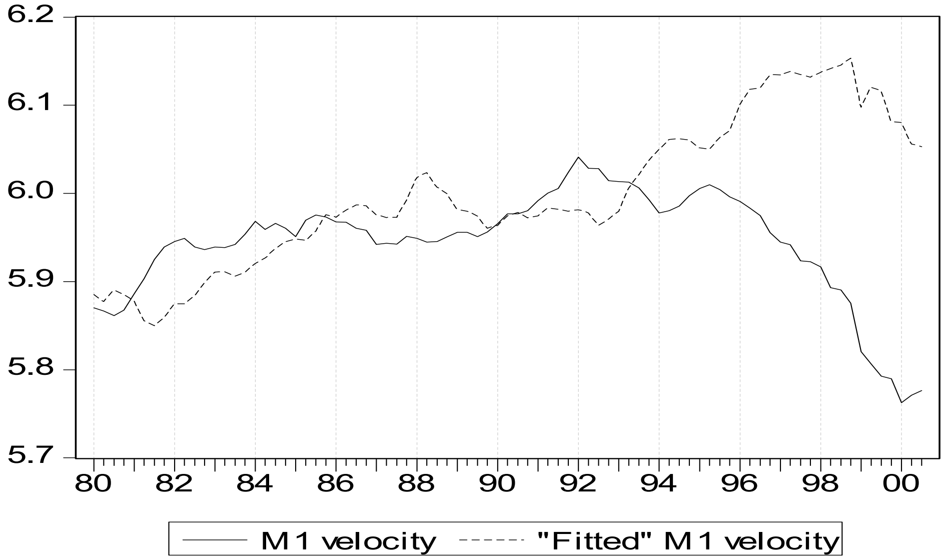


Chart 8
Fitted values for M1 velocity

State space model:



State space model imposing γ_t = average between 1980:1 and 1995:4



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