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ESTIMATING THE TREND OF M3 INCOME VELOCITY UNDERLYING THE REFERENCE VALUE FOR MONETARY GROWTH

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ISSN 1607-1484

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Abstract

This paper documents the analytical work that was carried out for the 2001 review of the assumption for the trend in M3 income velocity used to calculate the reference value for M3 growth. We analyse the medium-term trend in velocity using univariate time series tools and different money demand models. In addition, some cross-checking is carried out to address data compilation issues related to the accession of Greece in 2001 and to different weighting schemes used to aggregate historical euro area data. It is found that the trend decline in M3 income velocity over the medium term is within a range of $^1/_2$% to 1% per year.

Claus Brand, Dieter Gerdesmeier and Barbara Roffia[1, 2]

1 *We would like to thank Huw Pill and Mette Felding Schrøder for their invaluable past contribution to the work on the reference value. We are grateful for comments by Alessandro Calza, Günter Coenen, Vítor Gaspar, Hans-Joachim Klöckers, Michele Manna, Klaus Masuch, Francesco Mongelli, Sergio Nicoletti Altimari and Erikos Velissaratos. Any errors overlooked are, of course, our responsibility.*

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1 Introduction

General aspects of the reference value for monetary growth in the context of the ECB's monetary policy strategy

In October 1998, the Governing Council of the ECB announced the main elements of its stability-oriented monetary policy strategy. It provided a quantitative definition of the primary objective of monetary policy in the euro area, namely the maintenance of price stability. According to this, price stability was defined as a year-on-year increase in the Harmonised Index of Consumer Prices (HICP) of below 2%. The Governing Council also outlined the key features of the framework it uses to organise the analysis and assessment of economic data to support the pursuit of the overriding objective of price stability. In this respect, the Governing Council stressed that the achievement of price stability has to be seen in a medium-term context given the inability of monetary policy to control price developments over shorter periods. In light of the fundamental monetary nature of inflation over the medium term, the ECB assigned a prominent role to money. This element – known as the "first pillar" of the strategy – was signalled by the announcement of a quantitative reference value for monetary growth for the broad monetary aggregate M3.[1] The other element of the strategy – an analysis of a broad range of several non-monetary indicators (inter alia wages, the exchange rate, various measures of real activity, price and cost indices) to assess risks to price stability – was then subsumed under its "second pillar". This paper focuses on a key aspect of the first pillar, namely the derivation of the reference value for M3 growth (*cf.* ECB 1998, 1999a, 1999b, 2000a).

The reference value represents a public commitment by the ECB to analyse monetary developments thoroughly and to ensure that information in monetary developments is given appropriate weight in the decision-making process. Against this background, the reference value has to fulfil two basic criteria.

First, it should indicate the rate of growth of money which is consistent with price stability over the medium term. For this condition to be fulfilled, the monetary aggregate used to define the reference value must exhibit a stable (or at least predictable) relationship with the price level over the medium-term horizon. In the economic literature, the stability of the relationship between money and prices is typically evaluated in the context of a money demand equation which expresses money as a function of prices and other macroeconomic variables such as real income and interest rates. In the euro area, the broad aggregate M3 satisfies this property, as shown by Coenen and Vega (1999), Brand and Cassola (2000), and Calza, Gerdesmeier and Levy (2001).

Second, prolonged and/or substantial deviations of monetary growth from the reference value should, under normal circumstances, signal risks to price stability in the future. Therefore, the monetary aggregate used to define the reference value should normally contain information regarding future price developments. As shown by Trecroci and Vega (2000) and Nicoletti Altimari (2001), monetary aggregates, and M3 in particular, show satisfactory leading indicator properties for future inflation, especially over the medium-term horizon.

While money is related to inflation over medium-term horizons, the short-run relationship between money and inflation is more difficult to analyse. Therefore, in line with the ECB's aim of pursuing price stability over the medium term, the reference value is a medium-term concept, i.e. it specifies the growth rate of money which – over the medium term – is consistent with price stability. It is not defined over short horizons – like one year – and it is only changed when there are reasons to assume that fundamental factors affecting the medium-term trend of M3 consistent with price stability have changed.

The derivation of the reference value is based on the standard relationship between money, real income, inflation, and the income velocity of circulation of money. The latter variable can be defined as the frequency with which money is transferred between different money holders and thus determines how much

1 *See the glossary for the definition of M3.*

money is required to service a particular level of nominal transactions. According to this standard relationship, the change in the stock of money in an economy equals the change in nominal transactions minus the change in velocity. Using the ECB's definition of price stability (i.e. an annual increase in the HICP for the euro area of below 2%) and the assumptions regarding the trend in potential output growth (2% to 2½% per annum) and the medium-term trend in M3 income velocity (a decline between ½% and 1% per annum), a reference value of 4½% was derived by the ECB's Governing Council in 1998. It was also deemed important to annually re-assess the assumptions underlying the reference value. Therefore, it was announced that the reference value would be regularly reviewed by the Governing Council of the ECB. Its value has been confirmed in the reviews carried out in December 1999, 2000 and 2001 based on evidence that the assumptions underlying the derivation of the reference value had remained unchanged (*cf.* ECB 2000b, 2001e).

The reference value should not be misunderstood as implying a target for monetary growth. Experience shows that it is preferable for a central bank not to unduly rely on a single indicator when formulating monetary policy. As indicated by the two-pillar structure of its monetary policy strategy, the ECB deems a diversified and full-information approach to the analysis of the information underlying monetary policy decisions desirable. Therefore, the reference value does not entail a commitment on the part of the ECB to mechanistically change interest rates to correct deviations of monetary growth from the reference value to pursue a policy of price stability. Instead, the reference value is intended to help the Governing Council analyse and present the information contained in monetary developments in a coherent manner (*cf.* ECB (2000a), Masuch, Pill and Willeke (2001)).

Notwithstanding the importance of the reference value as a commitment and communication tool, it should be emphasised that the ECB does not interpret the prominent role of money in its strategy only in terms of the reference value. The first pillar also involves an analysis of the information contained in the components and counterparts of M3 (as shown in the consolidated Monetary Financial Institutions (MFI) balance sheet), as this is also relevant for a monetary policy aiming at price stability (*cf.* ECB (2001b)).

This paper provides some background information related to the assumption about the medium-term trend in M3 income velocity underlying the Governing Council's 2001 review of the reference value. For this study, quarterly data ranging from 1980 Q1 to 2001 Q2 have been used.[2]

The results of this study, which employs univariate time series tools as well as different money demand models, suggest that M3 income velocity declines at a rate between ½% and 1% per annum. Although the followed approaches reveal some differences regarding the trend decline in velocity, these differences are not very significant. Univariate non-structural approaches of velocity, not taking account of the possibility of structural breaks, tend to reveal a trend decline over the full sample period (1980 Q1-2001 Q2) which is close to the upper end of the assumed range. In contrast to this, univariate approaches allowing for a structural break and a change in the trend in the 1990s would suggest that the trend in velocity in the 1990s is closer to the lower end of the range. As a consequence, univariate approaches over the full sample and excluding a break in the trend may, to some extent, fail to capture the fact that the decline in inflation and interest rates throughout the sample period may have contributed to lower opportunity costs of holding money and thus to the past decline in velocity. In an environment of price stability, where inflation and interest rates should no longer exhibit a

2 *This paper is based on data available on 14 September 2001. The observation for the GDP deflator for 2001 Q2 was a forecast. As regards the M3 series, a preliminary estimate of the official M3 as published from November 2001 which excludes money market paper and other short-term debt securities with an initial maturity of up to two years was used. All data used in this study are available from the authors upon request.*

downward trend, the trend decline in velocity can thus be expected to be less pronounced than over a period dominated by dis-inflation and falling nominal interest rates. This information is captured by money demand models in which the evolution of opportunity costs of holding money (interest rates and/or inflation) is taken into account as fundamental determinants. As the reference value is a medium-term concept, the estimate of the velocity trend can be based on the long-run income elasticity of M3 and the assumption for medium-term potential output growth. In the light of this, all money demand models considered tend to reveal a trend decline which is around the mid-point or in the lower part of the range of $^1/_2$% to 1%.

The remainder of this paper is organised as follows. Section 2 contains a brief description of monetary developments and a general assessment of the trend in M3 income velocity in the euro area in the last two decades. It also briefly explains the methods used to construct the historical euro area data that are used throughout this paper. Section 3 provides estimates of the trend in M3 income velocity without taking into account information from other macroeconomic variables. To put these results into a broader perspective, Section 4 provides an analysis of the trend behaviour in velocity in relation to other macroeconomic variables. Hence, the velocity trend is investigated in the context of money demand models. The historical decline in M3 income velocity is explained by an income elasticity of money demand greater than one and the historical decrease in the opportunity costs for holding money. Section 5 contains a cross-check comparison of the analysis using different datasets, namely one containing historical euro-12 data (euro area* henceforth)[3] and the other with background series compiled using an aggregation method different from the one used in previous sections. No major differences arise when comparing the results from these different datasets. Finally, Section 6 summarises the findings of this study.

3 As will become clearer later on, historical euro-12 data (denoted as euro area data) include data for Greece as far back as possible, i.e. before January 2001 when Greece joined EMU (cf. Section 2).*

2 A first look at the data

2.1 The concept of M3 income velocity and its behaviour in the euro area

The velocity of circulation of money is a key concept in monetary theory (*cf.* Fisher (1911)). According to this, the basic identity relationship can be expressed as follows:

$$M \cdot V = P \cdot TR$$

where M represents the money stock, TR the volume of real transactions in an economy, P the price level and V the income velocity of circulation. As is quite common in the economic literature, the unknown transactions variable is replaced by real income (YR). Then, the relationship above can be written as:

$$V = (P \cdot YR)/M$$

Velocity is thus defined as the ratio of the current value of total nominal transactions to the stock of money. Expressed in other terms, the latter variable can be defined as the frequency with which money is transferred between different money holders and thus determines how much money is required to service a particular level of nominal transactions. Solving the equation above for money and rewriting this in terms of growth rates yields:

$$\Delta m = \Delta yr + \Delta p - \Delta v$$

According to this identity, the change in the money stock in an economy equals the change in nominal transactions (approximated by the change in real GDP plus the change in the price level) minus the change in velocity. To draw economic conclusions, further assumptions about the variables involved in this identity have to be made.

Following common economic wisdom, real income is in the long run essentially determined by supply-side factors (e.g. technology, population growth, the flexibility of markets and the efficiency of the institutional framework of the economy). Furthermore, velocity can be expected to be a function of a small number of explanatory variables (*cf.* Friedman (1956)). According to this, it is either a stable or predictable function of these determinants. Finally, the quantity of money in an economy can be assumed to be determined independently of any of the other three variables as it is supplied by the central bank. These further assumptions allow a translation of the Fisher identity into the *quantity theory of money*, which states that there is a stable relationship between the quantity of money and the price level. In line with this, the so-called "neutrality" of money, a general principle underlying standard economic thinking, states that changes in the money supply can in the long run lead to changes in nominal but not in real variables, i.e. changes in the money supply will have no long-run effect on real output or employment. Furthermore, prolonged periods of monetary growth in excess of what would be demanded to finance an economy's growth potential eventually result in inflation (*cf.* Friedman (1956) and (1968)). These basic considerations date back to the seminal work by David Hume (*cf.* Hume (1752)) and Irving Fisher (*cf.* Fisher (1911)).

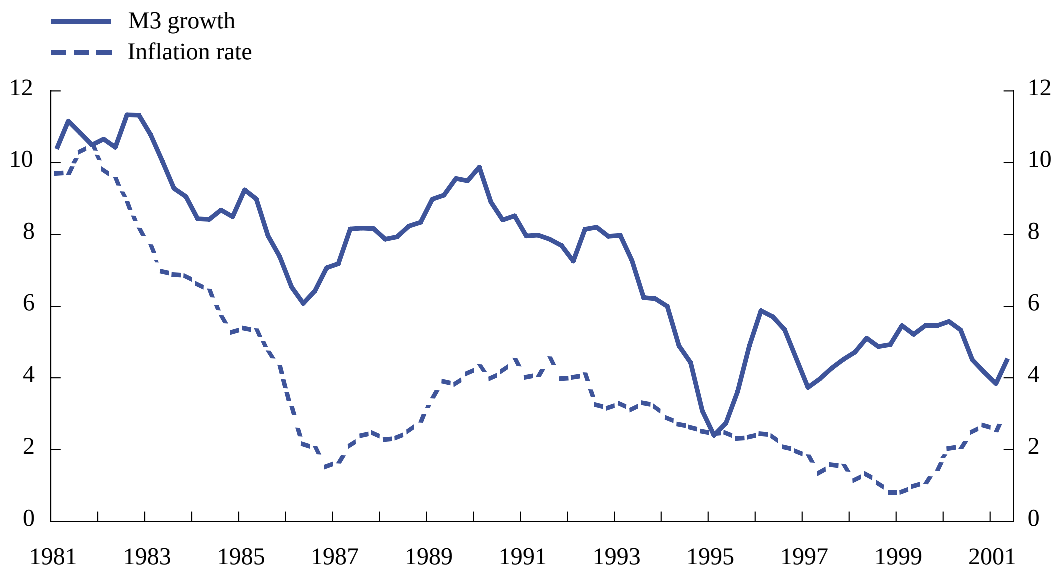
For these reasons, the behaviour of velocity is of fundamental importance for a central bank as changes in this variable may directly affect the link between money and prices. Although there have been economic theories stating that velocity can be approximated by a constant, it can be expected to be related to real income and also to the level of interest rates prevailing in an economy (see Section 4).

Turning to the actual developments in the euro area, as noted above, empirical evidence for the euro area suggests that money has good leading indicator properties for future inflation (*cf.* Nicoletti Altimari (2001)), especially over the medium term. Another and very intuitive way to approach the question of the stability of velocity may be to consider the behaviour of money and prices in the euro area. If developments in money and prices exhibit a similar pattern, this could be interpreted as a possible indication of stability in velocity. Figure 1 plots the annual inflation rates and M3 growth in the last two decades.

Figure 1

M3 growth and the inflation rate in the euro area

(Annual percentage change)

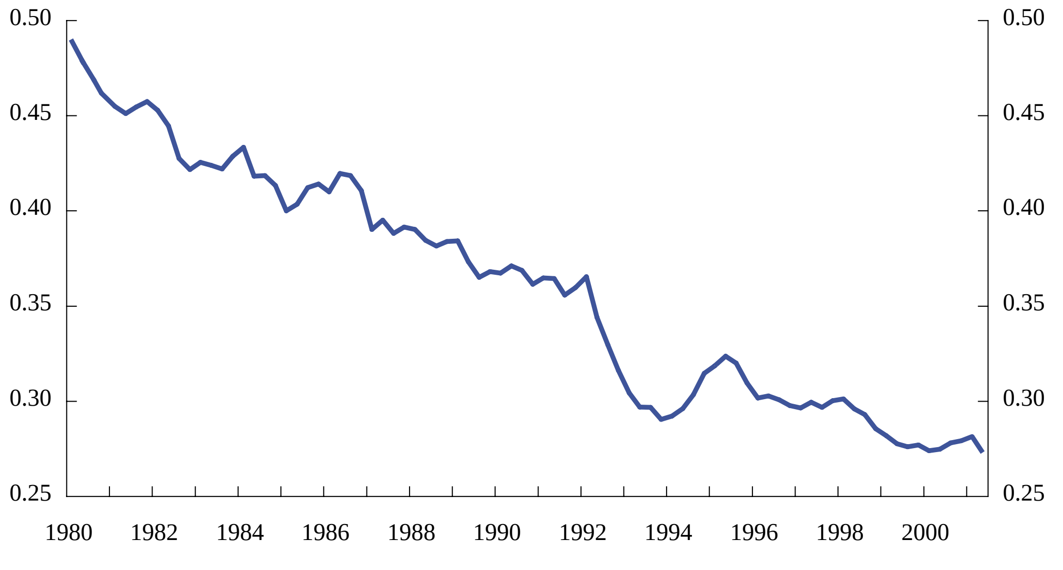


From the picture above, it can be inferred that, with the exception of the period around 1995, the two variables follow a fairly similar pattern. In 1995 M3 may have been distorted by some special factors, including portfolio shifts caused by a significant increase in the long-term interest rates in the euro area. This pattern is also mirrored in the behaviour of the income velocity of M3 in the euro area (see Figure 2 below).

Figure 2

M3 income velocity for the euro area

(Log level)

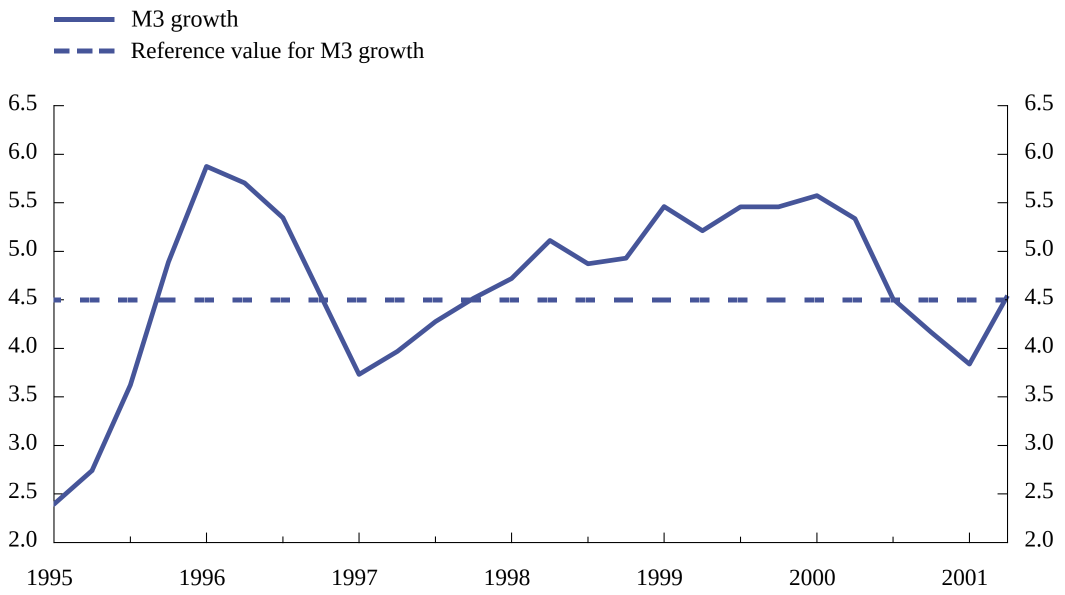


Generally, a downward trending and fairly stable behaviour can be observed from the time series pattern. In addition, the hump-shaped behaviour of M3 around 1995 is also reproduced in the velocity trend. Finally, when looking closer at the developments in M3 from 1995 onwards (see Figure 3 below), it can be noted that since the start of Stage Three of EMU, M3 was growing above the reference value until late 2000; after that period it reverted to reach values below 4½% until 2001 Q2.

Figure 3

M3 growth and the reference value in the euro area

(Annual percentage change)



2.2 Data and aggregation issues

As regards the data used in this study, it should be mentioned that the analysis throughout this paper is based on "euro area" data, i.e. "Euro 11" data until 2000 Q4 and "Euro 12" data from 2001 Q1 onwards.[4] The approach adopted has been chosen taking into account the limitations of both economic and statistical nature regarding the mere feasibility of constructing "euro area*" data using historical Greek data.[5] Due to relatively high inflation, the financial structure in Greece was characterised until the mid-1990s by instruments with a short maturity. Therefore, there were few alternatives to holding money in the past in Greece. As a consequence, no long-term interest rate series is available for Greece before 1992 Q4.[6] After the transition to a bond market was completed in the mid-1990s in Greece, one could, in principle, incorporate Greek long-term interest rates in the historical series of the euro area. However, any date for including Greek data in this time span seems to be quite arbitrary, particularly because for a protracted period

4 "Euro 11" data cover the 11 Member States of EMU up to end-2000, while "Euro 12" data cover the 12 Member States as from January 2001. Detailed information about the construction of the series employed in the main analyses can be found in Annex D at the end of the paper.

5 "Euro area" series denote statistical series including Greece (i.e. euro area plus Greece) prior to January 2001 as far back as possible.*

6 A ten-year government bond yield series has only been available since June 1997. From October 1992 to May 1997 only five-year (October 1992 to January 1996) and seven-year (February 1996 to May 1997) government bond yield series were available.

Greek developments were also probably affected by the changeover to the new market structure, which might have affected monetary developments. Therefore, there seem to be some economic reasons for including Greece in our analysis only from the time of its accession to the euro area.

The above notwithstanding, a separate section in this paper (*cf.* Section 5) contains an econometric analysis based on euro area* series. The purpose of this is to detect and analyse any possible differences in the outcome related to the inclusion of the available data for Greece in the back data.

An additional issue tackled in this paper concerns different aggregation methods for reconstructing historical euro area series on the basis of individual countries' data.[7] In the main analyses of this paper, M3 and nominal GDP series for the euro area have been compiled by adding up national data that have been converted into euro at the irrevocable fixed exchange rates announced on 31 December 1998 (and in the case of Greece determined on 19 June 2000). Using the same aggregation method for M3 and nominal GDP, fluctuations in the historical M3 income velocity series are purged of the effects of different aggregation methods. Otherwise, the common nominal trend will vary across different variables according to the way in which each variable has been constructed. However, this aggregation method differs from that used in other contexts (see Box 3 in Section 5.1 for further details). Therefore, it may be useful to adopt a robust approach by assessing the sensitivity of the results to different aggregation methods. For this reason, the results obtained using the aggregation method just described will also be compared with the results obtained using another aggregation method based on aggregating national series in log levels using fixed 1999 GDP weights based on PPP exchange rates.

7 *For a discussion of this topic, see Beyer, Doornik, and Hendry (2001).*

3 Univariate analysis of M3 income velocity

This section provides estimates of the trend in the M3 income velocity series without taking into account information from other macro-economic variables. This approach is based on a method that is dubbed *univariate* time series analysis (in contrast to *multivariate* time series analysis, which looks at the joint properties of a set of several macroeconomic variables). Univariate analysis neglects the possible impact that, for example, inflation and interest rates might have had on M3 income velocity.

The appropriate method to estimate this univariate trend depends on the time series properties of velocity. For this purpose we briefly describe the concept of (trend) *stationarity* versus *non-stationarity* (Section 3.1). The validity of either of these properties has important implications for the assessment of the trend contained in a series. As common in the literature, we test for these properties using unit root tests. As the results of these tests are found to be ambiguous, we present estimates of the trend based on both properties (Section 3.2 on trend stationarity and Section 3.3 on non-stationarity).

3.1 Stationarity properties of the velocity series

The following section focuses on whether it would be appropriate to model the behaviour of M3 income velocity as stable around a linear trend. In the light of this, Box 1 provides some more details about the implications with respect to the time series properties of velocity, depending on whether it is assumed to be stationary or not. If velocity were found to be stationary around a linear trend, its variance around that trend would be bounded. In contrast to this, if velocity were assumed to be non-stationary, theoretically it would deviate ever further from the trend over time.

Some standard unit root tests – testing for either model (1) or (2) in Box 1 – have been carried out over the entire sample period (1980 Q1-2001 Q2). The results of these tests are briefly described in Annex A, Section A.1. To sum up, M3 income velocity might be viewed as a borderline case between being stationary and non-stationary.

Box 1

Time series properties of the velocity series

The time series properties of M3 income velocity affect the analyses related to its medium-term trend. If the log level of velocity v_t at time t is stationary around a linear trend t, i.e.:[1]

$$v_t = \alpha + \beta \cdot t + \varepsilon_t \qquad t = 1,..,T \qquad (1)$$

where ε_t is some mean-zero stationary process (i.e. it is a random process which has a constant and time-independent variance), then the assumption for medium-term velocity developments can be summarised by estimates of β from eq.(1). If velocity is assumed to be stationary, its variance is constant over time and the covariance between two time instances depends only on the distance or lag between them and not on the actual time at which the covariance is computed. The impact of shocks on velocity will vanish over time.

In contrast to this, the log level of velocity is non-stationary, if it is a random walk with drift parameter μ,

$$v_t = v_{t-1} + \mu + \eta_t \qquad t = 1,..,T \qquad (2)$$

where η_t is some mean-zero stationary process and the lagged coefficient on velocity is assumed to be one, which explains why the series is said to contain a unit root. The impact of a random shock η_t on velocity v_t would never disappear as velocity might equivalently be written as an accumulation of past historical shocks:

$$v_t = v_0 + \mu \cdot t + \sum_{j=0}^{t} \eta_j \qquad t = 1,..,T$$

As a consequence, the variance of velocity would become a function of time t. Theoretically, under the unit root assumption, deviations of velocity from $\mu \cdot t$ would increase over time. However, the size of the random walk component η_t will also determine how far v_t might deviate from the linear trend within a specific period of time.

Under the unit root assumption, velocity can be differenced to obtain a stationary series. Taking the time difference of velocity in equation (2) (using the notation $\Delta v_t \equiv v_t - v_{t-1}$) yields

$$\Delta v_t = \mu + \eta_t \qquad t = 1,..,T \qquad .$$

This would permit the estimation of the drift term μ which could form the basis for the expected M3 velocity trend over the medium term.

To summarise, the choice between (1) and (2) as appropriate models for velocity may bear far-reaching and important economic as well as statistical implications. In the context of model (2), under the unit root assumption, velocity would be treated as a non-stationary time series to which shocks accumulate over time. In the context of model (1), velocity would be treated as a stationary (or mean-reverting) time series. In addition, regressing the level of velocity on a time trend in the context of model (1) while (2) is the appropriate one would lead to wrong conclusions about the model parameters.

1 *See, for instance, Harvey (1990) and Greene (1997).*

Unit root tests can also be carried out by relaxing the assumption of the constancy of the linear trend in equation (1) in Box 1. In particular, Perron (1989) has argued that some time series which are suggested to be non-stationary by conventional unit root tests might, in fact, be better described as stationary around a linear trend with a one-time structural break. This could also apply to the M3 income velocity series which may have experienced a structural break during the 1990s. The possible occurrence of this break may be explained as follows: first, the trend decline in velocity over the last twenty years might be related to the decrease in inflation and nominal interest rates which measure the opportunity cost of holding money and which occurred during the period of transition towards low inflation rates before the start of Stage Three of Economic and Monetary Union. Therefore, part of the trend decline experienced in the past before EMU would not have continued in a regime where price stability is maintained. Second, other possible structural breaks may be associated with technological progress in the provision of payment instruments connected with ICT innovation or with financial innovations, which might have caused shifts in M3 velocity. In addition to these economic arguments, statistical evidence on the difference in the trend estimates of various sub-samples (*cf.* Section 3.2) may also suggest the occurrence of a structural break.

Perron has proposed tests that permit a formal evaluation of the time series properties of velocity in the presence of a structural break. Following the methodology developed by Perron (1997), the timing of the structural break(s) can be determined by the testing procedure itself.[8] However, it must be kept in mind that the test is not suitable for assessing whether there was indeed a break.

In this context, three specifications of a structural break are investigated. The "*crash*" specification allows for a single jump in the time series (level) for M3 velocity, but the (slope of the) trend is unchanged following this jump.[9] The "*changing trend*" specification allows for the (slope of the) trend to change, but the velocity series itself is continuous (i.e. there is no jump). The "*combined*" specification permits

8 *Several specifications are possible. The results presented below are based on an algorithm that maximises the probability that the null of non-stationarity is rejected (i.e. minimising the t-statistic for testing the null hypothesis of non-stationarity). For a formal description of the methodology, cf. Perron (1997).*

9 *The terminology follows from Perron (1989).*

a jump both in the level and the slope of the trend of the velocity series. A graphical illustration of a hypothetical example for each of these three specifications can be found in Figure 4 below.[10]

The results of the Perron test presented in Table 1 again point to the borderline nature of the assessment of the time series properties of velocity. While for the "crash" and "changing trend" specifications the null hypothesis cannot be rejected, for the "combined" specification, the Perron test rejects the null hypothesis of non-stationarity in favour of the alternative hypothesis at the 1% significance level. The results of the tests might be seen as evidence that velocity is stationary around a changing trend in 1991 Q4.[11]

Figure 4

Specifications of a structural break according to Perron

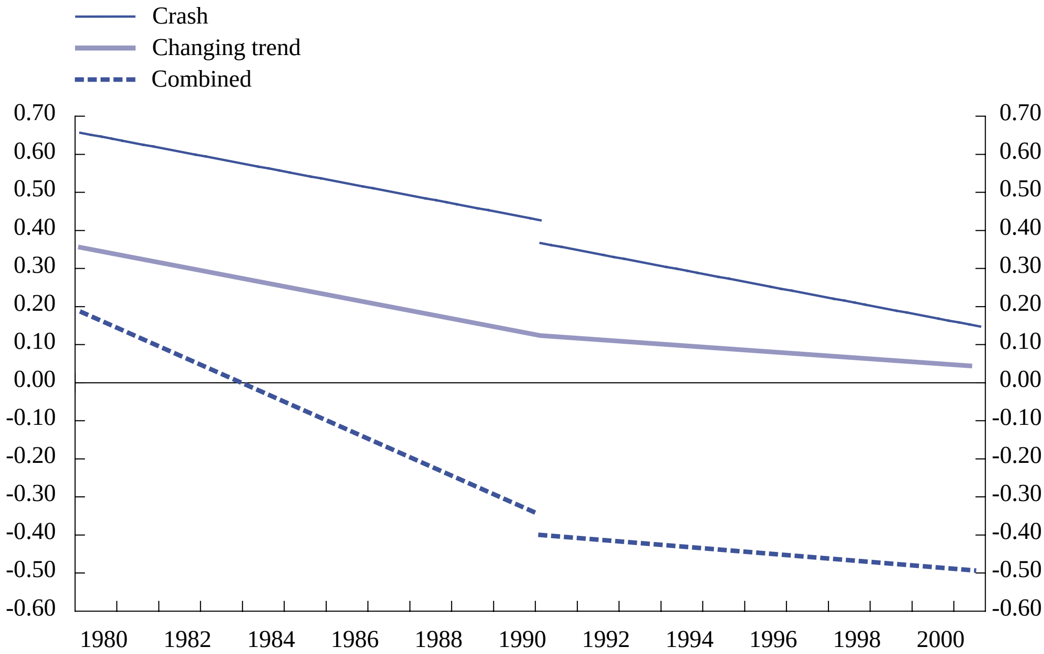


Table 1

Perron test with endogenously determined structural breaks

Model	Date of break	No. of lags	Test statistic
"Crash", i.e. jump in the level of velocity	1991 Q4	1	-4.57
"Changing trend", i.e. change in trend	1995 Q1	1	-4.19
"Combined", i.e. change in trend and jump in level	1991 Q4	3	-6.59**

Notes: *The number of lags is dictated by a testing-down procedure.*
***, * and † denote significance at 1%, 5% and 10%, respectively. The breakpoint is selected such that the value of the t-statistic for testing the null hypothesis of a unit root is smallest among the possible break points. For all the three tests: null hypothesis is non-stationarity, alternative hypothesis is stationarity around a trend function which contains a one-time break.*

10 *The values of the velocity trend (and, therefore, the figures reported on the axes) and the timing of the breaks in the picture have been assigned arbitrarily and only serve the purpose of graphically illustrating the three specifications of the Perron test.*

11 *The Perron test can also be carried out by imposing the timing of the break beforehand (cf. Perron (1989)). In this context, the Perron test for the unit root hypothesis for velocity against the trend-stationary alternative was performed by imposing a structural break in 1999 Q1, which corresponds to the start of Stage Three of EMU. Regardless of the specification of the possible structural break, the Perron test fails to reject the null hypothesis of non-stationarity of M3 income velocity in favour of the alternative hypothesis assuming a break in the trend in 1999 Q1 at the 5% significance level.*

To summarise, it appears that the time series properties of the log level of M3 income velocity can be considered as borderline between being stationary or non-stationary, possibly with a structural break during the 90s. However, a clear distinction between these two hypotheses is difficult on the basis of the tests considered. These borderline results suggest it is more appropriate to adopt an eclectic approach involving several specifications, rather than relying solely on a single methodology.

3.2 Trend estimates under the assumption that M3 income velocity is stationary around a linear trend

The results in this sub-section are based on techniques that do not restrict the velocity series to be non-stationary around a linear trend. As mentioned above, if the hypothesis that the log level of velocity is trend stationary as in model (1), medium-term developments can be comprehensively summarised by estimates of the trend. Table 2 below offers OLS estimates of linear trends fitted to M3 velocity over the entire period (1980 Q1-2001 Q2) and for different sub-samples. One pair of sub-samples (1980 Q1-1991 Q4 and 1992 Q1-2001 Q2) is determined by the break that can be found using the Perron test from Table 1 where the structural break is determined by the test procedure itself (see the dates for the "crash" and the "combined" specifications). In Table 2 we also consider a more restricted and recent time span of data starting from 1996 Q1 onwards. The choice of 1996 may be justified by the observation that, roughly from that year onwards, the euro area moved into a new regime with inflation below 2% (in terms of the GDP deflator). Moreover, around that time, long-term interest rates had reached values similar to those they exhibited in 2001. For sake of completeness of the analysis, we also present the value of the decline in M3 income velocity in the period 1998 Q2-2001 Q2, which spans the last three years of the sample, starting with the latest data available for the studies of the first exercise on the derivation of the reference value made in 1998.[12] The table also contains the standard equation diagnostics – LM tests for serial correlation, the White (1980) test for heteroskedasticity[13] and the Jarque-Bera test for normality (the p-values for these tests are shown in parentheses).

Because the diagnostics of the simple regressions (with the exception of those related to the sample period 1998 Q2-2001 Q2) were found to be relatively poor, thus pointing to some mis-specification, the estimates in Table 2 have been corrected for autocorrelation in the residuals using an univariate time series specification which includes autoregressive and moving average error components of different order. Moreover, the variance-covariance matrix was White-adjusted for heteroskedasticity (*cf.* Table 2).

The point estimates for the velocity trend shown in Table 2 for the longer sample period and for the two sub-samples covering the 1980s, all lie relatively close to -1%. For the more recent sub-sample (1992 Q1-2001 Q2), the point estimates are closer to -½%. It appears that ½ and 1% are the lower and the upper boundaries of the range for the trend decline in M3 income velocity, respectively. When looking at shorter sample periods, the trend decline in M3 income velocity in 1996 Q1-2001 Q2 and in 1998 Q2-2001 Q2 would lie in the lower part of this range (being at about 0.58% and 0.53% per annum, respectively). All in all, these results broadly point to an annual trend decline in velocity in the range of ½% to 1%.

12 *It should be noted that the time span of three to five years is basically too short to reliably estimate the trend of velocity.*

13 *Heteroskedasticity refers to a situation when the errors in the regression equation do not have a constant variance. The consequences of heteroskedasticity on the least squares estimators are that: (a) the estimators are still unbiased but inefficient (i.e. they have a higher variance); (b) the estimates of the variances are biased, thus invalidating tests of significance and confidence intervals.*

Table 2

OLS estimates of linear trends for velocity with correction for autocorrelation of residuals

Sample	*N*	Order of auto-correlation	Constant	Trend % per quarter	R^2	ACORR. LM(1)
1980 Q1-2001 Q2	84*	2	**0.469**	**-0.234**	0.99	0.07
			(0.008)	(0.013)		(0.79)
1980 Q1-1991 Q4	47*	1	**0.469**	**-0.222**	0.97	1.43
			(0.005)	(0.015)		(0.23)
1992 Q1-2001 Q2	38	2[(a)]	**0.398**	**-0.133**	0.96	0.33
			(0.008)	(0.011)		(0.56)
1996 Q1-2001 Q2	22*	1	**0.405**	**-0.145**	0.91	1.89
			(0.034)	(0.044)		(0.17)
1998 Q2-2001 Q2	13	0	**0.394**	**-0.132**	0.53	5.05
			(0.030)	(0.038)		(0.02)

Sample	ACORR. LM(4)	HET. (White)	NORM. (JB)	Implied annual trend % *±2 Std. Err. confidence interval*
1980 Q1-2001 Q2	5.16	6.70	3.13	**-0.94** ± 0.10
	(0.27)	(0.04)	(0.21)	
1980 Q1-1991 Q4	3.40	3.73	2.01	**-0.89** ± 0.12
	(0.49)	(0.15)	(0.37)	
1992 Q1-2001 Q2	0.50	6.42	4.06	**-0.53** ± 0.09
	(0.97)	(0.04)	(0.13)	
1996 Q1-2001 Q2	10.34	0.56	1.23	**-0.58** ± 0.35
	(0.04)	(0.75)	(0.54)	
1998 Q2-2001 Q2	7.91	1.11	1.988	**-0.53** ± 0.30
	(0.10)	(0.57)	(0.37)	

Notes: *for the constant and the trend standard errors are shown in parentheses. (*) denotes the number of included observations after adjusting endpoints.*
(a) for the sub-sample 1992 Q1-2001 Q2 indicates that an ARMA(2,1) model has been used.
The implied annual trend (measured in %) is derived by multiplying by four the quarterly trend (measured in %)
The 2 Standard Error (Std. Err.) bounds around the point estimate correspond to a 95% probability confidence interval.

For the sake of completeness, in Figure 6 we illustrate the velocity trend resulting from the "combined" hypothesis in the presence of a structural break in 1991 Q4 derived from the Perron test. The results presented in Table 1 suggest that the test rejects non-stationarity of velocity if a structural break is allowed for in the early 1990s. As can be seen from Figure 6, this result seems to be well in line with the changes in the velocity trend over the different samples.

Figure 5

M3 income velocity trends

(Log level)

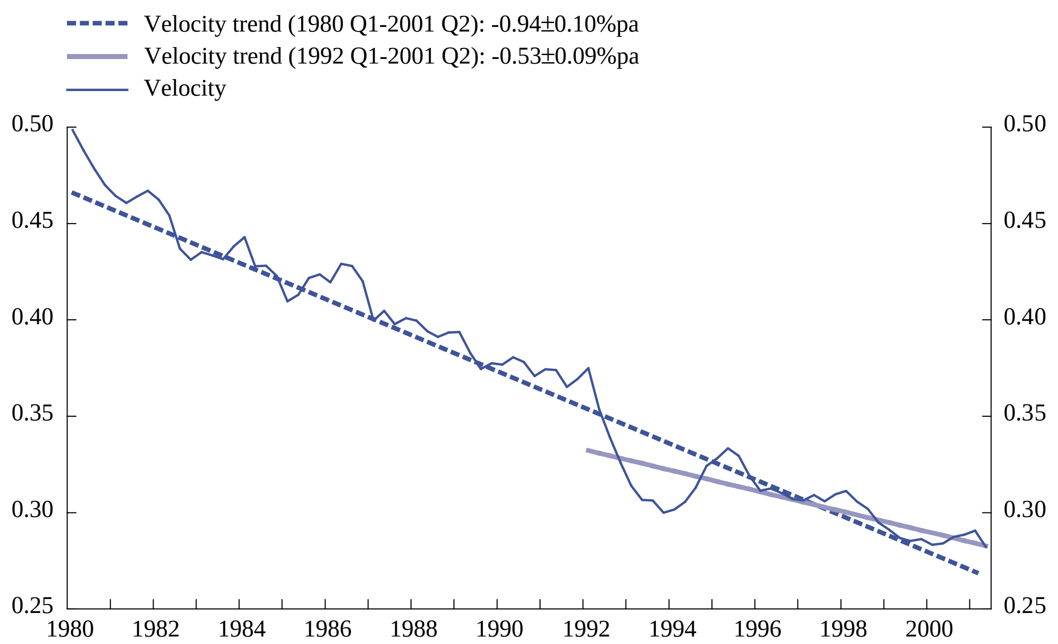
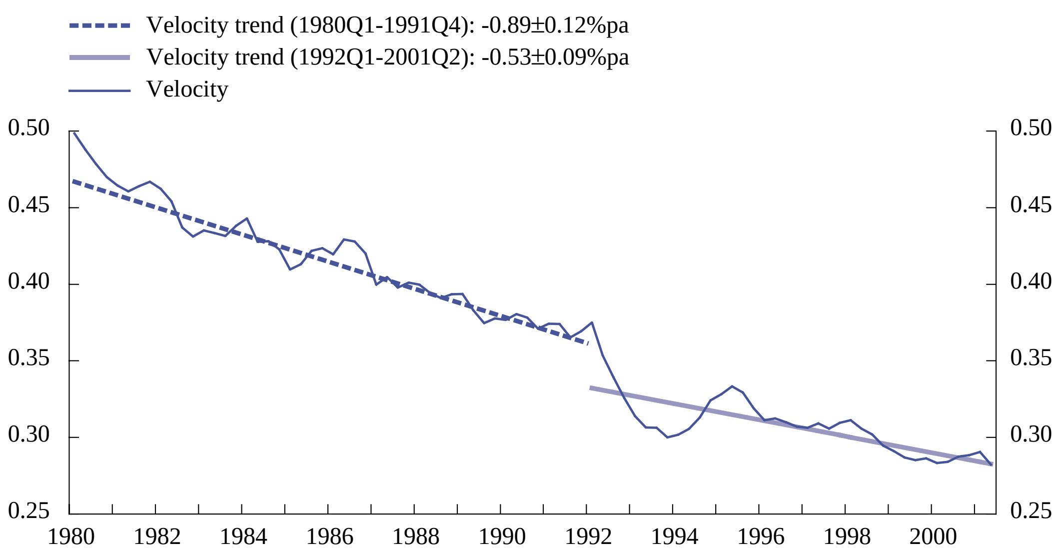


Figure 6

M3 income velocity trend assuming an endogenously determined structural break in 1991 Q4 ("combined" specification)

(Log level)



3.3 Trend estimates under the assumption that M3 income velocity is non-stationary

When applying a univariate analysis, one way to proceed with the analysis under the maintained hypothesis that velocity is non-stationary is to envisage velocity as evolving according to a random walk with drift (see eq. (2) in Box 1). To investigate the historical trend behaviour under this assumption, one possibility is to estimate the trend from the first differences of velocity. Alternatively, the model can be cast into a *random walk plus noise* representation to estimate the drift term.

Table 3

Estimates of the drift under the assumption that M3 income velocity follows a random walk with drift

Sample	Average quarterly trend in velocity %	Std. Err.	Implied annual trend in velocity % ± *2 Std. Err. confidence interval*
1980 Q1-2001 Q2	-0.254	0.072	**-1.02** ± 0.58
1980 Q1-1991 Q4	-0.275	0.099	**-1.10** ± 0.79
1992 Q1-2001 Q2	-0.229	0.107	**-0.92** ± 0.86
1996 Q1-2001 Q2	-0.167	0.078	**-0.67** ± 0.62
1998 Q2-2001 Q2	-0.222	0.102	**-0.89** ± 0.81

(A) Estimates of the drift from the time difference of velocity

If velocity follows a random walk with drift (as described by expression (2) in Box 1), an unbiased estimate of the drift coefficient can be obtained by taking the average of the first difference of M3 velocity. The results of this exercise are presented in Table 3. However, it must be taken into account that the estimates of the drift are just dependent on the first and the last observations (see Harvey (1993), p. 114).

All in all, the annual trend decline in M3 velocity implied by the results in Table 3 is broadly in line with the assumption of a range of $^1/_2$% to 1%, although it is somewhat steeper for early sub-periods.[14]

(B) Other trend estimates under the unit root assumption

Under the unit root assumption, the underlying model can be written as a so-called *random walk plus noise model* suggested by Harvey (1990) which also allows an estimation of the coefficient of the linear drift term. Details of this model are given in Annex A, Section A.2. The results from this exercise suggest that the best guess about the evolution of velocity should be based on the assumption of the drift term implying an annual decline of 0.71% to 1.35% with a mid-point of 1.03%.

14 In particular, the point estimates for the annual trend decline in velocity are greater on average in the earliest sub-samples, while in the latest sub-samples they are well within the range of $^1/_2$% to 1% p.a.

3.4 Summary of the univariate analysis

The purpose of this section has been to provide estimates of the trend in the M3 income velocity series using univariate time series analysis, which does not take into account information from other macro-economic variables. The main results are the following. Standard statistical tests over the entire sample period (1980 Q1-2001 Q2) suggest that M3 income velocity might be viewed to be a borderline case between being stationary (possibly with a structural break during the 1990s) or non-stationary around a linear trend.

The assumption about the time series behaviour of velocity, however, does not seem to fundamentally affect the assessment of its medium-term trend. A general feature is that both approaches, not taking account of the possibility of structural breaks, tend to reveal a trend decline over the full sample period (1980 Q1-2001 Q2) which is at or close to the upper end of the assumed range, namely around 1%. In contrast, an approach allowing for a break and a change in the trend in the 1990s would suggest that the trend decline in velocity in the 1990s is closer to the lower end of the range (½%).

4 Derivation of medium-term developments in velocity in the context of money demand models

4.1 Review of long-term income elasticities of existing money demand models

This section analyses the medium-term trend in M3 income velocity in the context of money demand models. Money demand equations are an adequate tool for examining the long-run relationship between money and prices. As expressed in the concept of the reference value, over the medium term, monetary growth in line with the reference value should be consistent with the maintenance of price stability over that horizon. The stability of the money demand relationship or the predictability of money demand is an important pre-condition for ensuring this desirable feature. Moreover, the (long-run) income elasticity embodied in money demand models can be used for estimating the trend in velocity over the medium term consistent with the ECB's definition of price stability and depending on the medium-term assumption for the trend in potential output growth.

Three recent studies have investigated the demand for euro area M3. They are summarised in Box 2 below.

Box 2

Money demand models

Money demand in the euro area was studied prior to the Stage Three of EMU. Fagan and Henry (1999) and Fase and Winder (1999) already found evidence supportive of the view that a stable long-run relationship exists between broad monetary aggregates and its traditional determinants. For M3, as defined by the ECB, further models have been developed in the recent past. This box briefly summarises the key features of the models presented in Coenen and Vega (1999; henceforth CV), Brand and Cassola (2000; henceforth BC) and Calza, Gerdesmeier and Levy (2001; henceforth CGL). Using multivariate time series models, CV and BC derive money demand functions comprising real M3, real GDP, short-term and long-term interest rates and inflation.[1] In the same vein, CGL focus on real M3, real GDP, the own rate of return on M3 and the short-term interest rate. A common result of these models is that the existence of a stable long-run relationship – i.e. *cointegration* – among the variables involved cannot be rejected. Therefore, M3 exhibits a stable long-run relationship with key macroeconomic variables. The money demand functions underlying these models are expressed in terms of real M3, where nominal M3 is deflated by the GDP deflator. This implies that the demand for nominal money fully adjusts to price movements in the long run, so that the desired level of real balances remains unchanged. Therefore, the models incorporate the assumption of long-run homogeneity between money and prices. Although the models differ with respect to the choice of the opportunity cost variables, they share the common feature of including real GDP as a scale variable. Moreover, all models show fairly similar income elasticities that are greater than one.

The Coenen-Vega (1999) model

The salient feature of the CV study is that, starting from a multivariate framework, a single-equation error-correction representation for real M3 is derived. This suggests that money is modelled to play a rather passive role in the way the five key macroeconomic are determined. The following long-run relationship was found to be supported by the data:

$$(m - p)_t = c + \beta_1 \cdot y_t - \beta_2 \cdot (l_t - s_t) - \beta_3 \cdot \pi_t \,,$$

where m, p, y and π denote nominal M3, the GDP deflator, real GDP and inflation (in terms of the GDP deflator), respectively; while s and l denote the short-term market interest rate and the long-term interest rate (with the exception of the interest rates and inflation small letters denote logarithms). The long-run money demand function underlying the error-correction term uses the spread between the ten-year bond yield and the three-month interest rate, and the inflation rate as the opportunity cost variables. Hence, the short-term rate was used as a variable approximating the own rate of return on M3. This was partially motivated by the fact that, at the time the study was carried out, data on the own rate of return on M3 was not available for the euro area.

The Brand-Cassola (2000) model

While BC start from the same set of data, its distinguishing feature is that the demand for M3 is modelled within a system of equations, rather than in the context of a single equation. The model investigates how key long-run relationships among monetary and financial variables such as M3 and interest rates can be used to model the historical behaviour of variables that are of interest for the policy maker, in particular inflation and income fluctuations.

Three equilibrium relationships play a crucial role within this framework: (i) a money demand function where the opportunity cost is measured by the long-term interest rate; (ii) a Fisher relation linking the long-term interest rate and inflation; (iii) and a term structure equation linking long-term and short-term interest rates,

$$(m - p)_t = c_1 + \beta_1 \cdot y_t - \beta_2 \cdot l_t \qquad \text{(i)}$$

$$\pi_t = c_2 + \beta_3 \cdot l_t \qquad \text{(ii)}$$

$$l_t = c_3 + s_t \qquad \text{(iii)}$$

Therefore, in the BC framework the (long-run) demand for real M3 balances is explained by two factors, real GDP and the long-term interest rate. Deviations of the variables from these long-run relationships play a key role in determining the five variables captured by the system.

The Calza-Gerdesmeier-Levy (2001) model

By explicitly incorporating a measure of the own rate of return on M3, the CGL model aims at capturing the role of opportunity costs on money holdings more accurately. It also seeks to quantify the impact of changes in short-term interest rates on M3. The distinguishing feature of this model is the inclusion of the spread between the three-month interest rate and the own rate of return on M3 as the opportunity cost variable for holding M3. The levels as well as the dynamics of the different measures of opportunity costs differ considerably. In fact, over the last twenty years, the own rate of return on M3 and the short-term interest rate deviated from each other quite substantially, even though the difference has recently become less marked. The long-run relationship in the CGL model is then specified in the following (semi-) log-linear form:

$$(m - p)_t = c + \beta_1 \cdot y_t - \beta_2 \cdot (s_t - own_t).$$

In essence, one cointegrating vector relating to 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. In line with the results from BC, CGL find some evidence that money demand has to be modelled as a system rather than in a single-equation framework.

1 *The short-term and long-term rates are measured by the three-month money market rate and ten-year government bond yields, respectively.*

Some fairly straightforward transformations can be used to illustrate the relationship between the change in velocity and money demand. The starting-point consists of a simple standard money demand function:

$$m - p = \alpha + \beta_1 \cdot y - \beta_2 \cdot o - \beta_3 \cdot \pi \,, \qquad (3)$$

where m denotes the nominal money stock, p the GDP-deflator, y real GDP, π the change in the GDP deflator over a quarter earlier, on an annualised basis, i.e. the inflation rate (all these variables are expressed in logarithms); o represents a measure of opportunity costs which may be different across models.

Using the definition of velocity implied by the quantity identity and taking logs and time differences, in combination with (3), the following formula (4) can be derived:[15]

$$\Delta v = \Delta y + \Delta p - \Delta m$$
$$\Leftrightarrow \Delta v = \Delta y + \Delta p - \Delta p - \beta_1 \cdot \Delta y + \beta_2 \cdot \Delta o + \beta_3 \cdot \Delta \pi$$
$$\Leftrightarrow \Delta v = (1 - \beta_1) \cdot \Delta y + \beta_2 \cdot \Delta o + \beta_3 \cdot \Delta \pi \,. \qquad (4)$$

Assuming stationary opportunity costs and a regime of price stability (with $\Delta \pi = \Delta o = 0$), and replacing the level of actual income by its trend y^*, equation (4) yields the medium-term trend in velocity Δv^*:

$$\Delta v^* = (1 - \beta_1) \cdot \Delta y^* . \qquad (5)$$

This formula can be used to compute an estimate for the velocity trend over the medium term based on the estimated long-run income elasticity from the money demand functions. Given stationary opportunity costs and a regime of price stability (and therefore stationary inflation), a decline of income velocity is thus associated with a long-run income elasticity exceeding one. (In the literature, an elasticity exceeding one is usually interpreted as suggesting the relevance of wealth effects in the demand for money.) Following these considerations, it seems obvious that, in a standard money demand framework, the implied assumption for the medium-term decline in velocity is partly related to the assumption for the trend in potential output growth. For instance, a higher assumption for trend real GDP growth implies, ceteris paribus, a faster decline in M3 velocity.

Table 4 (upper part) reports the estimated long-run income elasticities in the baseline versions of the three money demand specifications described above using euro area data. As already mentioned above, these baseline versions are based on euro area data for the period 1980 Q1-2001 Q2 and focus on the aggregate M3. For the Coenen-Vega model (CV henceforth), a (long-run) income elasticity of 1.27 can be computed, while in the Brand-Cassola-study (BC henceforth) a slightly higher (long-run) income elasticity of money demand of 1.34 is obtained. Similar to this, the Calza-Gerdesmeier-Levy model (CGL henceforth) reports an income elasticity of 1.31. Given the

Table 4

Comparison of different money demand models

Model	Coenen / Vega (CV)	Brand / Cassola (BC)	Calza / Gerdesmeier/ Levy (CGL)
Model description	Single-equation error-correction model	Structural cointegrating VAR	VEC model
Long-run income elasticity	1.27	1.34	1.31
(Std. Err.)	(0.06)	(0.03)	(0.04)
Implied annual velocity trend assuming			
Potential output growth = 2%	-0.32% to -0.76%	-0.56% to -0.79%	-0.48% to -0.78%
Potential output growth = 2¼%	-0.36% to -0.85%	-0.63% to -0.89%	-0.53% to -0.88%
Potential output growth = 2½%	-0.40% to -0.95%	-0.70% to -0.99%	-0.59% to -0.98%

15 For reasons of simplicity, the constant term is neglected.

standard errors of the coefficients, the differences between the three models are not very pronounced.

An important conceptual difference, which has implications for the velocity estimate, is that CV include the inflation rate in the money demand function, whereas BC as well as CGL exclude it. The CV study implies that inflation has played some role in explaining the observed downward trend in income velocity in the euro area. Consequently, some of the trend decline in M3 income velocity in the past can be attributed to the decline in the inflation rate over the last twenty years. Declining inflation makes money holdings more attractive, increases the equilibrium holding of M3 relative to nominal GDP and therefore is associated with declining M3 velocity. In an environment of price stability where inflation is no longer declining, one would anticipate a lower trend decline in velocity.

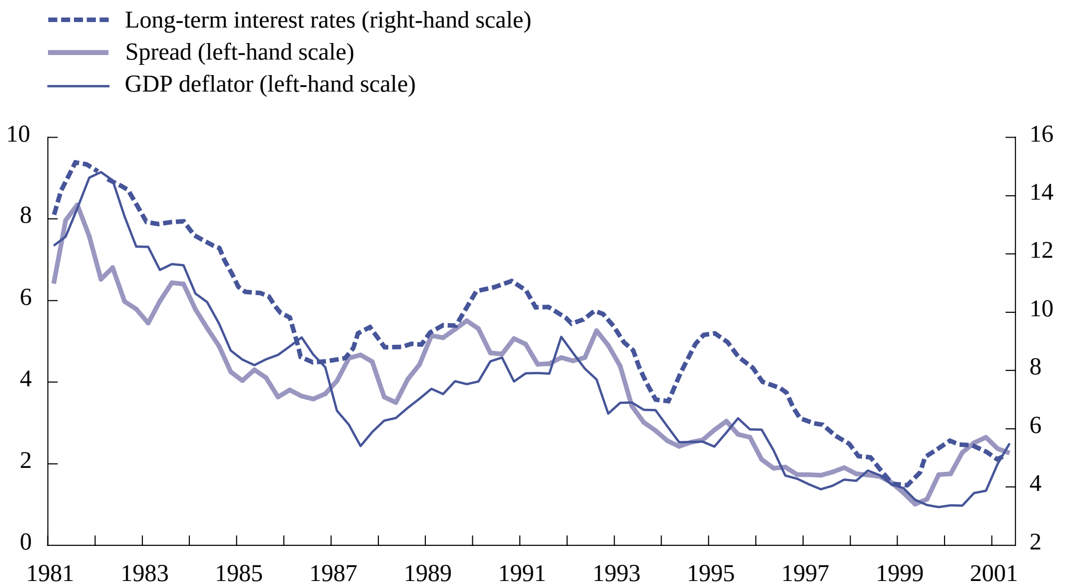
The evidence provided in the BC and in the CGL studies suggests that part of the trend decline in velocity over the last twenty years can be attributed – in the BC model – to the decline in long-term interest rates or – in the CGL model – to the decline in the spread between the short-term interest rate and the own rate of M3 (see Figure 7 below). Compared with the CV specification, a slightly larger proportion is explained by the long-run income elasticity and trend in potential output growth.

Looking at the figures shown in the lower part of Table 4, if we take into account both estimation uncertainty (implying 95% confidence bands around the point estimate for the long-run income elasticity of money demand) and the uncertainty regarding different assumptions for the trend in potential output growth (in the range of 2% to $2^1/_2$%), an interval of -0.32% to -0.95% for the medium-term trend in velocity consistent with price stability can be obtained in the CV model. The upper bound is related to an assumed potential output growth of 2%, while the lower bound is calculated for a value of $2^1/_2$%.

Figure 7

The long-term interest rate, the spread and the GDP deflator for the euro area

(Percentage points)



Note: annual percentage changes in the GDP deflator are shown. Spread denotes the difference between the short-term interest rate and the own rate of return on M3.

Similarly, given the respective confidence interval around the point estimate for the long-run income elasticity of money demand, a range of -0.56% to -0.99% (in the BC model) and of -0.48% to -0.98% (in the CGL model) is obtained. In conclusion, the empirical evidence from the available money demand frameworks suggests so far that assuming a decline in the range of $^{1}/_{2}$% to 1% per annum over the medium term seems well justified.

4.2 Stability of money demand models

For the assessment of medium-term trends in velocity in the context of money demand models, it is of particular interest whether the stable relationships identified in these models have remained intact. It seems desirable to shed some light on the uncertainties regarding the fundamental stability properties of M3 with the introduction of a common currency in 1999, as this change in the policy regime might have affected the stability of the relationships. Therefore, to provide further evidence on the stability of a long-run relationship between M3 and the macroeconomic variables GDP, prices and interest rates, we have re-investigated the stability of the long-run money demand relationships identified in the context of the BC, CGL and CV money demand system. Figure 11 and Figure 12 in Annex B show standard recursive tests and *recursive* estimates of the long-run coefficients of the three money demand models.

It should be borne in mind that the stability tests actually focus on the stability of an entire model, including its short-run dynamics, and not just its long-run parameters. Therefore, if such a test were to reveal instabilities, this would not necessarily imply instability in the long-run parameters of the money demand model which are important for the medium-term trend in M3 income velocity. For this reason, stability tests and recursive estimates of long-run parameters should be seen in conjunction.

None of the diagnostic checks for the BC and CGL models suggest any instability either of the models' short-run specification or of their long-run relationships, while one of the recursive test statistics for the short-run specification of the CV model indicates some slight problems at a few time instances. It should be noted, however, that the original version of the CV model was based on euro area data compiled using a different aggregation method. More importantly, the recursive estimates of the long-run parameters of this model do not show any signs of instability.

To provide additional details on the stability of the BC and the CGL model, we have estimated a single-equation money demand function based on the respective specification and adopted a *stochastic coefficient technique*, i.e. a technique that allows the model coefficients to vary randomly. With this tool, it is also possible to look at the evolution of the parameters over time. The details of this exercise can be found in Annex B, Section B.2.

Overall, the results suggest that the income elasticity accounting for the velocity trend is remarkably stable in all three money demand models. In addition, there appear to be no signs of instability particularly related to the start of Stage Three of EMU.

5 Sensitivity analysis using different datasets

This section focuses on whether the assumption for M3 income velocity would remain valid when using either the most recent euro area* series, or M3 and GDP series compiled using a different aggregation method. Therefore, based on visual inspection, a brief illustration of the impact on the M3 income velocity series attributable to the use of these two different datasets is provided in the section below. Our analysis then continues by reporting the main results found on the basis of the univariate analysis of the time series properties of velocity (Section 5.2) and on the multivariate analysis of the relationship between money, prices and output in the context of structural money demand equations (Section 5.3).

5.1 The impact on the velocity trend using different datasets

As explained in the introduction, the analysis related to the assumption on medium-term trend decline in velocity underlying the review of the reference value is based on euro area data (i.e. including Greece only from January 2001). However, it is of interest to analyse whether the inclusion of Greek data from before 2001 might have an impact on the velocity trend with respect to the results found for the series based on euro area data.[16] As Figure 19 in Annex C shows, a visual inspection of M3 growth rates suggests that the historical pattern in the data differs only slightly in the most recent periods and that the inclusion of Greece in the back data only slightly affected the developments in monetary aggregates for the period 1997 to 2000. Moreover, when comparing nominal GDP data[17] (see Figure 20 in Annex C) it is evident that the inclusion of Greece did not have any major impact on the annual percentage change in nominal GDP of the euro area.

Against this background, a simple visual inspection of the resulting series for the log level of M3 velocity (see Figure 8 below) suggests that the velocity trend is not much affected when including historical series for Greece before January 2001.

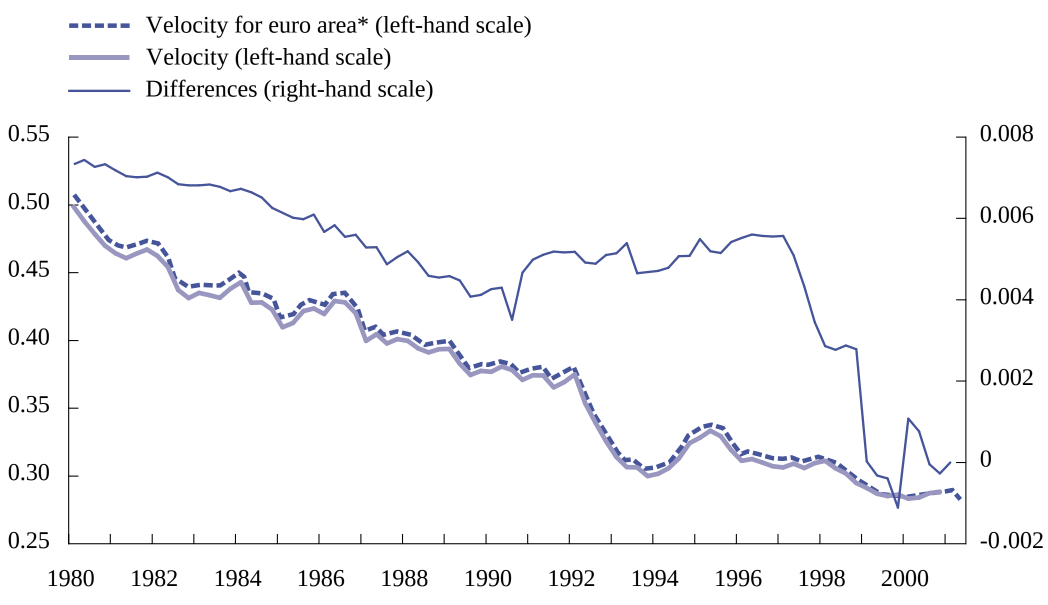
16 *As far as long-term interest rates are concerned, euro area* series include Greek data only as from October 1992 onwards (see footnote 6).*

17 *The GDP series for both the euro area and euro area* have been compiled using the same aggregation method, namely irrevocable fixed euro exchange rates announced on 31 December 1998 and determined on 19 June 2000 in the case of Greece.*

Figure 8

Comparison of M3 income velocity series

(Log level)



Another issue related to euro area series is that their construction relies on the choice of the aggregation method of national data. In fact, there exist various methods of aggregating individual countries' series for constructing historical euro area data and each of these methods has its own advantages and drawbacks. The following Box 3 presents a brief discussion of the pros and cons of the two aggregation methods which have been considered in this study.

Box 3

The construction of euro area series based on alternative aggregation methods

To construct historical euro area-wide series, national data must be aggregated.[1] In the main analyses of this paper, M3 and nominal GDP series have been compiled by adding up national data that have been converted into euro at the irrevocable fixed exchange rates announced on 31 December 1998 (and determined on 19 June 2000 in the case of Greece). This method sums nominal national stocks (and flows) (X_z) which have been converted into euro at the irrevocable fixed exchange rates (e_z), according to the following formula:

$$X_{euro\ area} = \sum_{z \in A} e_z X_z \qquad A = \{BE, DE, GR, ES, FR, IE, IT, LU, NL, AT, PT, FI\}.$$

The recourse to fixed exchange rates instead of current exchange rates avoids having very volatile aggregate series. Indeed, especially in the short term, results using current exchange rates may mirror fluctuations in the exchange rates, rather than the sought underlying movements in the variables.[2]

The aggregation method just illustrated coincides with the approach followed for the *official* euro area M3 series published by the ECB. In addition, from an economic perspective, the aggregation method based on irrevocable fixed exchange rates also has the advantage of preserving the balance sheet and other adding-up constraints imposed by the statistical framework. In the context of analysis of the MFI consolidated balance sheet (e.g. the interaction between money and credit growth) this permits the balance sheet constraints to be imposed in econometric exercises.

However, this aggregation method differs from that used in other contexts. For example, the published data for the determinants of money demand (interest rates and Eurostat nominal and real GDP[3]) are not aggregated using the irrevocable fixed exchange rates prior to January 1999. Moreover, for series that are not based on nominal stocks or flows – such as the interest rates – this aggregation method cannot be applied. Finally, the area-wide macroeconomic model of the ECB is also based on series constructed using aggregation methods different from the irrevocable fixed exchange rates (*cf.* Fagan, Henry and Mestre (2001)).

In the light of this, it may be useful to adopt a robust approach and cross-check the results obtained using different aggregation methods. The other aggregation method which is considered in this paper is based on fixed GDP weights. It constructs a log level of the euro area aggregate as the weighted sum of the log levels of the national stocks (and flows), where the weights (w_z) are the share of the country GDP at market prices in 1999 (measured at PPP exchange rates):

$$\ln X_{euro\ area} = \sum_{z \in A} w_z \ln X_z \qquad A = \{BE, DE, GR, ES, FR, IE, IT, LU, NL, AT, PT, FI\}.$$

This aggregation method has the advantage that the growth rate of the euro-area wide aggregate variable is the weighted average of the growth rates of the national contributions.

Moreover, it can also be straightforwardly applied to other variables which are not nominal stocks or flows (i.e. to calculate the euro area interest rates by taking a GDP weights-based average of national interest rates, without transforming them in logarithms). Obviously, this method also presents some drawbacks. For instance, the area-wide stocks obtained do not satisfy the balance sheet identities. Consequently, when studying the inter-relationship between different components of the MFI balance sheet, the balance sheet restrictions cannot be imposed. Moreover, as regards, for instance, the level of the euro area money stock, this can only be presented in the form of an index.

Finally, as far as the construction of seasonally adjusted series is concerned, comparable data would require either the provision of seasonally adjusted national contributions or alternatively a seasonal adjustment of the aggregate data.[4]

1 *An illustration of a proposal for another aggregation method which is not used in this paper can be found in Beyer, Doornik and Hendry (2001).*
2 *As shown in Winder (1997), independence from the specific choice of the numeraire is achieved by making recourse to fixed base-period exchange rates.*
3 *Eurostat GDP series prior to 1999 are constructed by aggregating national series on the basis of contemporaneous annual ECU exchange rates. Obviously, with the adoption of a single currency on 1 January 1999, Eurostat GDP are also based, from 1999 onwards, on the aggregation procedure using the irrevocable fixed exchange rates.*
4 *Seasonally adjusted series for national M3 are not available (the seasonal adjustment is carried out on the euro area aggregate), whereas the seasonally adjusted euro area aggregate GDP is constructed from the national seasonally adjusted GDP series.*

The analysis undertaken in the previous sections was based on euro area series compiled as a simple summation of the historical data of each Member State, assuming fixed exchange rates throughout the sample period (see Box 3 above for arguments in favour of the adoption of this approach). However, another approach which could be employed is based on the variables being aggregated in log levels using fixed GDP weights. Therefore, it may also be useful to check the robustness of the results obtained using the series compiled with the aggregation procedure based on the irrevocable fixed exchange rates against those obtained using the method just discussed. In what follows, our analysis will be focused on using euro area series for nominal GDP and M3 compiled by aggregating log-level national series using GDP weights based on PPP exchange rates (also labelled as GDP-PPP weights henceforth for simplicity).[18]

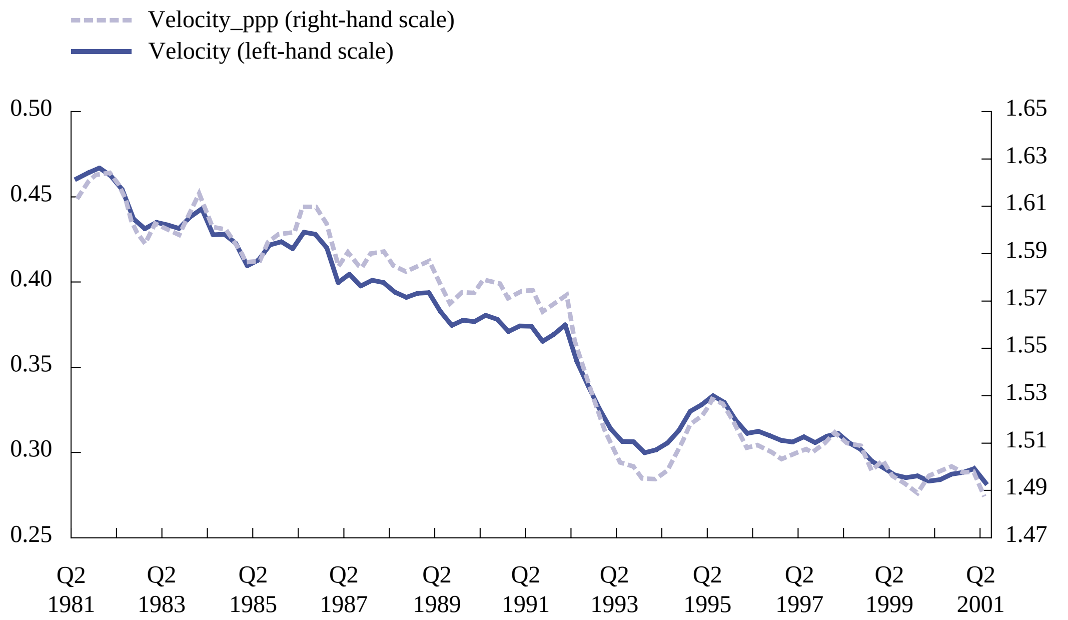
As done for the euro area* series, we also show (see Annex C) a graphic comparison of the annual growth rates of M3 and nominal GDP for the euro area derived from two types of aggregation methods: irrevocable fixed exchange rates and GDP-PPP weights. The impact of using different aggregation methods on the velocity series is provided in Figure 9 below, which compares the velocity series based on the M3 and nominal GDP data constructed using the irrevocable fixed exchange rates (solid line, labelled as "velocity") and the GDP-PPP weights (dotted line, denoted as "velocity_ppp").[19]

18 *The methodology followed to derive the M3 and nominal GDP series is described in Annex D.*
19 *The difference in the levels (and therefore in the scaling) of the two velocity series (see Figure 9) can be attributable to the differences in the compilation of the M3 series. M3 based on GDP-PPP weights was constructed multiplying its index by the December 1998 stock of M3 based on the irrevocable fixed exchange rates (see Annex D for further detail). However, this affects only the level of velocity and not the trend on the resulting M3 income velocity series.*

Figure 9

Comparison of M3 velocity series using different aggregation schemes

(Log level)



One of the reasons which might explain the differences in the developments of the variables underlying velocity is the fact that different weights are attributed to some countries under the two weighting schemes. Therefore, the aggregate growth rate of GDP and M3 will reflect the impact of some countries exhibiting, for instance, a higher trend decline in velocity which may be given a lower weight under the aggregation scheme based on GDP weights with respect to the other aggregation method. Moreover, given that the aggregate variables based on GDP-PPP weights have been constructed starting from the log levels of national series, differences in the growth rates of the aggregate may also arise as a consequence of the approximation of the growth rates calculated out of the aggregated log variables.

5.2 Estimates of the trend of M3 income velocity

The analysis carried out in Section 3 is now applied to the velocity series derived from the two datasets illustrated in the previous section. The results of a series of tests for the non-stationarity of the velocity series for both the euro area* and the euro area based on GDP-PPP weights over the sample period 1980 Q1-2001 Q2 (*cf.* Annex A, Section A.1) clearly show that the time series properties of M3 velocity – taking into account the trend – are, as in the case of the euro area series, borderline between being integrated of order one, or not, at conventional significance levels.[20]

Assuming that the log level of velocity is trend stationary, Table 5 below compares the simple OLS estimates of linear trends fitted to M3 velocity for the euro area, for the euro area*

20 Moreover, we also carried out the Perron test with endogenously determined structural breaks for the velocity series based on GDP-PPP weights. The results seem to suggest that the null hypothesis of non-stationarity can be rejected at a conventional significance level for both the "crash" and the "combined" specifications. For these specifications, the date of the structural break selected by the Perron test (i.e. 1991 Q4) coincides with the date which was selected when applying the same test to the velocity series for the euro area based on the irrevocable fixed exchange rate aggregation.

and for euro area based on GDP-PPP weights over the different sub-samples considered in Table 2. With regard to M3 income velocity for euro area*, a mere comparison of the trend estimates suggests that the coefficient estimates are not greatly affected when euro area* data are used, notwithstanding the trend decline in velocity for the euro area being just slightly lower than the decline in velocity for the euro area*. The univariate analysis of euro area* velocity – as in the case of the euro area velocity – also points towards a trend decline closer to 1% over the longest sample period. For the shorter and more recent sub-samples the estimates of the trend decline are well within the range of ½% to 1%. The somewhat larger difference between euro area and euro area* trend estimates over the most recent short sample periods can be explained by the rather high M3 growth rates in Greece in the period 1997 to 1999.

As regards the velocity series based on GDP-PPP weights, the results presented in Table 5 show a lower decline in the log of velocity based on GDP-PPP weights compared with the series based on fixed exchange rates. The point estimate for the velocity trend for the largest sample period lies close to the mid-point of the range, whereas for shorter sub-samples the point estimates are close to, and mostly somewhat lower than, -½%.

Table 5

OLS estimates of linear trends for M3 velocity using different datasets

	Euro area		*Euro area**		*Euro area – GDP-PPP weights*	
Sample	Implied annual trend %	*± 2 Std. Err. confidence interval*	Implied annual trend %	*± 2 Std. Err. confidence interval*	Implied annual trend %	*± 2 Std. Err. confidence interval*
1980 Q1-2001 Q2	**-0.94***	± 0.10	**-0.97***	± 0.09	**-0.73***	± 0.17
1980 Q1-1991 Q4	**-0.89***	± 0.12	**-0.91***	± 0.12	**-0.45***	± 0.14
1992 Q1-2001 Q2	**-0.53***	± 0.09	**-0.58***	± 0.13	**-0.30***	± 0.07
1996 Q1-2001 Q2	**-0.58***	± 0.35	**-0.70***	± 0.47	**-0.35***	± 0.23
1998 Q2-2001 Q2	**-0.53**	± 0.30	**-0.62**	± 0.34	**-0.40**	± 0.31

Note: The estimates of the trend are obtained from a stationary time series model including autoregressive and moving average components of different order. indicates the OLS estimates of linear trends for velocity which have been corrected for autocorrelation of residuals (cf. Table 2).*

The 2 Std Err. bounds around the point estimate correspond to a 95% probability confidence interval. Standard errors have been corrected for heteroskedasticity.

Estimates for the velocity series based on "euro area – GDP-PPP weights" for the first two sample periods in the table are carried out starting from 1981 Q2.

5.3 Multivariate analysis in the context of money demand models

The analysis presented in Section 4 focusing on money demand models is repeated in this section using euro area* data and the euro area data based on the GDP-PPP aggregation method. The results are presented in Table 6 below.

As regards euro area* data, re-estimating the CV model, a (long-run) income elasticity of 1.31 can be obtained (instead of 1.27). As in the case of the euro area data, the BC study and the CGL study report slightly higher (long-run) income elasticities of money demand (1.35 in both cases, instead of 1.34 and 1.31 for BC and CGL, respectively). The lower parts suggest that a (95%) confidence interval of -0.30% to -1.04% for the medium-term trend in velocity consistent with price stability can be obtained in the CV model. Similarly, given the respective confidence interval around the point estimate for the long-run income elasticity of money demand, a range of -0.58% to -1.01% (in the BC model) and of -0.54% to -1.06% (in the CGL model) is obtained. In sum, it can be concluded that these results still support the assumption of a trend decline in velocity of ½% to 1%.

Finally, the re-estimation of the three money demand models using euro area data based on GDP-PPP weights reveal broadly similar results. While the BC and CV model yield an income elasticity of 1.24, it is slightly higher in the CGL model (1.27). According to the lower part of Table 6, an interval of -0.26% to -0.86% for the medium-term trend in velocity (consistent with price stability) can be obtained in the CV model. Similarly, the respective confidence intervals are -0.36% to -0.78% (in the BC model) and -0.37% to -0.89% (in the CGL model).

While these ranges – to a large extent – overlap with the ½% to 1% assumption for the trend decline in velocity, they suggest that the point estimates would be all in the lower part of this range. As for the interpretation of these results, it has to be borne in mind that the original CV model has been estimated using an M3 measure that was constructed using fixed GDP weights based on PPP exchange rates, while the BC and the CGL model relied on the official historical euro area M3 compiled by using the irrevocable fixed exchange rates. The results indicate that the use of the fixed GDP-PPP weights aggregation procedure seems to lead to a slight decrease of the trend estimates for the M3 income velocity.

Table 6

Comparison of different money demand models

Model	Model description	Dataset	Long-run income elasticity *(Std. Err.)*	Implied annual velocity trend assuming		
				Potential output growth rate = 2%	*Potential output growth rate = $2^1/_4$%*	*Potential output growth rate = $2^1/_2$%*
CV	Single-equation error-correction model	Euro area	**1.27** (0.06)	-0.32% to -0.76%	-0.36% to -0.85%	-0.40% to -0.95%
		Euro area*	**1.31** (0.06)	-0.30% to -0.83%	-0.44% to -0.94%	-0.49% to -1.04%
		Euro area GDP-PPP weights	**1.24** (0.05)	-0.26% to -0.69%	-0.30% to -0.77%	-0.33% to -0.86%
BC	Structural cointegrating VAR	Euro area	**1.34** (0.03)	-0.56% to -0.79%	-0.63% to -0.89%	-0.70% to -0.99%
		Euro area*	**1.35** (0.03)	-0.58% to -0.81%	-0.66% to -0.91%	-0.73% to -1.01%
		Euro area GDP-PPP weights	**1.24** (0.03)	-0.36% to -0.62%	-0.40% to -0.70%	-0.45% to -0.78%
CGL	VEC model	Euro area	**1.31** (0.04)	-0.48% to -0.78%	-0.53% to -0.88%	-0.59% to -0.98%
		Euro area*	**1.35** (0.04)	-0.54% to -0.84%	-0.60% to -0.95%	-0.67% to -1.06%
		Euro area GDP-PPP weights	**1.27** (0.04)	-0.37% to -0.71%	-0.42% to -0.80%	-0.46% to -0.89%

6 Conclusions

This paper documents the analytical work carried out regarding the assumption for the trend in M3 income velocity for the 2001 review of the reference value for M3 growth. In deriving the reference value for monetary growth, since its announcement in 1998, it has been assumed that M3 income velocity would decline at a rate of between $^1/_2$% and 1% each year over the medium term. This note provides a reassessment of this assumption using univariate time series tools as well as different money demand models that have been developed by ECB staff.[21]

Univariate non-structural approaches of velocity, neglecting the possibility of structural breaks, tend to reveal a trend decline over the full sample period (1980 Q1-2001 Q2) which is at, or close to, the upper end of the assumed range, namely around 1%. In contrast, univariate approaches allowing for a break and a change in the trend in the 1990s would suggest that the trend decline in velocity in the 1990s is closer to the lower end of the range ($^1/_2$%).

Money demand models which incorporate additional information on the evolution of the opportunity costs of holding money (interest rates and/or inflation) also tend to reveal a trend decline which is around the mid-point or in the lower part of the range of $^1/_2$% to 1%.

This seems to suggest that, considering the full sample period, a simple trend estimate may not represent the best estimate of medium-term trend in velocity in the future. It may to some extent fail to capture that the decline in inflation and nominal interest rates throughout the sample period may have contributed to the past decline in velocity. Thus, the process of disinflation should have contributed to making the holding of liquid assets more attractive. In contrast, in an environment of price stability, where inflation and interest rates should no longer exhibit a downward trend, the trend decline in velocity is likely to be less pronounced than over a period dominated by disinflation and falling nominal interest rates. Using money demand models which incorporate additional information on the evolution of opportunity costs of holding money it is possible to account for the effect that the disinflation process had on the historical trend decline. In the context of these models, in an environment of price stability, the trend decline would be around the middle of the range of $^1/_2$% to 1%.

A further cross-checking of the results across different approaches is carried out using other datasets which include either Greek data as far back as possible before 2001 or series which have been compiled using a different weighting scheme to aggregate euro area data. These two approaches reveal some differences regarding the trend decline in velocity, but from a quantitative perspective, the differences are rather minor. Considering Greek data further back than 2001 did not seem to significantly influence the trend estimates. However, if instead of the irrevocable fixed exchange rates, fixed 1999 GDP weights at PPP exchange rates were used to aggregate money and income, the trend decline would seem to be somewhat lower. However, in this case, the point estimates of the decline in velocity derived on the basis of money demand models are still between $^1/_2$% and $^3/_4$%.

All in all, the results presented in this study point to a trend decline in M3 income velocity in the range of $^1/_2$% to 1%. This result is fairly robust across different models and across different ways of aggregating euro area data.

21 It should be noted that the analysis based on the three money demand models currently used at the ECB suggests that M3 continues to exhibit the required properties of having a stable relationship with key macroeconomic variables such as prices, income and interest rates.

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Annex A
Univariate analysis

A.1 Standard unit root tests

In order to test for the existence of a unit root in the velocity series, we have carried out the Dickey-Fuller (DF), the Augmented Dickey-Fuller and the Phillips-Perron (PP) tests for the sample period 1980 Q1-2001 Q2.[22] These tests are all based on the null hypothesis that the series being investigated is non-stationary. The results of these tests clearly reject the null hypothesis that the first difference of M3 velocity is I(1) in favour of the alternative. Moreover, the results of the test for non-stationarity of the series measured in levels are borderline if a trend is included. Albeit at the 10% significance level, the ADF test rejects the null of non-stationarity of M3 velocity. However, it is well known that the power of unit root tests is low in the relatively short samples typical of macroeconomic data.[23] One suggested approach to overcome the problems associated with the low power of ADF and PP tests is to implement additional tests that have the null hypothesis of stationarity against the alternative of a unit root and use these to confirm the analysis of ADF and PP tests. One example of such a test has been proposed by Kwiatowski, Phillips, Schmidt and Shin (1992) (henceforth, KPSS). The results of the test on the M3 velocity series (with the null hypothesis of the log level of M3 velocity series being stationary around a linear trend) again turn out to be borderline. For those versions of the KPSS test that adjust for auto-correlation in the shocks to velocity with the lag parameter greater than two, the KPSS test fails to reject trend stationarity at the 1% level. In addition, for truncation lags equal to four, the trend stationarity cannot be rejected even at the 5% level of significance.

In sum, these tests suggest that the time series properties of M3 velocity over the entire sample period 1980 Q1-2001 Q2 are borderline between non-stationarity (I(1)) and trend stationarity.

As far as the velocity series based on euro area* data is concerned, the results of the tests for non-stationarity over the sample period 1980 Q1-2001 Q2 clearly reject, as for the euro area velocity series, the null hypothesis that the first difference in M3 velocity is I(1). Moreover, for euro area* velocity (in levels) both the ADF and the PP tests reject the null of non-stationarity at 10% level, whereas for the euro area the PP test failed to reject the null. The KPSS test fails to reject the null at 5% significance for truncation lags greater than 2.

Finally, we have also carried out the DF, ADF, PP and KPSS tests on the stationarity of the velocity series based on the GDP-PPP weights aggregation method. The conclusion is that, while the ADF and PP fail to reject the null of non-stationarity of the series, the KPSS test fails to reject trend stationarity at 1% significance level for truncation lags greater than one (at 5% level for lags equal to four).

A.2 Measuring the impact of the random walk component within a state space modelling framework

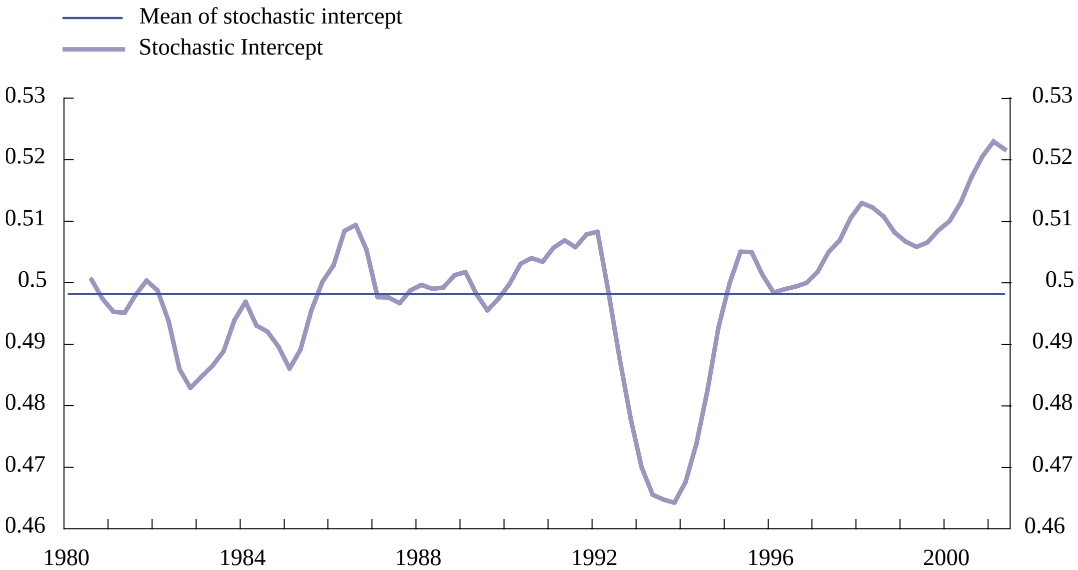
The assumption that velocity follows a random walk with drift can also be presented in the context of the following *random walk plus noise model* suggested by Harvey (1990):[24]

$$v_t = \alpha_t + \beta \cdot t + \varepsilon_t, \qquad \varepsilon_t \sim NID(0,\sigma^2_{\varepsilon}), \qquad t = 1,...,T$$
$$\alpha_t = \alpha^* + \alpha_{t-1} + \omega_t, \qquad \omega_t \sim NID(0,\sigma^2_{\omega}),$$

22 The results of these tests are not reported here due to the lack of space, but are available from the authors upon request.
23 For a discussion about the low power of unit root tests, see Maddala (1992) and Cochrane (1991).
24 The model presented in this section was estimated using STAMP 6.0.

where the disturbance terms are independently and normally distributed. The behaviour of velocity is ultimately determined by the stochastic trend α_t and the drift term $\beta \cdot t$. capable of capturing the dynamics in velocity.[25] Moreover, the table suggests that under the unit root assumption, the best guess about the evolution of velocity should be based on the assumption about the drift term implying an annual decline around the mid-point -1.032%.[26]

Figure 10
Time varying parameter from random walk model



Although a linear trend is included in the model, deviations of velocity from its trend will infinitely increase with time. Figure 10 shows how α_t was estimated to evolve over time.

Table 7 below summarises an estimate of the random walk plus noise model for the whole sample period (1980 Q1-2001 Q2). The standard statistical tests on the whiteness of the residuals suggests that the model is well

25 *To save space, these figures are not shown in detail. They are available from the authors upon request.*

26 *This result is derived by considering 95% confidence bands around β. As the model has been estimated for quarterly data, the annual percentage change is derived from multiplying these estimates by 400.*

Table 7
Random walk plus noise model of income velocity of M3

Parameter	Std. Err.	Implied annual trend in velocity % *± 2 Std. Err. confidence interval*
$\alpha^* = -0.018$	0.009	**-1.032** ± 0.32
$\beta = -0.00258$	0.0004	

Annex B
Stability tests in the context of the money demand studies

B.1 Stability tests for the money demand models based on euro area data

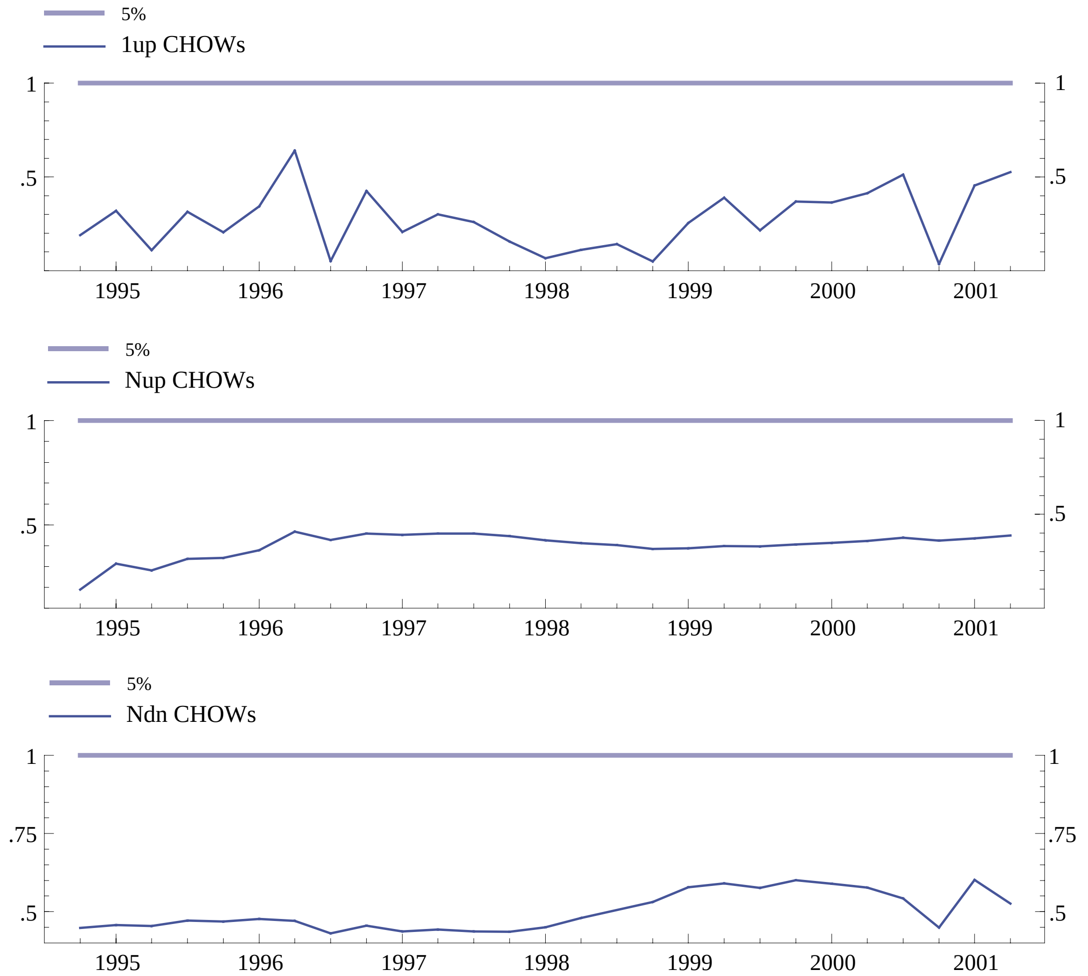
The figures below contain some stability tests for the money demand models which have been illustrated in Section 4.1 in the main text based on euro area data. Figure 11 presents recursive estimates of conventional stability tests on the BC, CGL and CV models as such, while Figure 12 shows recursive estimates of the three (freely estimated) long-run parameters in the cointegration space of the BC, CGL and CV money demand models. It shows the following long-run coefficients: for the BC model, income elasticity and interest semi-elasticity of money demand and the coefficient in front of long-term rates entering the Fisher relationship,[27] for the CGL model the income elasticity and the interest rate semi-elasticity of money demand and for the CV model the income elasticity, the spread (defined as the difference between the long-term and short-term interest rates) semi-elasticity and the inflation coefficient of money demand, respectively.

27 Interest rates are divided by 100.

Figure 11

Chow's 1-step ahead, break-point test for parameter constancy of the system and predictive failure test

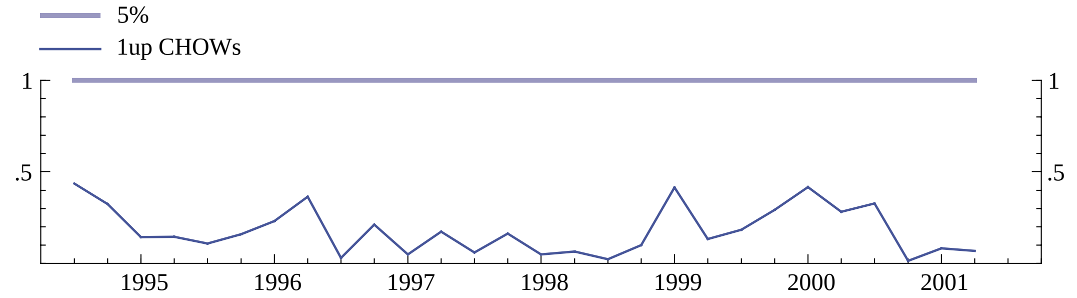
BC Model

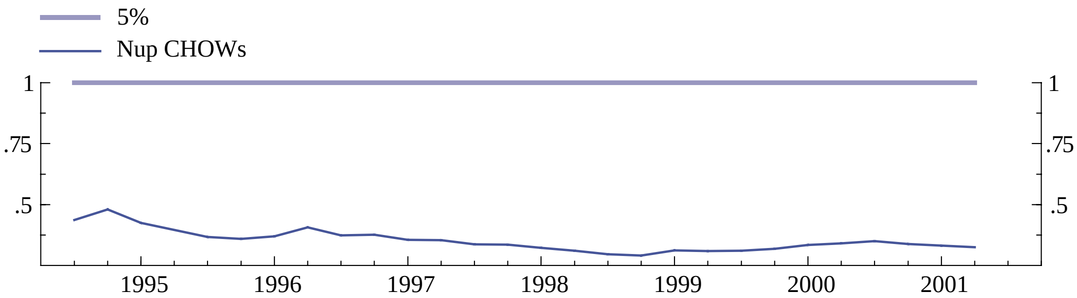


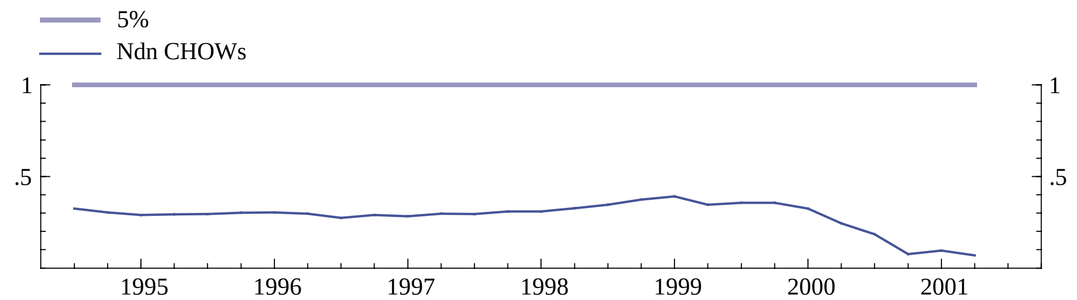
Note: Values above the 5% critical value level may signal instability of the parameters; the 5% critical level is indicated by the horizontal straight lines. The chart at the top provide 1-step F-tests, the one in the middle forecast F-tests, and the one at the bottom break-point F-tests).

Figure 11 continued

CGL Model



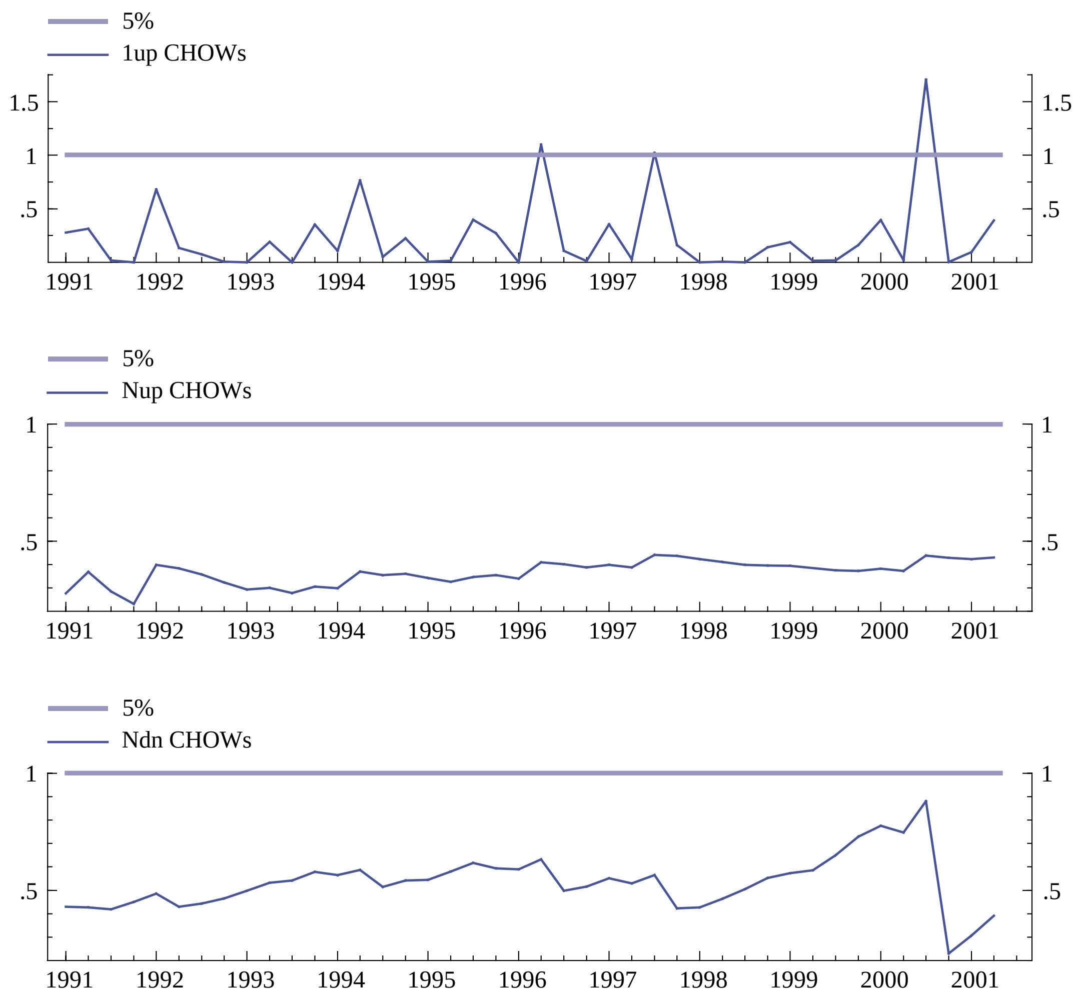




Note: See the note for the BC model above.

Figure 11 continued

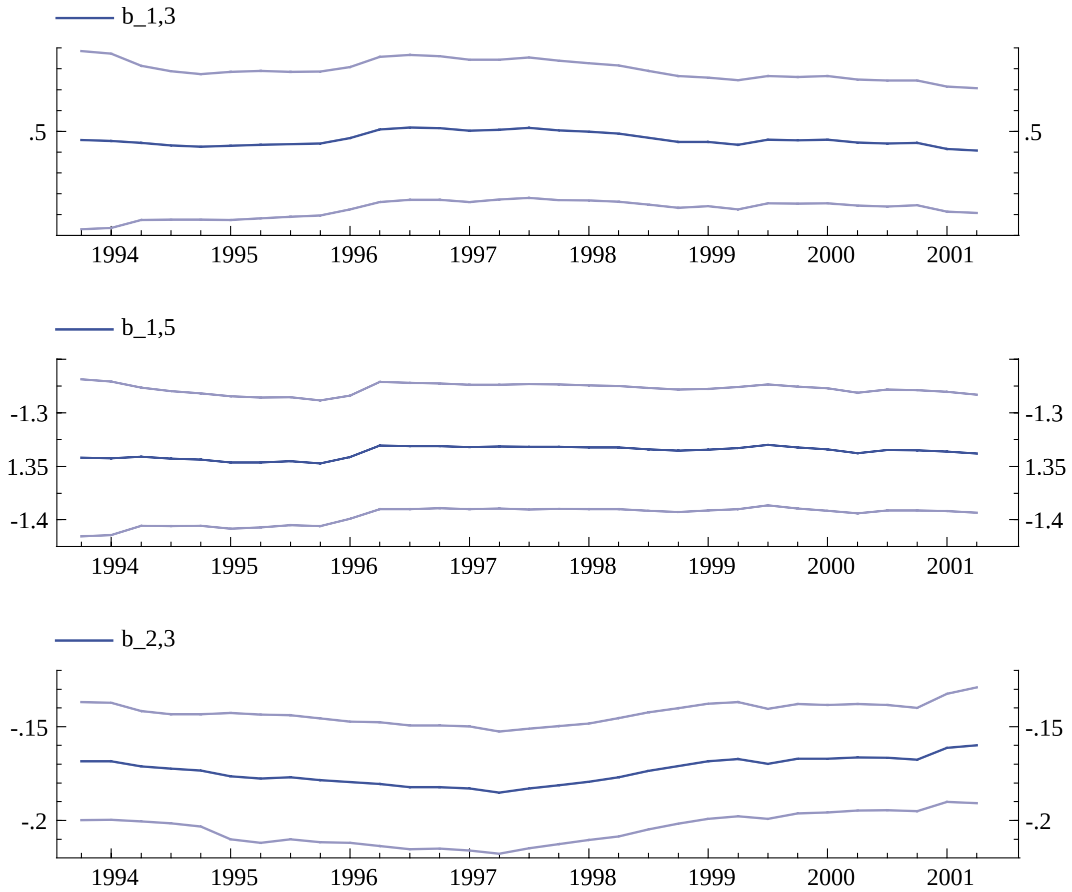
CV Model



Note: See the note for the BC model above.

Figure 12
Recursive estimates of long-run coefficients

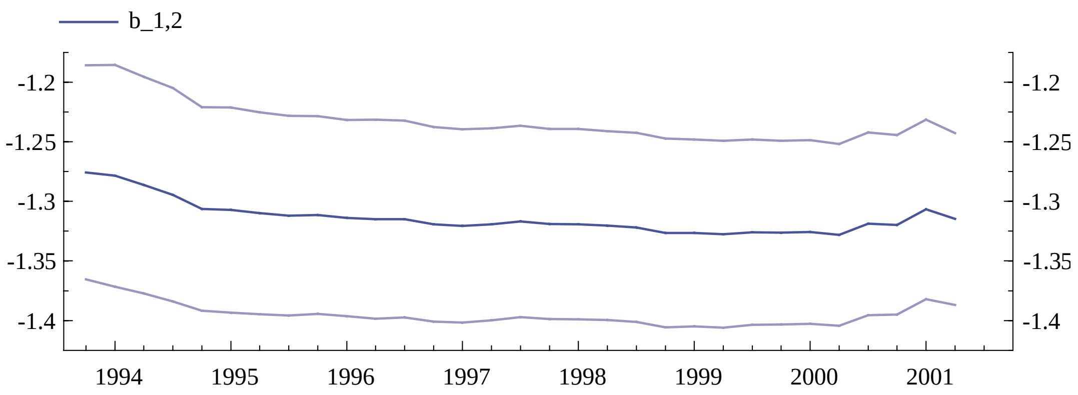
BC Model

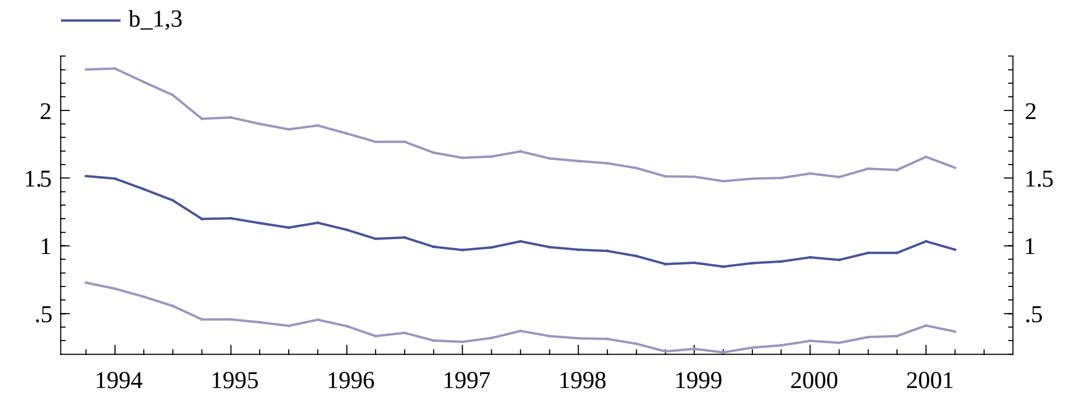


Note: The coefficients b_1,3, b_1,5 and b_2,3 denote the interest rate semi-elasticity, the income elasticity of money demand and the coefficient in front of the long-term interest rates entering the Fisher relationship, respectively.

Figure 12 continued

CGL Model

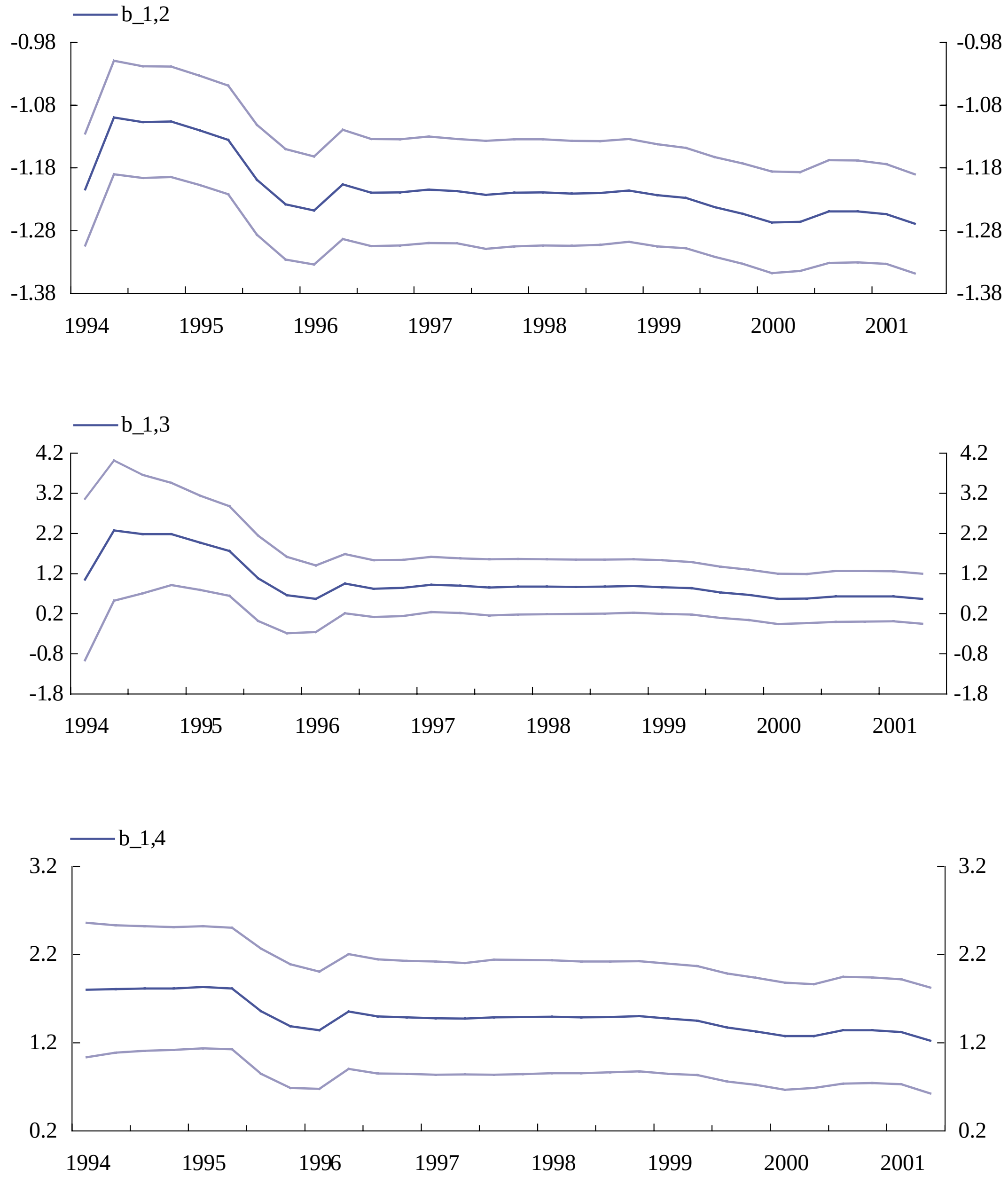




Note: The coefficients b_1,2 and b_1,3 denote the income elasticity and the interest rate (defined as the spread between the short-term interest rate and the own rate of return on M3) semi-elasticity of money demand, respectively.

Figure 12 continued

CV Model



Note: The coefficients b_1,2, b_1,3 and b_1,4 denote the income elasticity, the spread (defined as the difference between the long-term and short-term interest rates) semi-elasticity and the inflation coefficient of money demand, respectively.

B.2 A stochastic coefficient approach to investigate the stability of money demand models

Additional information on the stability of the BC and the CGL models have been obtained from estimating single-equation money demand specifications and adopting a *stochastic coefficient technique* (based on the Kalman filter, see Box 4 below). This technique allows the model coefficients to vary randomly. Contrary to the systems developed in these studies, however, we focus on a single-equation approach for money demand. This is done for reasons of simplicity. Applying the technique in a system's framework is thus left for future research.

Box 4

A stochastic coefficient approach to modelling money demand using the Kalman filter

This box focuses on the relaxation of the constant coefficient hypothesis. From the enormous variety of different time-varying parameter (TVP) models, a variant was chosen that can be characterised as "moderately adaptive" as against models of "no adaptivity" (i.e. fixed parameter models).[1] Following the literature, the general model can be expressed in terms of the following equations:

$$\Delta(m-p)_t = H'_t\gamma_t + \xi_t \quad (6)$$

$$\gamma_t = T\gamma_{t-1} + \eta_t \quad (7)$$

$$\xi_t \sim \mathrm{N}(0,\sigma^2),\ \eta_t \sim \mathrm{N}(0,\mathrm{Q}),\ \gamma_0 \sim \mathrm{N}(a_0,\Sigma_0) \quad (8)$$

where H_t contains all the explanatory variables.

Equation (6) (the so-called *measurement equation*) is similar to the classical regression model except that the parameter vector γ (i.e. the state variable) is allowed to vary over time according to equation (7) (the so-called *transition equation*), which – in this case – is a multivariate and first-order autoregressive (AR(1)) model for the state vector. The last equation describes the properties of the errors of measurement and transition equations, which are, furthermore, mutually and serially uncorrelated.

Finally, the framework used above includes the initial conditions for the state vector (i.e. the *a priori* distribution). In the present application, it is assumed that $T=I$, where I is an identity matrix. This implies that γ_t follows a multivariate random walk, and, since it is not stationary, evolves over time to accommodate the structural changes that might have taken place during the sampling period. Furthermore, a matrix Q was specified, the elements of which were estimated (using the maximum likelihood method) together with the rest of the parameters of the model.[2]

The Kalman Filter algorithm provides *a posteriori* estimates of the vector γ_t by expressing the expectation of this vector constrained by the information variable up to the period t, Ω_t, and the *hyperparameter* vector $\omega_0(a_0,\Sigma_0)$. This conditional mean provides an optimal estimator for γ_t, in the sense that it minimises the mean square error.[3]

With respect to the money demand equation presented above, we proceed using the following modelling approach. All parameters – including those of the long-run relationship – are allowed to vary. Apart from giving indications about the general stability of the model as such, this allows a particular focus on how the trend behaviour of velocity might be affected by instabilities. Note that under a regime of price stability, the trend behaviour of velocity is determined by the income elasticity of money demand (*cf.* Section 4.1 in the main text).

1 *See Granger (1986) for more details on this issue.*
2 *For a more detailed discussion of the state space modelling framework in econometrics, see Hamilton (1994).*
3 *See Harvey (1989) for a more technical description of the properties of the Kalman Filter.*

B.2.1 A single-equation error-correction representation of the Brand-Cassola model

The single-equation error-correction representation for M3 on which the stochastic representation will be based is of the following autoregressive-distributed lag (ADL) form drawing on the original vector error correction system:[28]

$$\Delta(m-p)_t = c + \alpha[(m-p)_{t-1} + \beta_1 y_{t-1} + \beta_2 l_{t-1}] + \gamma_{11}\Delta y_{t-1} + \gamma_{12}\Delta l_{t-1} + \gamma_{13}\Delta s_{t-1} + \gamma_{14}\Delta \pi_{t-1} + \gamma_{15}\Delta(m-p)_{t-1} + \gamma_{01}\Delta y_t + \gamma_{02}\Delta l_t + \gamma_{03}\Delta s_t + \gamma_{04}\Delta \pi_t \quad (9)$$

where m, p, y and π denote, respectively, nominal M3, the GDP deflator, real GDP and inflation (in terms of the GDP deflator). s and l denote the short-term interest rate and the long-term interest rate, respectively.[29]
Equation (9) can be estimated using OLS, thereby obtaining the long-run coefficients and the dynamic coefficients in one step (the main modelling strategy lies in the fact that it can be applied irrespective of whether the regressors require time differencing to yield stationarity or not (*cf.* Box 1 above and Pesaran et al. (1996)):

$$\Delta(m-p)_t = c + \alpha[(m-p)_{t-1} + \beta_1 y_{t-1} + \beta_2 l_{t-1}] + \gamma_{11}\Delta y_{t-1} + \gamma_{12}\Delta l_{t-1} + \gamma_{13}\Delta s_{t-1} + \gamma_{14}\Delta \pi_{t-1} + \gamma_{15}\Delta(m-p)_{t-1} + \gamma_{01}\Delta y_t + \gamma_{02}\Delta l_t + \gamma_{03}\Delta s_t + \gamma_{04}\Delta \pi_t \quad (10)$$

The following estimated (parsimonious) version of (10) was found to fit the data sufficiently well (with "t-statistics" in parenthesis):[30]

$$\Delta(m-p)_t = -\underset{(-3.33)}{0.501} - \underset{(-4.31)}{0.096}(m-p)_{t-1} + \underset{(4.17)}{0.127}y_{t-1} - \underset{(-2.14)}{0.231}l_{t-1} + \underset{(2.20)}{0.806}\Delta l_t - \underset{(-5.33)}{0.742}\Delta\pi_t + \underset{(6.22)}{0.497}\Delta(m-p)_{t-1} - \underset{(-2.32)}{0.911}\Delta l_{t-1} - \underset{(-1.91)}{0.133}\Delta y_{t-1} - \underset{(-3.13)}{0.424}\Delta\pi_{t-1}$$

The long-run relationship underlying this representation is the following:

$$(m-p)_t = 1.32y_t - 2.4l_t.$$

Considering the uncertainty underlying these estimates, they can be considered to lie well within the ranges of the system estimates of this relationship provided in BC (2000).

The stochastic coefficient method (see Box 4) was applied to the parsimonious version of model (10).[31] All model coefficients were allowed to vary. The evolution of the long-run coefficients of the monetary equilibrium and the loading coefficient of the monetary disequilibrium can be implicitly calculated from the evolution of the respective elements of the state variable. Figure 13, Figure 14 and Figure 15 show the evolution of the implied long-run income elasticity, the implied long-run interest rate semi-elasticity, and of the adjustment parameter (loading coefficient) from 1985 Q3 to 2001 Q2. The estimates of the parameters are smoothed estimates. It is apparent that the income elasticity, which accounts for the trend behaviour of velocity, under the assumption of price stability, behaves in a remarkably stable manner. There are some fluctuations, but their scale is absolutely negligible. In contrast to this, the interest rate semi-elasticity is estimated to have fluctuated widely. This is in line with the greater uncertainty surrounding the estimate of this coefficient in the linear model. As with the linear OLS estimate presented above, a striking feature of the stochastic estimates of the loading coefficient (corresponding to α in equation (9)) is that it is about half the size of

28 *Except for the interest rates all variables are in logs. Time differences are denoted by Δ. In this application, interest rates have been divided by 400.*

29 *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 with the nominal long-term interest rate.*

30 *AdjR^2=0.56; Std. Err. of regression: 0.003; Durbin's h=-0.857; Sample period: 1980 Q2-2001 Q2.*

31 *As a-prioris for the distribution of the state vector for its mean, the OLS coefficient estimates were used and for its variance the variance-covariance matrix of the OLS coefficient estimates with the diagonal elements multiplied by 100. The estimation carried out in this section was done using EViews 3.1.*

the respective coefficient obtained within the systems approach (see BC (2000)). Therefore, the forces pulling the variables towards the monetary equilibrium are generally lower. From the stochastic evolution of the loading coefficient, it is also evident that these forces have varied over time. From about 1991 to about 1993 they seem to have been particularly weak. While these results suggest that there are considerable uncertainties with the estimation of the interest rate semi-elasticity of the demand for M3, the income-elasticity accounting for the velocity trend is remarkably stable. In addition, there are no signs of instability particularly related to the start of Stage Three of EMU.

Figure 13

Stochastic evolution of income elasticity in BC money demand function

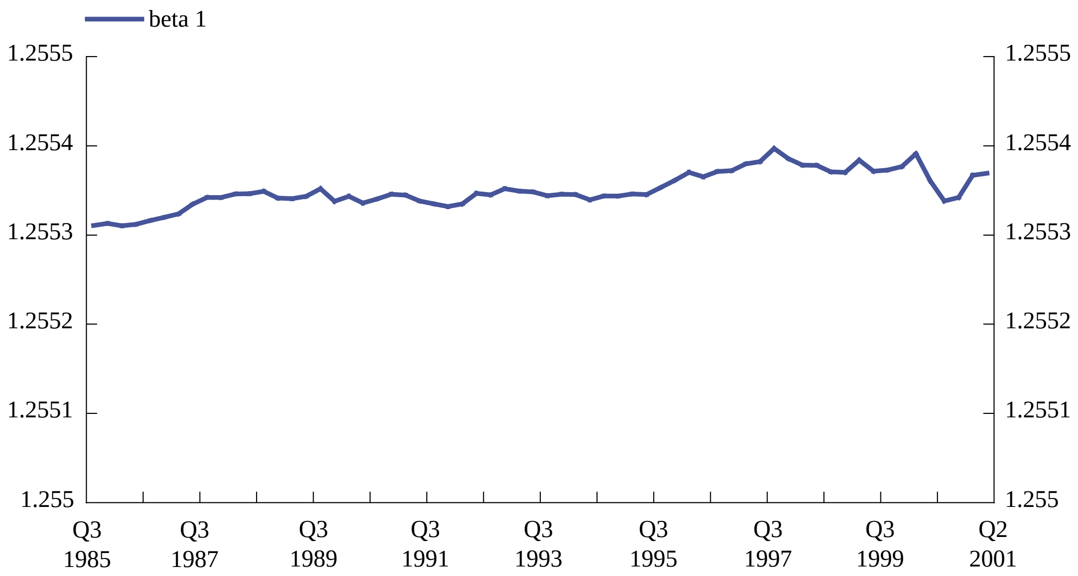


Figure 14

Stochastic evolution of interest rate semi-elasticity in BC money demand function

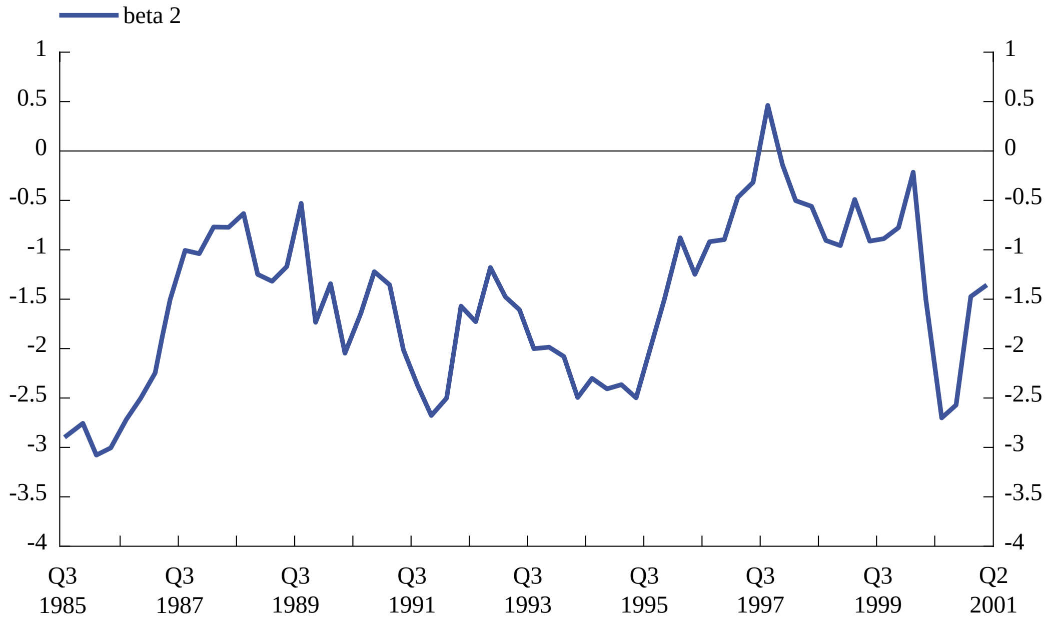
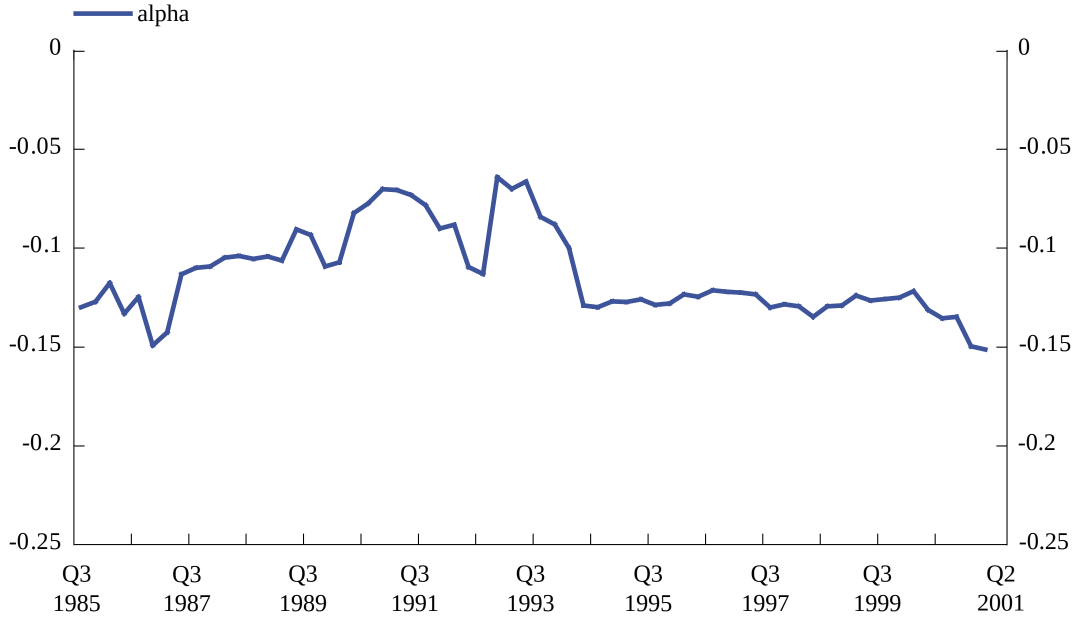


Figure 15

Stochastic evolution of (implicit) loading coefficient of monetary disequilibrium in BC money demand function



Running the Kalman filter for the whole sample period (*cf.* Box 4), thus using all available information, yields the following distribution of the stochastic version of model (10):[32]

$$\Delta(m-p)_t = \underset{(-1.151)}{-\,0.634} - \underset{(-3.103)}{0.151}(m-p)_{t-1} + \underset{(3.028)}{0.190}y_{t-1}$$
$$-\,\underset{(-0.412)}{0.207}l_{t-1} + \underset{(1.843)}{2.231}\Delta l_t - \underset{(-4.345)}{0.520}\Delta\pi_t$$
$$-\,\underset{(-0.0525)}{0.005}\Delta(m-p)_{t-1} - \underset{(-0.031)}{0.094}\Delta l_{t-1}$$
$$-\,\underset{(-4.338)}{0.262}\Delta y_{t-1} - \underset{(-3.205)}{0.406}\Delta\pi_{t-1} \qquad (11)$$

The long-run relationship implied by this representation is:

$$(m-p)_t = 1.255y_t - 1.371l_t. \qquad (12)$$

The estimate of the single money demand equation using a random coefficient method is broadly in line with the OLS estimates. More importantly, it does not reveal instabilities in the income elasticity of money demand which is crucial to assess the trend in M3 income velocity.

B.2.2 A single-equation error-correction representation of the Calza-Gerdesmeier-Levy model

In the context of the CGL model, the single-equation error-correction representation for M3 on which the stochastic representation will be based is of the following ADL form:

$$\Delta(m-p)_t = c + \alpha[(m-p)_{t-1} + \beta_1 y_{t-1}$$
$$+\,\beta_2(s-own)_{t-1}] + \gamma_{12}\Delta(m-p)_{t-1}$$
$$+\,\gamma_{13}\Delta s_{t-1} + \gamma_{14}\Delta l_{t-1} + \gamma_{15}\Delta own_{t-1} + \gamma_{16}\Delta oil_{t-1}$$

where m, p, y and oil denote nominal M3, the GDP deflator, real GDP and the oil prices; while s, l and own denote the short-term market interest rate, the long-term market interest rate and the own rate of M3, respectively. Estimating the equation outlined above by OLS yields the following results:[33]

$$\Delta(m-p)_t = \underset{(-2.2)}{-\,0.563} - \underset{(-2.6)}{0.091}(m-p)_{t-1} + \underset{(2.5)}{0.126}y_{t-1}$$
$$-\,\underset{(-0.8)}{0.172}(s-own)_{t-1} + \underset{(1.1)}{0.106}\Delta y_{t-1}$$
$$-\,\underset{(3.2)}{0.311}\Delta(m-p)_{t-1} - \underset{(-0.4)}{0.183}\Delta s_{t-1} - \underset{(-3.0)}{1.703}\Delta l_{t-1}$$
$$+\,\underset{(1.2)}{1.428}\Delta own_{t-1} + \underset{(3.5)}{0.010}\Delta oil_{t-1}$$

The long-run relationship underlying this representation is:

$$(m-p)_t = 1.38y_t - 1.89\,(s-own)_t.$$

As for the BC model, the stochastic coefficient method was applied to the parsimonious version of the model.[34] Again, all model coefficients were allowed to vary. The evolution of the long-run coefficients of the monetary equilibrium and the loading coefficient of the monetary disequilibrium can be implicitly calculated from the evolution of the respective elements of the state variable. The following figures show the evolution of the implied income elasticity, the implied spread semi-elasticity, and of the loading coefficient from 1985 Q3 to 2001 Q2. All parameter estimates are smoothed estimates. As in the BC model, the income elasticity, which accounts for the trend behaviour of velocity, under the assumption of price stability, behaves in an extraordinarily stable manner. Moreover, the spread semi-elasticity as well as the adjustment parameter show a fairly stable behaviour over time. In accordance with the BC model, there are no signs of instability particularly related to the start of Stage Three of EMU.

32 AdjR^2=0.99; Std. Err. of regression: 1.7E-9; Durbin's h=1.44; Sample period: 1980 Q2-2001 Q2. In this application, in line with Brand and Cassola (2000), interest rates have been divided by 400.

33 AdjR^2=0.25; Std. Err. of regression: 0.004; LM(12)=21.7 (p-value: 0.05); sample period: 1980 Q2-2001 Q2.

34 In line with the BC model, as a-prioris for the distribution of the state vector, for its mean, the OLS coefficient estimates were used and for its variance the variance-covariance matrix of the OLS coefficient estimates with the diagonal elements multiplied by 100.

Figure 16

Stochastic evolution of income elasticity in CGL money demand function

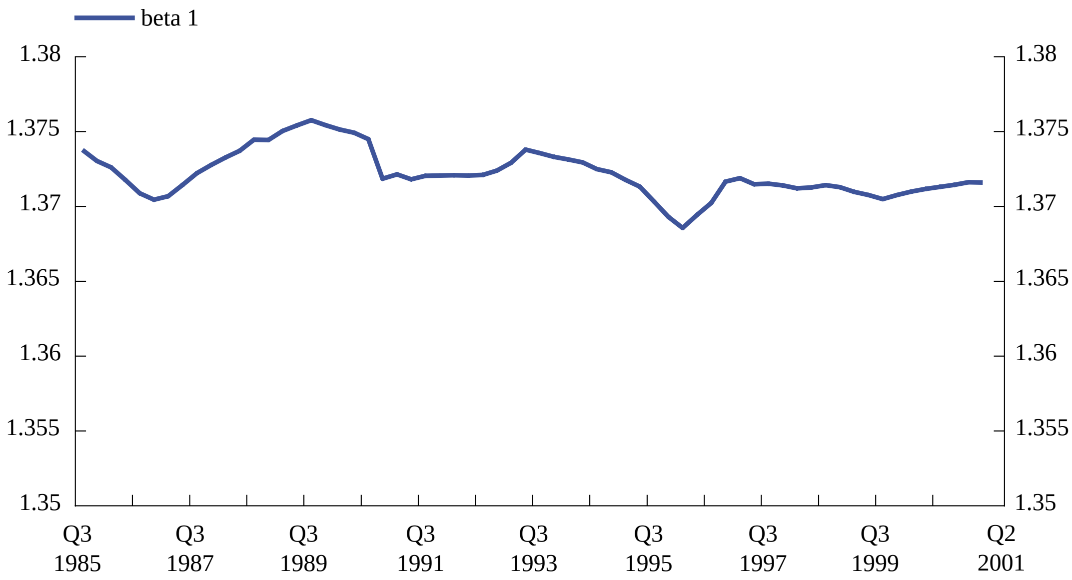


Figure 17

Stochastic evolution of spread semi-elasticity in CGL money demand function

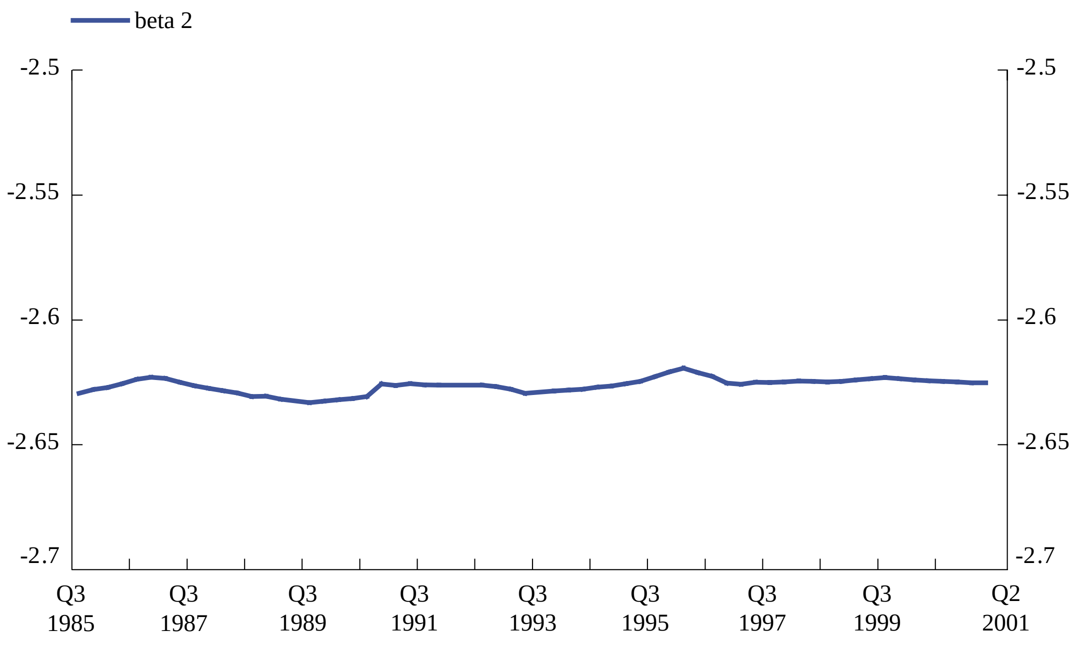
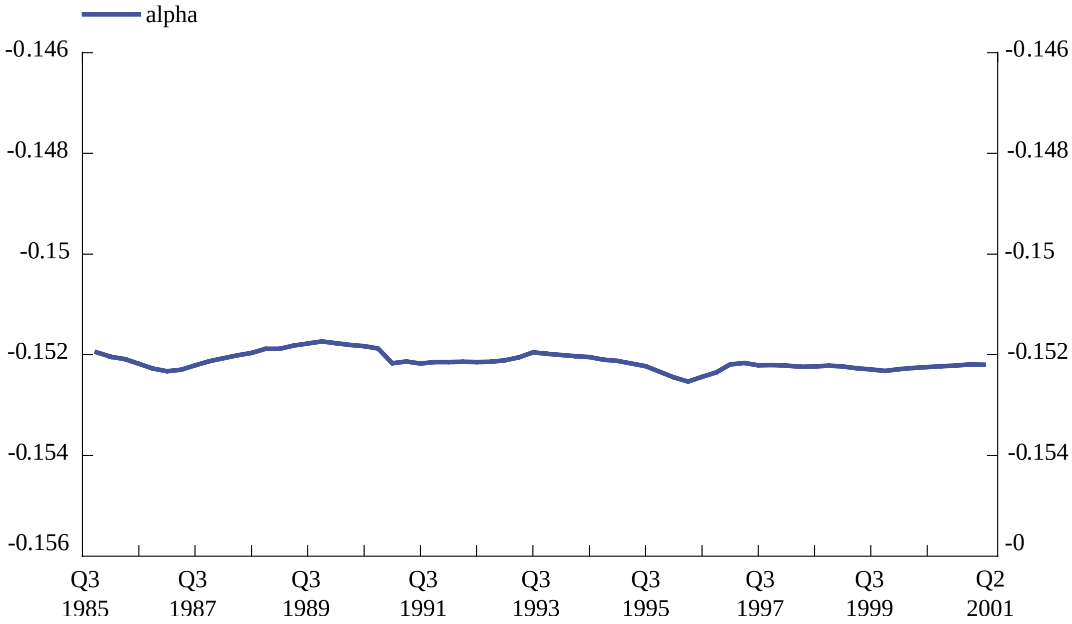


Figure 18

Stochastic evolution of (implicit) loading coefficient of monetary disequilibrium in CGL money demand function



The posterior distribution of the stochastic version of the model is:[35]

$$\Delta(m-p)_t = \underset{(-5.3)}{-0.916} - \underset{(-6.3)}{0.152}(m-p)_{t-1} + \underset{(6.2)}{0.209}y_{t-1}$$
$$- \underset{(-2.4)}{0.399}(s-own)_{t-1} - \underset{(-5.0)}{0.293}\Delta y_{t-1}$$
$$+ \underset{(1.4)}{0.110}\Delta(m-p)_{t-1} + \underset{(0.1)}{0.011}\Delta l_{t-1} + \underset{(3.3)}{0.307}\Delta s_{t-1}$$
$$- \underset{(-1.6)}{0.550}\Delta own_{t-1} + \underset{(0.8)}{0.068}\Delta oil_{t-1}$$

The long-run relationship implied by this representation is:

$$(m-p)_t = 1.372y_t - 2.625(s-own)_t.$$

As opposed to the estimates of the linear model, these estimates are the best which can be obtained using all available information in an efficient manner.

35 AdjR^2=0.99; Std. Err. of regression: 2.51E-6; Sample period: 1980 Q2-2001 Q2. T-statistics in parenthesis.

Annex C
Sensitivity analysis

The figures in this Annex contain a graphic comparison of the annual growth rates of the M3 and nominal GDP series for the euro area used in the main analysis in the text (solid line) with the M3 and GDP series for the euro area* and using the GDP-PPP aggregation method (dotted line).

Figure 19

Comparison of M3 data: euro area versus euro area*

(Annual percentage change)

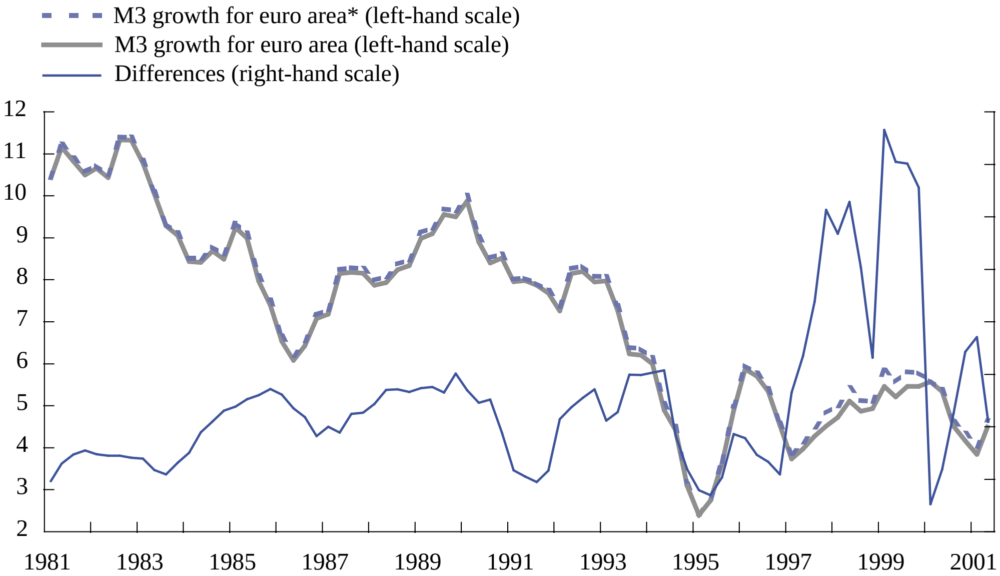


Figure 20

Comparison of nominal GDP data: euro area versus euro area*

(Annual percentage change)

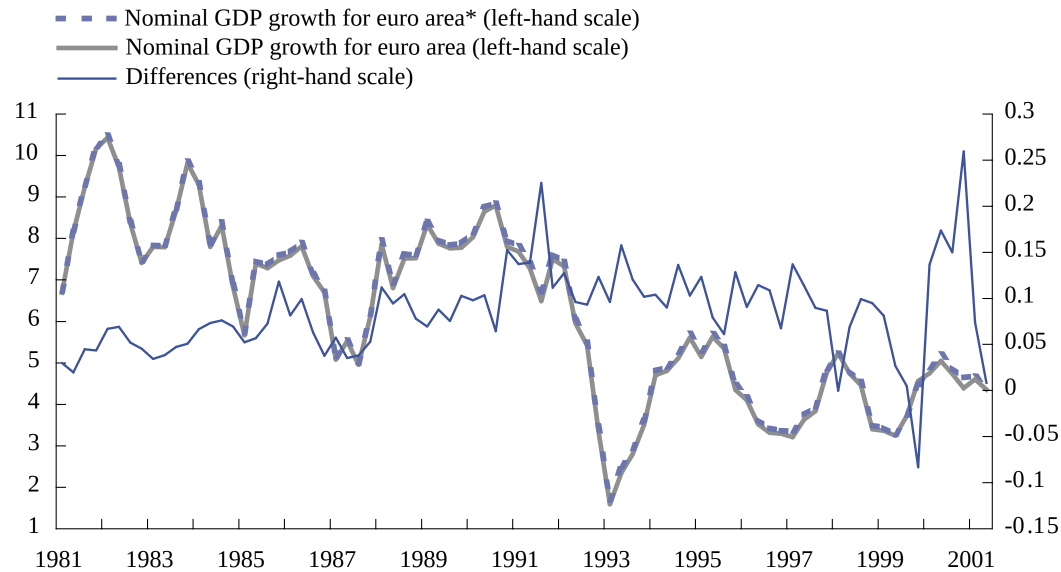


Figure 21

Comparison of euro area M3 data using different aggregation schemes

(Annual percentage change)

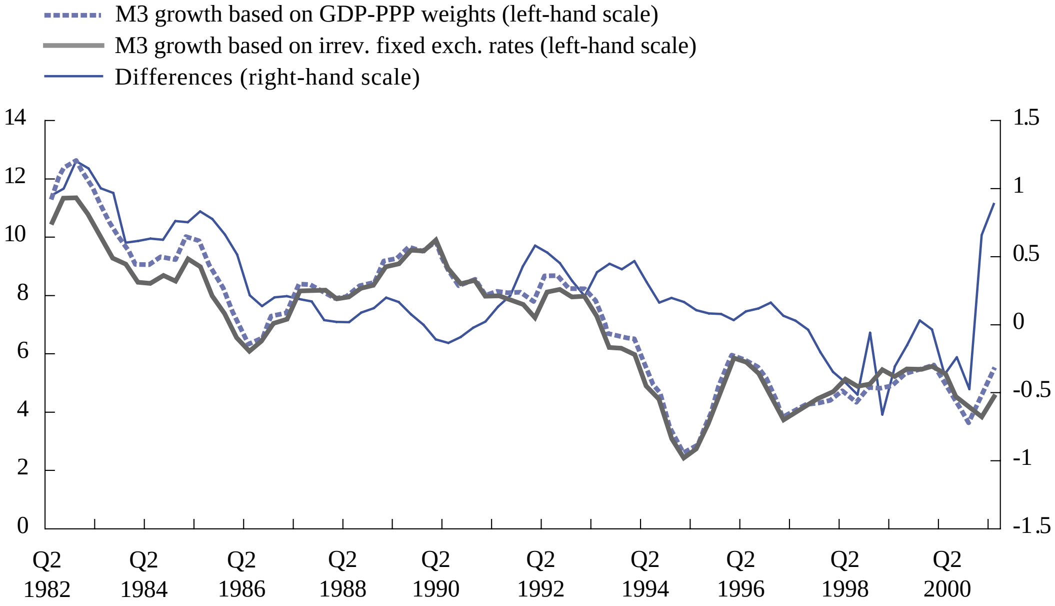
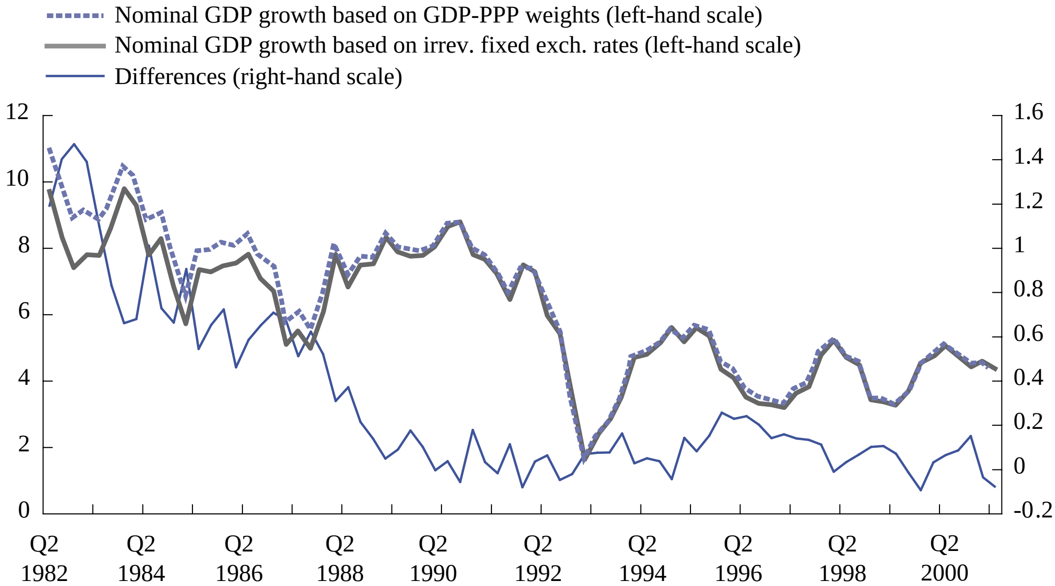


Figure 22

Comparison of euro area nominal GDP data using different aggregation schemes

(Annual percentage change)



Annex D
Data description

D.1 Monetary data

All the data used are denominated in euro. The seasonally adjusted M3 series for the euro area and for the euro area* have been constructed using the index of adjusted stocks and the (end-of-the-month) stock for the corresponding area. The following procedure has been applied:

a) the M3 seasonally adjusted index of adjusted stocks for the euro area (euro area*) has been re-based to be equal to 100 in January 2001;

b) this re-based index is then multiplied by the value of the seasonally adjusted stock for the euro area (euro area*) M3 in January 2001, this stock being derived by aggregating national stocks at irrevocable fixed exchange rates.[36] Therefore, the percentage change between any two dates (after October 1997) corresponds to the change in the aggregate excluding the effect of reclassifications, other revaluations or exchange variations and any other changes which do not arise from transactions.

c) quarterly data are averages of monthly data.

The procedure which was followed to compile euro area data aggregated using GDP weights consisted in:

a) compiling the seasonally adjusted index of adjusted stocks of M3 as a weighted average of the national log index using the 1999 GDP weights at PPP exchange rates;

b) re-basing this index equal to 100 in December 1998;

c) multiplying this index by the value of the seasonally adjusted stock of M3 in December 1998, this stock being compiled aggregating national stock using the irrevocable fixed exchange rates aggregation method;

d) quarterly data are averages of monthly data.

D.2 Nominal GDP data

The ESA 95 framework has to the widest degree possible been introduced into the historical series, so that the euro area GDP series have, to the widest extent possible, been based on the new national ESA 95 data. The ESA 95 regulation is being phased in gradually from 1999 to 2005.

Table 8 below gives an overview of the current state of the implementation of ESA 95 in the nominal GDP data in the individual countries. As is evident from the table, annual and quarterly data are not yet available for all countries going back to 1980. Therefore, the compilation of the quarterly euro area aggregate involves an estimation of missing data. The ECB's DG-Statistics has provided estimates for the quarterly data going back to 1980 through the following four-step procedure:[37]

- Quarterly ESA 95 data for each country are used when available;
- When for a period only annual ESA 95 data and quarterly non-ESA 95 data are available, the annual ESA 95 data are distributed over quarters according to the split of the quarterly non-ESA 95 data;

36 The seasonal adjustment is carried out on the aggregated (index and stock) series for the euro area.

37 It should be emphasised that such procedures in some cases only produce very rough estimates. These should not be considered at national level, but only for the purpose of euro area aggregation, where the resulting error in the aggregate is of lesser magnitude, since the roughest estimates relate to countries with low weights in the euro area aggregate.

- When for a period only non-ESA 95 data are available, they are appended to the ESA 95 series, by linking with the first available ESA 95 year, i.e. the previous non-ESA 95 series are rebased to the level of the ESA 95 data for the first available ESA 95 year;

- When for a period no quarterly data are available, the annual data (always available, but possibly obtained by mixing ESA 95 and previous series) are distributed among the quarters using the distribution of the euro area quarterly subset compiled under the two first steps.

The series for the euro area (euro area*) seasonally adjusted nominal GDP is constructed from seasonally adjusted national data. The procedure followed consists in:

a) Aggregating national GDP data using the irrevocable fixed exchange rates of 31 December 1998[38] for the period 1980 Q1-1998 Q4;

b) from 1999 Q1 onwards the official Eurostat series is used;[39]

c) As regards the euro area GDP series, an "artificial" series is then compiled. This series, from 2000 Q4 onwards, covers the euro-12 series; the observations from 2000 Q4 backwards are extrapolations based on growth rates calculated from the series compiled in point (a) and (b), i.e. covering the euro area – which, before 2001 Q1, refers to the euro-11 GDP data.

It should be emphasised that the nominal GDP series used for the derivation of the reference value since 1998 are not the official series on euro area nominal GDP published by Eurostat.

Table 8

Availability of data on nominal GDP compliant with the ESA 95 regulation

Country	Quarterly data		Annual data
	Seasonally adjusted	Non-seasonally adjusted	
Belgium	1985 Q1-2001 Q2	1985 Q1-2001 Q2	1980 – 2000
Germany	1991 Q1-2001 Q2	1991 Q1-2001 Q2	1991 – 2000
Greece	Not available	1970 Q1-2001 Q2	1970 – 2000
Spain	1980 Q1-2001 Q1	1980 Q1-2001 Q1	1980 – 2000
France	1978 Q1-2001 Q2	1978 Q1-2001 Q2	1978 – 2000
Ireland	Not available	1997 Q1-2000 Q4	1990 – 2000
Italy	1970 Q1-2001 Q2	1970 Q1-2001 Q2	1970 – 2000
Luxembourg	Not available	Not available	1995 – 2000
Netherlands	1977 Q1-2001 Q1	1977 Q1-2001 Q2	1977 – 2000
Austria	1988 Q1-2000 Q1	1988 Q1-2000 Q1	1988 – 2000
Portugal	1995 Q1-2001 Q1	Not available	1988 – 2000
Finland	1975 Q1-2000 Q1	1975 Q1-2000 Q1	1970 – 2000

The official (i.e. Eurostat) nominal GDP series is constructed before 1999 Q1 using an aggregation method which differs from the one used for M3.[40] Using the official GDP series would introduce spurious fluctuations into the velocity series related to exchange rate developments.[41] On the contrary, using the same aggregation method for both nominal GDP and M3, when calculating the M3 income velocity, the implicit price trend included in the two variables are weighted in the same way[42] and fluctuations in the historical M3

38 For compiling the euro area series, the irrevocable fixed exchange rate determined on 19 June 2000 for Greece is used.*
39 Obviously, the series in point (a) is re-scaled to match the Eurostat series in 1999 Q1.
40 The series for nominal GDP published by Eurostat is compiled using the current exchanges rate and is measured in ECU up to 1998 Q4.
41 As a matter of fact, the resulting velocity series would present spurious changes also attributable to exchange rate fluctuations and changes in the sterling exchange rate.
42 This would not be the case if the velocity series were compiled using the official series for euro area nominal GDP as published by Eurostat. As already mentioned in footnote 40, the series for nominal GDP published by Eurostat is compiled using current exchange rates. The resulting velocity series would include spurious changes caused by exchange rate fluctuations arising simply from the different aggregation methods used to construct nominal GDP and M3. Such a series would furthermore include distortions caused by changes in the sterling exchange rate, since the series published by Eurostat is measured in ECU prior to 1999.

income velocity series are purged of the effects of different aggregation methods.

As regards the nominal GDP series compiled using the 1999 GDP weights at PPP exchange rates,[43] this series has been constructed as follows:

a) The log levels of national seasonally adjusted nominal GDP series are aggregated using the 1999 GDP weights at PPP exchange rates up to the latest observation (i.e. up to 2001 Q2);

b) As regards the euro area GDP series, to avoid the break in 2001 Q1 due to the inclusion of Greece, the same method illustrated in point (c) above was applied. Therefore, for the euro area an "artificial" series is compiled which, from 2000 Q4 onwards, covers the euro-12 series, while the observations before 2000 Q4 are extrapolations based on growth rates calculated from the euro area series compiled in point (a).

D.3 Other series

The euro area (euro area*) seasonally adjusted real GDP series (at 1995 constant prices) has been constructed by aggregating national GDP data using the irrevocable fixed exchange rates. The series has been re-scaled in order to be consistent with the nominal GDP series in 1995. As for the euro area nominal GDP, an "artificial" euro area real GDP series has also been constructed using the procedure illustrated in point (c) above.

The GDP deflator is calculated as a simple ratio between nominal and real GDP. In the case of the aggregation method based on GDP weights, the nominal and real GDP series are first recovered from logarithms to calculate the deflator.

The euro area nominal interest rates used are weighted averages of national interest rates calculated with fixed weights based on 1999 GDP at PPP exchange rates. National short-term rates are three-month market rates. For short-term interest rates from January 1999 onwards, the euro area three-month EURIBOR is used. Long-term interest rates correspond to ten-year government bond yields, or the closest available maturity.

For the compilation of the own rate of return on M3, see Calza, Gerdesmeier and Levy (2001). As explained in that paper, this rate is computed for the period January 1980 – to date 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 (*cf.* Calza, Gerdesmeier and Levy (2001), p. 19).

The series for oil prices – world-market prices, energy raw material, crude oil – is taken from the BIS database and converted into euro using the BIS exchange rate series of the euro vis-à-vis the US dollar.

43 Source: Eurostat and ECB calculations.

Annex E
Index of notation and glossary

Acronyms

ADF: Augmented Dickey-Fuller test
ADL: Auto-regressive distributed lag
BC: Brand-Cassola (2000)
CGL: Calza-Gerdesmeier-Levy (2001)
CV: Coenen-Vega (1999)
DF: Dickey-Fuller test
EMU: Economic and Monetary Union
ESA: European System of Accounts
ESCB: European System of Central Banks
GDP: Gross domestic product. It can be nominal (i.e. at "current prices") or real (i.e. at "constant" 1995 prices).
KPSS: Kwiatowski, Phillips, Schmidt and Shin test
MFIs: Monetary Financial Institutions
MMF: Money market fund
NCBs: National central banks
PP: Phillips-Perron test
PPP: Purchasing power parity
TVP: Time varying parameter
VAR: Vector autoregression
VEC: Vector error correction

Notation

(Greek letters denote model coefficients and moment matrices unless otherwise indicated here, lower-case variables denote logarithms of their upper-case counterparts)

l_t :	long-term nominal interest rate (10-year government bond yield) at time $t=1,...,T$
m_t :	log of nominal stock of M3 at time $t=1,...,T$
o :	general expression for opportunity costs of holding money
own_t :	own rate of return on M3 holdings
p_t :	log of the price level (measured by the GDP deflator) at time $t=1,...,T$
s_t :	short-term nominal interest rate (3-month money market rate) at time $t=1,...,T$
t :	time index or time trend with $t=1,...,T$
TR :	volume of real transactions in an economy
v_t :	log of M3 income velocity, calculated as $v_t = p_t + y_t - m_t$ at time $t=1,...,T$
y_t :	log of real GDP at time $t=1,...,T$
y_t* :	log of potential output at time $t=1,...,T$
γ_t :	state vector of a state space model
Δ :	time difference of a series on a quarter earlier: $\Delta x_t \equiv x_t - x_{t-1}$, where x_t denotes the log of an economic variable
$\varepsilon_t,\eta_t,\varpi_t,\xi_t$:	mean-zero, serially uncorrelated innovation processes
π_t :	inflation rate (measured as the annualised quarter-on-quarter change in the GDP deflator) at time $t=1,...,T$

Glossary

ESA 95 data: These data refer to the ESA95 harmonised national account data which are provided by Eurostat. The compilation follows the accounting definitions and computational methodology adopted in the ESA95 Regulation (Official Journal L310 of 30/11/96).

European System of Central Banks (ESCB): the European Central Bank and the national central banks of the EU Member States.

Eurosystem: the European Central Bank and the national central banks of the EU Member States which have adopted the euro.

M3: it consists of currency in circulation, overnight deposits, deposits with an agreed maturity of up to two years, deposits redeemable at notice up to three months, repurchase agreements, money market fund shares/units, money market paper and debt securities with a maturity of up to two years and is net of unit/shares of money market funds, money market paper and other short-term securities with a maturity of up to two years issued by MFIs and held by non-euro area residents (as published from November 2001).

Monetary Financial Institutions (MFIs): financial institutions which form part of the money-issuing sector of the euro area. This sector includes the Eurosystem, resident credit institutions as defined in Community law and all other resident financial institutions whose business is to receive deposits and/or close substitutes from entities other than MFIs and, for their own account (at least in economic terms) to grant credit and/or invest in securities.

Money Market Fund (MMF): fund that invests in short-term securities.

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1 "The impact of the euro on money and bond markets" by Santillán, M. Bayle and C. Thygesen, July 2000.

2 "The effective exchange rates of the euro" by L. Buldorini, S. Makrydakis and C. Thimann, February 2002.

3 "Estimating the trend of M3 income velocity underlying the reference value for monetary growth" by C. Brand, D. Gerdesmeier and B. Roffia, May 2002.