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Stephen G. Hall
George Hondroyiannis
P.A.V.B. Swamy
George S. Tavlas

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Stephen G.Hall
Leicester University and NIESR

George Hondroyiannis
Bank of Greece

P.A.V.B. Swamy
U.S. Bureau of Labor Statistics

George S. Tavlas
Bank of Greece

ABSTRACT

As part of its monetary policy strategy, the European Central Bank has formulated a reference value for M3 growth. A pre-requisite for the use of a reference value for M3 growth is the existence of a stable demand function for that aggregate. However, a large empirical literature has emerged showing that, beginning in 2001, essentially all euro area M3 demand functions have exhibited instability. This paper considers euro-area money demand in the context of the portfolio-balance framework. Our basic premise is that there is a stable demand-for-money function but that the models that have been used until now to estimate euro area money-demand are not well-specified because they do not include a measure of wealth. Using two empirical methodologies - - a co-integrated vector equilibrium correction (VEC) approach and a time-varying coefficient (TVC) approach - - we find that a demand-for-money function that includes wealth is stable. The upshot of our findings is that M3 behaviour continues to provide useful information about medium-term developments on inflation.

Keywords: Money demand; VEC, time varying coefficient estimation; Euro area
JEL classification: C20; E41

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Correspondence:
George Tavlas,
Economic Research Department,
Bank of Greece, 21, E. Venizelos Ave.,
102 50 Athens, Greece
Tel. +30210-320 2370
Fax +30210-320 2432
email: gtavlas@bankofgreece.gr

1. Introduction

Since the inception of the euro area on January 1, 1999, a prominent role has been assigned to money within the monetary-policy strategy of the European Central Bank (ECB). [1] In particular, the ECB has set a reference value of 4 ½ per cent for the annual growth of broad money (M3), a growth rate viewed as consistent with price stability over the medium term.[2] Apart, however, from a brief period between mid-2000 to mid-2001, when the growth of M3 was below its reference value, since the start of the euro area M3 growth has consistently exceeded its reference value by magnitudes typically ranging from 2 to 5 percentage points per annum.[3] This circumstance has raised concerns about (1) the possibility of a monetary overhang that could at some point lead to higher inflation (ECB, 2004) and (2) the relevance of a reference value for money growth in the formulation of monetary policy.

A pre-requisite for the use of a reference value for M3 growth is the existence of a stable demand function for that aggregate. Yet, beginning in 2001, essentially all euro area M3 demand functions have exhibited instability. One response, especially by researchers at the ECB, has been to adjust M3 for portfolio shifts in the light of heightened financial-market uncertainty during the period 2001-2003.[4] Another approach has been to augment money-demand functions with additional variables, particularly variables relating to the return in equity-markets and the volatility of share-market prices, on the presumption that both the decline in equity-market prices and a rise in their volatility during 2001-03 led to a flight into money balances (Beyer, Fischer, and von Landesberger, 2007). The upshot of these attempts to repair the M3 demand function has been to produce specifications that exhibit stability through 2003; thereafter, however, the demand for M3 again exhibits instability (Beyer, Fischer, and von Landesberger, 2007; Fischer, Lenza, Pill, and Reichlin, 2007).

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[1] For a detailed description of the ECB's monetary-policy strategy, see Issing, Gaspar, Angeloni, and Tristani (2001)

[2] This reference value is based on the assumption that, with trend output growth estimated at 2 to 2 ½ per cent and trend velocity declining by around ½ to 1 per cent, in order to keep inflation below 2 per cent, the money stock should grow by 4 ½ to 4 ¾ per cent per year.

[3] See the discussion below in Section 2.3.

[4] See Beyer, Fischer and von Landesberger (2007). Effectively, this approach involves adjusting M3 growth for portfolio shifts into money balances during periods of exceptional financial-market volatility caused, for example, by the September 11, 2001 terrorist attacks.

This paper considers euro-area money demand in the context of the portfolio-balance framework proposed by Brainard and Tobin (1968) and Tobin (1969).[5] This framework contains the following implications for the empirical specification of money demand. First, unlike other conceptual approaches, which treat income and wealth interchangeably as determinants of transactions money demand, in the portfolio balance model wealth is the variable that constitutes the total budget constraint on the holdings of assets, including money. An increase in wealth results in increased demands for all assets, whereas an increase in income increases the demand for money at the *expense of* other assets, so that *both* income and wealth belong in the money-demand function. However, in the light of the absence of a euro-area measure of financial and housing wealth, most empirical work on euro-area money demand has used income, in place of wealth, as the scale variable. In this paper, we construct a measure of wealth, using stock-market valuation as a proxy, and we consider a variable that captures the difference between real stock-market valuation and real income as a determinant of money demand. It is important to stress that the wealth variable should in theory include all wealth, that is, financial wealth, housing wealth, human wealth, and other assets. In particular, we believe that financial and housing wealth variables have moved in quite distinct ways and, as we discuss below, this factor is an important element in the explanation of the demand for money. In the absence of reliable data, a proxy for these variables is included in the money-demand function. Second, we assume a two-asset model comprised of money and equities. In such a framework, a change in the money supply operates on the rate of return on equities so that the relevant opportunity cost for holding money balances is the rate of return on equities minus the own rate of return on money.

Our basic premise is that there is a stable, but complex, demand-for-money function, but the models presently used to estimate euro-area money demand are not well-specified, given the lack of good wealth data.[6] Consequently, in the absence of a

[5] Friedman (1956) also proposed the money demand function that included both the rate of return on equities and wealth. However, Friedman did not adopt a portfolio balance analytic framework.

[6] By "complex" we do not mean that the stable demand-for-money function is necessarily complicated, but that it may be non-linear with heteroscedastic and contemporaneously and serially correlated errors, with possibly more explanatory variables than included in the models presently used to estimate euro-area money demand. This stable model may appear complicated, but is the result of correcting for model misspecifications which, if uncorrected, can result in misestimated coefficients. Before accepting a model as well-specified, it is a good idea to check whether appropriate corrections for the model misspecifications have been applied to it, since model misspecifications are unavoidable for reasons given in Swamy and Tavlas (2001). Zellner (2007, p. 335) is a critic of complicated models.

well-specified model, most recent studies of euro-area money demand exhibit instability. We adopt two empirical methodologies to shed light on this issue - - a co-integrated vector equilibrium correction (VEC) approach and a time-varying coefficient (TVC) approach. The latter approach is designed to reveal the biases in coefficients that may result from model misspecifications. Applying the VEC methodology to a portfolio-balance model, our results provide support for the view that a portfolio-balance specification of M3 demand is stable over the estimation period, 1980:Q1-2006:Q3.[7] A key implication of this finding is the need to incorporate a wealth variable in the money-demand specification. Application of TVC estimation to a money-demand model incorporating both income and wealth reveals that the purported rise in the income elasticity of M3 demand, detected in some previous studies, reflects specification biases.

The remainder of the paper consists of three sections. Section 2 presents the model and the empirical approaches. Section 3 describes the data and presents the empirical results. Section 4 concludes.

2. Theoretical and Empirical Underpinnings

2.1 *Theoretical Framework*

As noted above, our approach is to use the portfolio-balance model to estimate the demand for money. Specifically, assuming that the asset choices of investors involve money (M) and equities, the demand for real money balances can be written as follows:

$$m - p = f(\overset{+}{y}, \overset{+}{w}, \overset{+}{r^m - \dot{p}^e}, \overset{-}{r^e - \dot{p}^e}) \tag{1}$$

where m is the log of nominal M3, p is the log of the price level, y is the log of real income, w is the log of the real value of wealth, r^m is the own rate of return on money, $\dot{p}^e$ is the expected inflation rate, and r^e is the rate of return on equities.[8] In

[7] Although the euro area was formed on January 1, 1999, data for the euro area are available in the Data Warehouse of the ECB beginning with the first quarter of 1980.

[8] Under the Brainard-Tobin (1968) set-up, the main indicator of the stance of monetary policy is the rate of return on equities. Brainard and Tobin (1968, p. 104) argued that: "Nothing else [other than the equity yield], whether it is the quantity of 'money' or some financial interest rate, can be more than an imperfect indicator of the effective thrust of monetary events and policies."

equation (1), real rates of return are approximated by nominal rates minus the expected inflation rate.

We also assume rate-of-return homogeneity of degree zero, implying that, if all rates of return change by x per cent, real quantities of assets in investors' portfolios relative to real income and real wealth will not change. Thus, only rates-of-return differentials affect money demand. Rate-of-return homogeneity implies that we can use interest differentials, selecting one of the assets as numeraire; we use m as a numeraire. Therefore, the money-demand function can be re-written as:

$$(m-p) = f(\overset{+}{y}, \overset{+}{w}, r^e \overset{-}{-} r^m) \tag{2}$$

When f is linear, the money-demand function (in semi-logarithmic form) becomes:

$$(m-p)_t = a_0 + a_1 y_t + a_2 w_t + a_3 (r^e - r^m)_t + u_t \tag{3}$$

where u_t is an added error term.[9] Adding and subtracting $a_2 y_t$ on the right-hand-side of (3) gives:

$$(m-p)_t = a_0 + a_1' y_t + a_2 (w-y)_t + a_3 (r^e - r^m) + u_t \tag{4}$$

where $a_1' = a_1 + a_2$. [10] The functional form of model (2) may or may not be linear as we assumed here and hence model (4) derived from this linearity assumption may or may not accurately represent a long-run demand function for the real money stock M3. We consider both the possibilities in this paper. Specifically, we consider both a VEC approach that assumes the linearity of (2) and a TVC approach that does not do so.

2.2 *Estimation Approaches*

In this paper, two estimation procedures - - VEC and TVC - - are used to assess the properties of money demand. These approaches are very different in nature, but have a surprisingly common underlying philosophy.

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[9] Typically, u_t is assumed to fulfill certain conditions (e.g., independence of u_t and the explanatory variables included in (3) to produce unbiased or consistent estimators of the coefficients of (3). For a critique of these conditions, see Pratt and Schlaifer (1988, p. 34). As discussed in Swamy and Tavlas (2001), the TVC procedure is not subject to this critique.

[10] Our specification is identical to that derived by Tobin (1969, p. 20, equation (I.2)), except that Tobin included the ratio of income to wealth rather than the ratio of wealth to income.

The VEC procedure is an implementation of the approach to modeling developed within the dynamic modeling tradition (for a detailed account, see Cuthbertson, Hall and Taylor (1991)). This approach begins from a general statement of the true economic system, referred to as the data generation process (DGP). The DGP, by definition, is correct and well-specified, but the approach also recognizes that no empirical model can fully capture the DGP. The process of modeling is viewed as an attempt to provide a reasonable approximation to the DGP (a congruent model) through an iterative search procedure involving marginalizing, conditioning and model specification, and an extensive formal set of econometric tests. Even at the end of a successful modeling exercise, a claim of having uncovered the truth cannot be made. All that can be claimed is that a reasonable approximation to certain aspects of the DGP has been found.

The TVC approach (for descriptions, see Swamy and Tavlas (1995, 2001, 2005, 2007)) also takes as its point of departure the idea that there is a true, stable economy. Unlike the VEC approach, however, the TVC approach takes the view that any econometric model is almost certainly a misspecified version of the truth. This misspecification may take the form of omitted variables, endogeneity problems, measurement errors, and incorrect functional form (broadly, the dynamic modeling ideas of marginalization, conditioning and model specification). These problems are expected to produce estimated coefficients that will be unstable and time-varying. Hence, a TVC estimation technique is used that tries to identify the causes of the coefficient instability by using a set of 'driving' variables.[11] The idea underlying the technique is to, first, estimate a model with coefficients that are allowed to vary as a result of the fundamental misspecifications in the model, and, then, to identify the specification biases that are occurring in the underlying coefficients and to remove them. If the process is successfully done, we observe a set of biased coefficients, which should exhibit considerable time variation, and a set of bias-corrected coefficients; the latter should reveal the underlying stable parameters of interest.[12]

A great advantage of the TVC approach is that it is robust to the true model being highly non-linear. Non-linearity, of course, is almost certainly the case and we can often see serious problems with standard linear models. For example, many

[11] As noted below, these variables are called "coefficient drivers".
[12] In contrast to the VEC approach, the TVC approach involves no pretesting. For criticisms of pretesting, see Maddala and Kim (1998, pp. 229-231) and Friedman and Schwartz (1991, pp. 47-49).

money demand functions find the income elasticity to be above 1. This result, however, cannot be a permanent feature of a model because, if income grows continuously, the money supply would eventually become larger than total income. In fact, either the model must be non-linear or the coefficients must change to ensure that this impossible event does not occur. The TVC approach does exactly this. The VEC approach, therefore, can only really be seen as a local approximation to the true non-linear model. Typically, we would expect that the condition is difficult to specify. In the context of our study, an issue is whether the approximation is a useful and congruent one.

In practice, the VEC approach usually begins by testing for the existence of a long-run equilibrium, or co-integrating, relationship among the variables in equation (4). If such a relationship exists, it is augmented with lagged differences of those variables and other stationary variables that economic theory may suggest as belonging in equation (4) in an attempt to capture the short-run dynamics of the variables in the system. Standard methodology employs a three-step procedure. In the first step, the variables are tested for stationarity. The second step involves vector autoregressive (VAR) estimation and misspecification testing, and tests for co-integration. Provided that one or more co-integrating relationships exist, the third step involves the estimation of a VEC specification containing the co-integrating relationship(s), lagged first differences of the variables in the co-integrating relationship(s), and any stationary variables thought to influence money demand. As explained below, the additional variables used in this paper include lagged changes in oil prices (to capture the impact of external developments on domestic prices at times of rapid changes in import prices) and current changes in annualized quarterly inflation (relaxing short-term price homogeneity) - - both used by the ECB in estimation of the "workhorse model" (Fischer, Lenza, Pill, and Reichlin, 2007) - - and several trending variables constructed from available financial wealth variables, as discussed in detail below.

Under the TVC approach, the coefficient of each explanatory variable included in (4) can be viewed as the sum of three terms: (1) a component measuring the effect of the explanatory variable on m - p without specification bias, that is, the bias-free component, (2) the omitted-variables bias component, and (3) the measurement-error-bias component.[13] We are interested in obtaining the bias-free component because if it is zero the relationship between m - p and the explanatory variable is considered to be spurious.[14] To separate this component from the remaining two components, we use "coefficient drivers" in conjunction with the TVC model.[15] Intuitively, coefficient drivers, which should be distinguished from instrumental variables, may be thought of as variables, though not part of the explanatory variables of money demand, that serve two purposes. First, they deal with the correlation between the included explanatory variables and *their coefficients*.[16] In other words, even though it can be shown that the included explanatory variables are not unconditionally independent of their coefficients, they can be conditionally independent of their coefficients given the coefficient drivers. Second, the coefficient drivers allow us to decompose the coefficients of the TVC model into their respective components. TVC estimation is apt to be an especially relevant procedure for capturing dynamics during periods of structural change, as experienced by the economies comprising the euro area since the early 1980s. In effect, the driver variables are capturing the misspecifications in the econometric model.[17]

We bring together the two estimation approaches in this study. First, we undertake an assessment of the co-integration properties of the standard model (*i.e.*, the model without a wealth variable) and find that it is, indeed, misspecified. We then add a number of variables that produce successful and stable co-integration. Next, we turn to the TVC approach, using these additional variables as coefficient drivers. We find that they do successfully remove the time variation in the estimated coefficients and reveal underlying stable, bias-free, parameters. Thus, in the case of euro-area money demand, the two techniques support each other.

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[13] The intercept of (4) also consists of three components (Swamy and Tavlas, 2001).

[14] See Swamy, Tavlas and Mehta (2007). The definition of spurious regression presented by those authors applies to both linear and non-linear regression models and, unlike Granger and Newbold's (1974) definition, takes into account the specification biases contained in the coefficients of those models.

[15] The TVC procedure is required because each of the three components is likely to be time-varying. All the three components are time-varying if the underlying "true" model is non-linear. The omitted-variables bias component is time-varying if the set of omitted variables changes over time and the relationship between included and excluded variables is non-linear. The measurement-error-bias component is time-varying if these errors change over time.

[16] A formal definition of coefficient drivers is provided in Swamy and Tavlas (2006).

[17] Pratt and Schlaifer (1988, p. 49) pointed out that a Bayesian will do much better to search like a non-Bayesian for concomitants that absorb 'proxy effects' for excluded variables. The rationale underlying our search for coefficient drivers is identical with the rationale provided by Pratt and Schlaifer for the need to search for concomitants.

2.3 *Existing Models*

The majority of euro-area money-demand models have been estimated using the VEC methodology.[18] In general, studies using data through the year 2000 tended to find evidence of money-demand stability. As noted above, beginning around the middle of 2001 virtually all euro-area M3 demand models have been characterized by instability, whereby instability is taken to mean the absence of a co-integrating relationship.

In response to this instability, the ECB has employed the following long-run money-demand model:

$$(m-p)_t = k + 1.3\,y_t - 1.1\,(r^i - r^m)_t \tag{5}$$

where r^i is the nominal interest rate on short-term inter-bank deposits. This particular specification, without w and with r^e replaced by r^i in equation (3), due to Calza, Gerdesmeier and Levey (2001), is considered by the ECB to be its "workhorse" money-demand model. In obtaining co-integration, Calza, Gerdesmeier and Levey began by specifying the following model

$$(m-p)_t = \beta_0 + \beta_1 y_t + \beta_2\,(r^i - r^m)_t + \beta_3\,(r^l - r^m)_t \tag{6}$$

where r^l is a long-term interest rate constructed as a GDP-weighted average of yields on national 10-year government bonds (or their closest substitutes) of euro-area economies. While the authors obtained a co-integrating relationship over the estimation period 1980:Q1 - 1999:Q4, they found that the coefficient on the long-term spread carried the wrong sign and was close to zero. Therefore, on the basis of the results of exclusion tests, they restricted the coefficient on the long-term spread (*i.e.*, $r^l - r^m$) to zero and re-estimated the system including only the variables y_t and $r^i - r^m$. The resulting system was again found to be co-integrated. However, because this function became unstable after 2001:Q2, in their monetary analysis the ECB staff subsequently froze the coefficients at the values (shown in equation (5)) estimated as of 2001:Q2 (*i.e.,* at the values that produced co-integration).

To illustrate the problem confronting standard specifications of euro-area money demand, we re-estimated the Calza, Gerdesmeier, and Levey model over the

[18] A review of the empirical literature on euro-area money demand is provided in Bayer, Fischer, and von Landesberger (2007).

period 1980:Q1 - 2006:Q3 based on data provided by the ECB staff. The results are reported in Table 1. As shown in the table, none of the Johansen co-integration tests is able to reject the null hypothesis that there is no co-integration.

The instability of euro-area money demand is reflected in the behavior of M3 income-velocity. Figure 1 shows income velocity during the period 1980:Q1-2006:Q3. Over the period 1980:Q1-2001:Q2, velocity declined by about 0.9 per cent per year, with some (temporary) instability evident during 1992-95. After 2001:Q2, the trend decline in velocity appears to have undergone a break, with the decline in velocity during 2001:Q3-2006:Q3 averaging 3.4 per cent per year. This decline in velocity was accompanied by an acceleration of M3 growth in late 2006 to a level of more than double its reference value of 4 ½ per cent. As shown in Figure 2, inflation remained near the ECB's definition of price stability of close to, but below, 2 per cent despite the acceleration of M3 growth.

3. Data and Empirical Results

The estimates reported below are based on quarterly data for the euro area over the period 1980:Q1 – 2006:Q3. The variables used are broad money (M3), real GDP, nominal GDP, the GDP deflator, the own rate on M3, oil prices (in euros), and a measure of euro-area stock prices.[19] As discussed below, the latter variable (euro-area stock prices) was used to construct a proxy for euro-area wealth and to derive a measure of the rate of return on equities.[20] The measure of euro-area nominal stock prices was approximated using the German stock-market-price index[21] for the period 1980:Q1 to 1986:Q4 (because a euro-area European stock price index was not available for this period) and the Dow Jones Euro Stock index from 1987:Q1 to 2006:Q3.[22]

The stock of real M3 (m-p) was measured by the log of M3 minus the log of the GDP deflator. Real income, y, was measured as the log of real GDP. A problem that we faced is that a comprehensive wealth variable for the euro-area does not exist.

[19] Oil prices were originally in dollars but were converted into euros using market exchange rates.
[20] All data except stock prices were provided by the staff of the ECB. For additional details on the data, see Fischer, Lenza, Pill and Reichlin (2007).
[21] The German stock-price index was obtained from the International Financial Statistics (IFS), line 62.
[22] Data for stock prices were downloaded from the Data Warehouse of ECB.

Hence, a proxy for the log of real wealth to real income ratio (w-y) was constructed as the log of the ratio of observed stock prices to nominal income (log of real stock prices minus log of real income). That is, we used the stock market variable as a proxy for wealth; the proxy was employed to construct a variable that captures the difference between real wealth (as reflected by real stock-market valuation) and real income. The variable representing the spread on return on equities $(r^e - r^m)$ is the quarterly percent change in our stock-market valuation variable minus the own rate of return on M3.

The time series properties of all the variables were evaluated employing standard unit-root tests - - the augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and the Kwiatkowski et al. (KPSS) test.[23] All these tests suggested that real money, real income and the ratio of real wealth to real income were (unit-root) non-stationary, while their first differences were stationary.[24] The spread between stock returns (annual percentage change in stock prices) and the own rate on M3 was I(0). Consequently, real money balances, real income, and the ratio of real wealth to real income were included as I(1) variables in the VAR specification, while the spread between stock returns and own rate was included as I(0).

3.1 *VEC Results*

Our point of departure in estimating the long-run money-demand equation was to construct a VAR system with the vector of three endogenous variables, m-p, y, w-y, as its dependent variables and with six exogenous variables which are described below. Several of these exogenous variables were based on those used in previous studies. In particular, as in Calza, Gerdesmeier and Levy (2001) and Fischer, Lenza, Pill and Reichlin (2007, Appendix), our VAR system included a constant and the following two exogenous variables: (1) one quarter lagged changes in oil prices (Δoil_{t-1}), in order to take account of the difficulty of fully capturing the impact of external developments on domestic prices (*i.e.*, on the GDP deflator) at times of rapid changes in imported oil prices,[25] and (2) current changes in the annualized inflation rate ($\Delta \dot{p}$) (relaxing short-run price homogeneity).

[23] For a discussion of these tests, see Maddala and Kim (1998, pp. 45-146).
[24] The linearity of equation (2) is an important assumption underlying all these tests.
[25] This was the justification provided by Beyer, Fischer and von Landesberger (2007).

In addition to the above variables, our VAR specification includes the following four exogenous variables. (1) The spread between the rate of return on equities and the own rate of return on money, lagged one period. As noted above, this variable, which is I(0), is the relevant opportunity-cost variable within the context of the Brainard-Tobin framework. (2) A split trend (denoted as st1), with a value of zero until 2001:Q4 and the (trend) values of one to nineteen for the period 2002:Q1 to 2006:Q3. This variable aims to capture both the physical introduction of euro, beginning in 2002, and the rapid rise in housing wealth that occurred in many euro-area countries over the period 2002-2006. (3) Another split trend (denoted as st2), with trending values of 1 to 25 for the period 1988:Q1 - 1994:Q1, values which decline by 5 units in each of the next five quarters (i.e., through 1995:Q2), and values of zero otherwise. (4) A one period lag of an Hodrick-Prescott (HP) filter of the proxy for wealth to income (denoted as $hp(w-y)_{t-1}$). The split trend, st2, aims to capture several shocks that impacted on European financial markets during 1988-95, including (a) the emergence of the "New EMS" in 1988, under which there were no currency realignments until 1992:Q3, (b) German unification in 1990, and (c) the crisis among currencies in the EMS in late 1992 and in 1993.[26] Regarding the application of the HP filter to the ratio of the proxy for wealth to income, a comprehensive measure of wealth would include financial wealth, housing wealth, and other non-financial wealth. Were such a measure of wealth available, it would be expected to evolve more smoothly than any of its individual components. In the absence of such a comprehensive measure, the log of the ratio of wealth to income was smoothed using the HP filter, especially as our stock market variable is linked only to the German stock market for part of the period. Because transitory departures from this smoothed log ratio are expected to have some effect on money demand, both the variables, $(w\text{-}y)_t$ and $hp(w\text{-}y)_{t-1}$, are included in the system.

To briefly summarize, in the absence of an all inclusive measure of wealth for the euro area, we used four variables to proxy the evolution of wealth: (1) the ratio of (real) euro-area stock prices to (real) income; (2) a one-period lagged HP filter of this variable, filtered because we would expect wealth to move more smoothly than stock-

[26] The term "EMS" refers to the European Monetary System. Beginning in 1988, there were no re-alignments in the EMS until the crisis of 1992. This period of fixed central rates has been called the "new EMS" (Cobham, 1996). References to the EMS should be taken to refer to the currencies participating in the exchange-rate mechanism (ERM) of the EMS.

market prices; (3) a split trend (st1) aimed at capturing, in part, the rise in housing wealth in many euro-area countries beginning in 2002; and (4) another split trend (st2) that aims to capture the effects of several shocks in the late 1980s and early 1990s that may have affected the linkage between stock-market prices and euro-area wealth. In addition, because the spread between the rate of return on equities and the rate of return on money, which is in equation (4), was I(0), its one-period lagged value only appears in the dynamic error-correction model, though it still has an effect on long-run money demand.

The next step in the estimation procedure involved VAR estimation, misspecification testing and tests for co-integration among the variables.[27] To determine the lag length of the VAR model, alternate versions of the system were initially estimated using different lags. An Akaike information criterion, a Schwartz Bayesian criterion, and a Hannan-Quinn criterion were used to test the hypothesis that all these different versions are equivalent. Since each test revealed different numbers of lags, a lag exclusion test was performed. For one, two, and three lags, the estimated Wald statistic for the joint significance of all endogenous variables at those lags (one, two, and three) for each equation of the system (separately and jointly) suggested a lag length equal to two. Therefore, a VAR model of order two was used in the estimation procedure of co-integration.

The number of co-integrating relationships in the system was tested using the Johansen procedure (Johansen, 1995). This approach enables us (a) to determine the number of co-integrating vectors and (b) to identify and estimate the co-integrating vectors subject to appropriate specification testing. With three endogenous variables in equation (1) (real money balances, real income, and the ratio of real wealth to real income), the Johansen procedure yields at most three co-integrating vectors. As shown in Table 2, both the tests based on maximum eigenvalue and trace statistic led to the rejection of the null of zero co-integrating vectors in favor of three such vectors at the 1 or 5 per cent level of significance.

It is important to emphasize here that our model is not a closed VEC in the usual sense of Johansen (1988) where all the variables are treated as endogenous. Instead, here we have three I(1) variables ($(\text{m-p})_t$, y_t, and $(\text{w-y})_t$) which we treat as

[27] For a discussion of this procedure of estimation and testing, see Maddala and Kim (1998, pp. 155-242).

endogenous and three I(1) variables ($st1_t$, $hp(w\text{-}y)_{t\text{-}1}$, and $st2_t$) which we treat as exogenous. The system is thus analogous to that investigated by Davidson and Hall (1991). In a closed VEC involving n non-stationary variables there can be at most n-1 co-integrating vectors (Greene, 2003, p. 652). However in a conditional VEC involving n non-stationary endogenous variables and some exogenous variables, there may be n co-integrating vectors as the non-stationarity may now be due to the exogenous variables.[28] Of course if the co-integrating rank of the system is greater than 1, we have the problem that the co-integrating vectors are not identified and, thus, are not unique. This situation requires out-of-sample, *exact* information in the form of a formal set of identifying restrictions in order to obtain a unique set of vectors. Pesaran and Shin (2002) outline the basic rank and order conditions for identifying the co-integrating vectors uniquely. The basic order condition is that we require r^2 restrictions for exact identification, where r is the co-integrating rank.

Thus, nine restrictions are needed to just identify the three vectors. The first co-integrating vector is used to form the money-demand equation. To see how the variables, $(m\text{-}p)_t$, y_t, and $(w\text{-}y)_t$, in this money-demand equation diverge from equilibrium in the short run, consider the error correction model

$$\Delta(m\text{-}p)_t = \lambda[(m\text{-}p)_{t\text{-}1} - z'_{t\text{-}1}\theta] + x'_t\beta + \varepsilon_t \tag{7}$$

where $z'_{t\text{-}1} = [\, y_{t\text{-}1},\ (w\text{-}y)_{t\text{-}1},\ st1_{t\text{-}1},\ hp(w\text{-}y)_{t\text{-}2},\ st2_{t\text{-}1}\,]$, Δ is the first-difference operator, the variables, $\Delta(m\text{-}p)_t = (m\text{-}p)_t\text{-}(m\text{-}p)_{t\text{-}1}$, $x'_t = [\,\Delta(m\text{-}p)_{t\text{-}1},\ \Delta(m\text{-}p)_{t\text{-}2},\ \Delta y_{t\text{-}1},\ \Delta y_{t\text{-}2},\ \Delta(w\text{-}y)_{t\text{-}1},\ \Delta(w\text{-}y)_{t\text{-}2},\ \Delta p_t,\ \Delta oil_{t\text{-}1},\ (r^e - r^m)_{t-1}\,]$, and $[(m\text{-}p)_{t\text{-}1} - z'_{t\text{-}1}\theta]$, are I(0), $[1,\text{-}\theta']'$ is the co-integrating vector, $[(m\text{-}p)_{t\text{-}1}\text{-}z'_{t\text{-}1}\theta]$ is the error-correction term (ECT). This equation describes the variation in $(m\text{-}p)_t$ around its long-run trend in terms of a set of I(0) variables, x_t, and the error correction, $[(m\text{-}p)_t - z'_t\theta]$, which is the equilibrium error in the model of co-integration (Greene, 2003, p. 654).

In Table 3, the estimate of the co-integrating vector is reported as equation (a) and the estimates of λ and β with and without the restrictions that the coefficients of $\Delta y_{t\text{-}1}$, $\Delta(w\text{-}y)_{t\text{-}1}$, and $\Delta y_{t\text{-}2}$ are zero are reported as equation (b).

[28] That is, in a closed system there can be no source of non-stationarity other than from the interaction of the endogenous variables. In a conditional system, the non-stationarity may also be due to the trending exogenous variables.

The second vector is used to form the real-income equation and the third is used to form the wealth-to-income equation. As shown in Table 3, the coefficients on income and the log of the ratio of wealth to income in the money-demand equation are -0.829 and 0.248, respectively; the t-statistics indicate that the estimated coefficients are statistically significant at the 1 per cent level. The coefficient on income has the correct sign (that is, the income elasticity of money demand is +0.829), while the likelihood ratio tests (described in Johansen (1992)) do not reject the null hypothesis that the income coefficient is equal to -1 (the likelihood ratio (LR) = 0.566). The coefficient on the log of the ratio of wealth to income indicates that, other things being equal, as the ratio of wealth to income rises, the demand for real-money balances declines. However, there are two related effects here as the one-period lagged value of the HP filter of the wealth-to-income ratio is not independent in the long run of the wealth-to-income variable itself, and so we must take account of both variables together to get the total effect coming from the wealth-to-income ratio. This result is given by the sum of the two coefficients, 0.248 and -0.574, which is -0.326, so that if the ratio of wealth to income rises by 10 per cent we would expect real-money demand to rise by 3.2 per cent.

We estimated the VEC recursively to test the stability of money-demand equation. As reported in Figure 3, the recursive estimates of the coefficients of y and w-y variables indicate that these coefficients are fairly stable over the estimation period. Figure 4 reports the results of Chow's (1960) one-step-ahead, predictive failure, and break-point tests for the money-demand equation and for the system of the unrestricted VEC. The results indicate that the system is stable. As shown in Figure 5, the constancy of the coefficients of the short-run money-demand equation was tested using the CUSUM and CUSUM of squares (CUSUMQ) tests. In general, there is no sign of parameter instability in the system or in the estimated short-run money-demand equation. The CUSUM test exhibits no break point, while the CUSUMQ test shows a single break point (in 2005:Q1).

3.2 *TVC Results*

Next, we estimated the long-run money-demand equation using TVC technology. To do so, we modified equation (4) as follows:

$$(m - p)_t = a_{0t} + a_{1t} y_t + a_{2t} (w - y)_t \tag{8}$$

where the coefficients are time-varying. It is assumed that for j = 0, 1, 2:

$$a_{jt} = \pi_{j0} + \pi_{j1} z_{1t} + \ldots + \pi_{jp} z_{pt} + \varepsilon_{jt} \tag{9}$$

where the π's are constants, the ε_{jt} are contemporaneously and serially correlated as in Swamy and Tavlas (2001, p. 419), and the *z*'s are the coefficient drivers. Several points about this model are worth noting. First, equation (8) with time-varying coefficients can represent a long-run equilibrium equation even when the latter equation is non-linear. Second, under assumption (9), TVC model (8) gives an improved fixed-coefficient model with more than one heteroscedastic and serially correlated error term when equation (9) is substituted into equation (8). Finally, the explanatory variables of (8) may not be unconditionally independent of their coefficients but can be conditionally independent of their coefficients given the coefficient drivers.[29]

To mimic VEC estimation, we included only the I(1) variables (*i.e.,* m-p, y, and w-y) in model (8). Thirteen coefficient drivers were used corresponding to the three exogenous I(1) variables ($\mathrm{st1}_t$, $\mathrm{hp(w\text{-}y)}_{t\text{-}1}$, and $\mathrm{st2}_t$), the nine I(0) variables (two lags of $\Delta\mathrm{(m\text{-}p)}_t$, two lags of $\Delta\mathrm{y}_t$, two lags of $\Delta\mathrm{(w\text{-}y)}_t$, $\Delta\mathrm{p}_t$, $\Delta\mathrm{oil}_{t\text{-}1}$, and $(\mathrm{r}^{\mathrm{e}} - r^m)_{t-1}$) capturing the dynamics in the short-run money demand function, and the constant term (Table 3, equation (b)). Effectively, these coefficient drivers can be viewed as capturing the effects of specification errors, including omitted variables.

For j = 1, 2, a_{jt} is treated as a total effect while a portion of a_{jt} as a bias-free effect. This latter portion is defined as $\sum_{k \in S_1} \pi_{jk} z_{kt}$, where S_1 is a subset of {0, 1, …, p = 12}. That is, to derive the total-effect coefficients, we used the twelve variables employed in the VEC specification, plus the constant term. Next, to identify the bias-free portion, we needed a subset of 13 coefficient drivers, one of which is the constant term. We settled on a subset of five coefficient drivers to identify the bias-free component: the constant term, $\Delta\mathrm{y}_{t\text{-}1}$, $\Delta\mathrm{y}_{t\text{-}2}$, $\mathrm{hp(w\text{-}y)}_{t\text{-}1}$, and $\Delta\mathrm{oil}_{t\text{-}1}$.[30]

[29] For detailed discussions, see Swamy and Tavlas (2001, 2007).
[30] Other subsets of coefficient drivers yielded very similar results.

Table 4 presents both the total effects and the bias-free coefficients. Regarding the total effects, the (average) elasticity of income is 1.274;[31] it is significantly different from unity at the 1 per cent level. The coefficient on the wealth-to-income ratio is negative (-0.022) and not significant.[32] As reported above, a negative coefficient on this ratio was obtained in the co-integrating vector (Table 3, equation (a)).

The bias-free coefficients are quite different from the total effects. The (average) income elasticity is 1.113;[33] the null hypothesis that the coefficient on income equals unity cannot be rejected at the 1 per cent level. The coefficient on the wealth-to-income ratio is now positive and significant; the coefficient is 0.37, close to the 0.34 obtained as the total effect of the wealth-to-income ratio in the VEC specification (Table 3, equation (b)).[34]

Figure 6 presents the time profiles of the total effect and the bias-free effect yielded by TVC estimation for the income variable.[35] The estimated total effect (solid line) which contains omitted-variable and measurement-error bias components, increases after 1988 and decreases after 1993 until 1995. Towards the end of the estimation period, the estimated total effect increases. This time profile is consistent with the time profile of income velocity in Figure 1. The coefficient appears to be quite unstable. In contrast, the bias-free component (dotted line) appears to be stable during the estimation period. Thus, our proxy for wealth, along with coefficient drivers that are designed to reflect the influences of wealth not captured by our basic proxy for wealth and other influences, explain much of the movement of the biased coefficients of long-run money demand. The bias-free component takes values that are inconsistent with the observation that the income elasticity of money demand is rising in a period of sharp reduction of income velocity. In fact, as the bias-free effect shows, the π-coefficients of the income coefficient in (9) are pretty stable. The

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[31] $(1/T)\sum_{t=1}^{T}\hat{a}_{1t}$ = 1.274, where $\hat{a}_{1t}$ is an iteratively rescaled generalized least squares (IRSGLS) estimator of a_{1t} and T is the total number of observations.

[32] $(1/T)\sum_{t=1}^{T}\hat{a}_{2t}$ = -0.022, where $\hat{a}_{2t}$ is an IRSGLS estimator of a_{2t}.

[33] $(1/T)\sum_{t=1}^{T}\sum_{k\in S_1}\hat{\pi}_{1k}z_{kt}$ = 1.113, where $\hat{\pi}_{1k}$ is an IRSGLS estimator of π_{1k}.

[34] $(1/T)\sum_{t=1}^{T}\sum_{k\in S_1}\hat{\pi}_{2k}z_{kt}$ = 0.373, where $\hat{\pi}_{2k}$ is an IRSGLS estimator of π_{2k}.

[35] Figures 7 and 8 (Appendix) present the total effects and the bias-free effects of the constant and wealth-to-income ratio, respectively.

misleading impression of rising income elasticity of money demand is due to the failure to account for missing variables, especially wealth.

4. Conclusions

We have argued that the demand for money in the euro area is a stable function of more-than-the usual small set of variables. In particular, we believe that wealth is an important determinant of money demand and that we may not expect to find a stable relationship if we ignore this important factor using conventional, fixed-coefficient technology. With the portfolio-balance framework as our point of departure, we constructed a set of proxies for euro-area wealth; our basic (unfiltered) wealth variable was used to develop an opportunity cost variable, which we defined as the rate of return on equities minus the own rate of return on M3. As we have shown, this specification yields a stable money demand relationship. Apart from confronting this relationship with a variety of stability tests, all of which rely on the assumption of fixed coefficients, how much assurance can we have that this fixed-coefficient relationship approximates the true underlying relationship? To shed light on this issue, we used a TVC approach, which removes the biases caused by model misspecifications and recovers the underlying parameters of the system. This technique reveals a constant underlying set of parameters. Thus, both VEC and TVC techniques suggest that there is, in fact, a stable relationship determining the demand for money in the euro area.

To be sure, our measures of wealth are partial measures, constructed strictly on the basis of stock-market variables. One conclusion that emerges from our study is the need for more resources devoted to developing inclusive measures of euro-area wealth. Another conclusion is the usefulness of testing empirical specifications using both fixed-coefficient and time-varying coefficient estimation methods. In those cases, such as in our specification of a portfolio-balance approach to money demand, in which the methods yield similar results, a linear approximation can be considered useful and congruent.

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Table 1					
Johansen Co-integration Tests of Long-Run Money Demand, ECB "Workhorse" Model: Sample 1980:Q1 – 2006:Q3					
Variables included	Rank=0	Rank≤1	Rank≤2	Rank≤3	Co-integration
Maximum Eigenvalue					
(m-p), y, $(r^i - r^m)$, $(r^l - r^m)$	13.04	10.95	2.90	0.42	No
(m-p), y, $(r^i - r^m)$	9.82	2.61	0.37	-	No
Trace Statistic					
(m-p), y, $(r^i - r^m)$, $(r^l - r^m)$	27.31	14.27	3.32	0.42	No
(m-p), y, $(r^i - r^m)$	12.80	2.98	0.37	-	No
Notes: A VAR model of order two is used.					

Table 2

Johansen Co-integration Tests

Long-Run Demand for Money in Euro Area: Sample 1980:Q1-2006:Q3

VAR of order 2, Variables: (m-p), y, (w-y)
and six exogenous variables

Maximum Eigenvalue

Null	Alternative	Eigenvalue	Critical Values	
			95%	99%
r=0	r=1	29.50***	20.97	25.52
r<=1	r=2	17.63**	14.07	18.63
r<=2	r=3	13.10***	3.76	6.65

Trace Statistic

Null	Alternative	Trace	Critical Values	
			95%	99%
r=0	r>=1	60.23***	29.68	35.65
r<=1	r>=2	30.73***	15.41	20.04
r<=2	r>=3	13.10***	3.76	6.65

Note: r indicates the number of co-integrating relationships. The maximum eigenvalue and trace statistic tests are compared with the critical values from Johansen and Juselius (1990). **, *** indicates rejection of the null hypothesis at 5 and 1 per cent level.

Table 3

VEC Model Estimation

(a) Co-integrating Equation

$(m-p)_t$	y_t	$(w-y)_t$	$st1_t$	$hp(w-y)_{t-1}$	$st2_t$
1.000	-0.829	0.248	-0.02	-0.574	-0.0028
	(-5.55)	(6.35	(3.0)	(-2.39)	(-1.2)

(b) Dynamic money demand equation estimates

	Variables									
	Short-run dynamics									
	ECT	$\Delta(m-p)_{t-1}$	$\Delta(m-p)_{t-2}$	Δy_{t-1}	Δy_{t-2}	$\Delta(w-y)_{t-1}$	$\Delta(w-y)_{t-2}$	Δp_t	Δoil_{t-1}	$(r^e - r^m)_{t-1}$
unrestricted model	-0.034 (-2.23)	0.551 (5.73)	-0.103 (-1.14)	-0.055 (-0.71)	0.127 (1.64)	-0.004 (-0.63)	-0.001 (-0.18)	-0.146 (-4.70)	0.004 (1.69)	-0.001 (-0.08)
Parsimonious model	-0.034 (-2.27)	0.0552 (5,82)	-0.117 (-1.35)	-	0.121 (1.62)	-	-	-0.148 (-4.90)	0.004 (1.69)	-0.001 (0.84)

	Unrestricted	parsimonious
R^2	0.58	0.57
Adj-R^2	0.51	0.53
F-statistic	9.21	12.19
Sum sq. residuals	0.001	0.001
LM test of Autocorrelation	0.69	0.50
ARCH F-statistic	0.66	0.57

Note: t-ratios are in parentheses. The constant term of the unrestricted dynamic money-demand equation is equal to 0.21 with a t-ratio of 2.39 and of parsimonious equation is 0.019 with a t-ratio of 2.40. ECT = Error Correction term.

Table 4		
TVC Estimation of Long-Run Money Demand for Euro-Area		
Variables	Total effects (1)	Bias-free effects (2)
Constant	-9.425*** [-5.63]	-7.239*** [-1.66]
y	1.274*** [11.38]	1.113*** [14.86]
w-y	-0.022 [-1.13]	0.373*** [15.66]
$\bar{R}^2$	0.99	0.99

Notes: Figures in brackets are t-ratios. *** indicates significance at 1% level. The estimates in columns (1) are obtained using as coefficient drivers all the variables used in the short-run money demand equation (b) in Table 3, except the variables, m-p, y and w-y. The bias-free effects are estimated using five coefficient drivers: constant term, Δy_{t-1}, Δy_{t-2}, $hp(w-y)_{t-1}$, and Δoil_{t-1}.

Figure 1
Log of Income Velocity

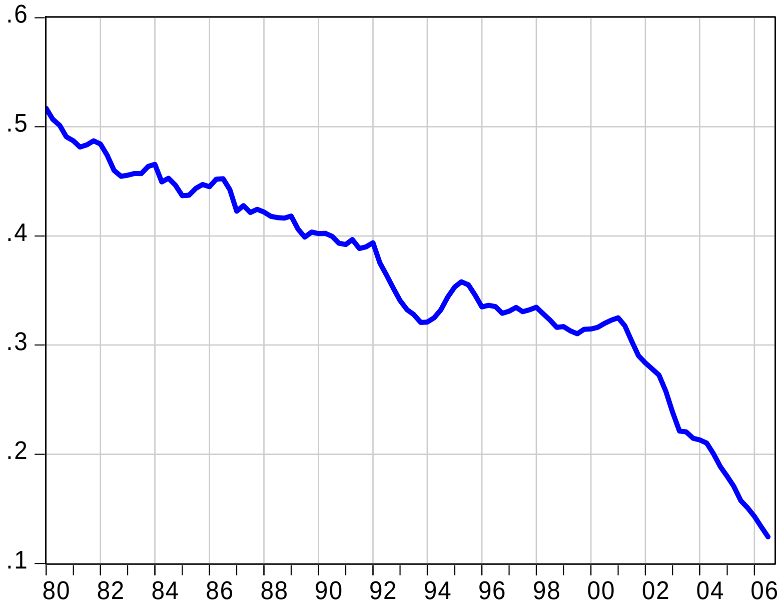


Figure 2
Annualized Inflation Rate and M3 Growth

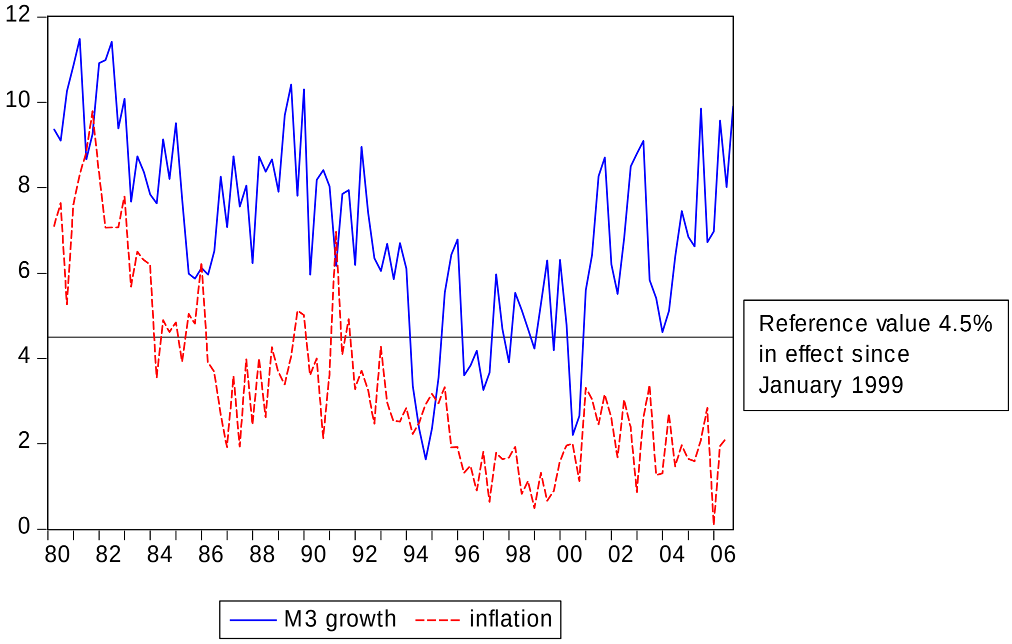


Figure 3

Recursive Estimates of the Coefficients of Long-Run Money Demand Equation

(Top and bottom lines represent ± 2 standard deviations)

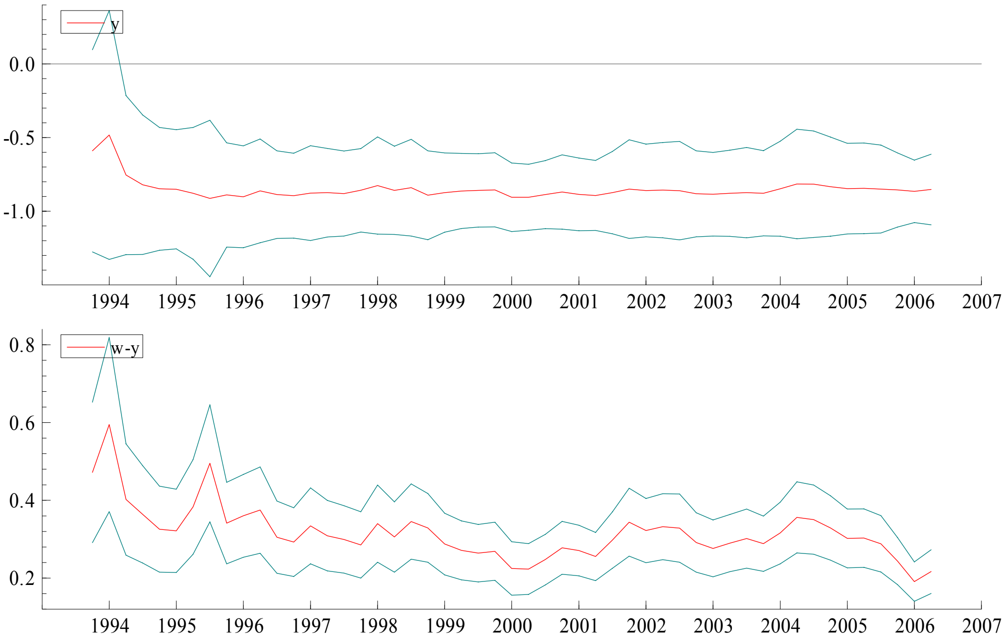


Figure 4

Chow's One-Step Ahead, Predictive-Failure and Break-Point Tests of the Constancy of the Coefficients of Long-Run Money-Demand Equation

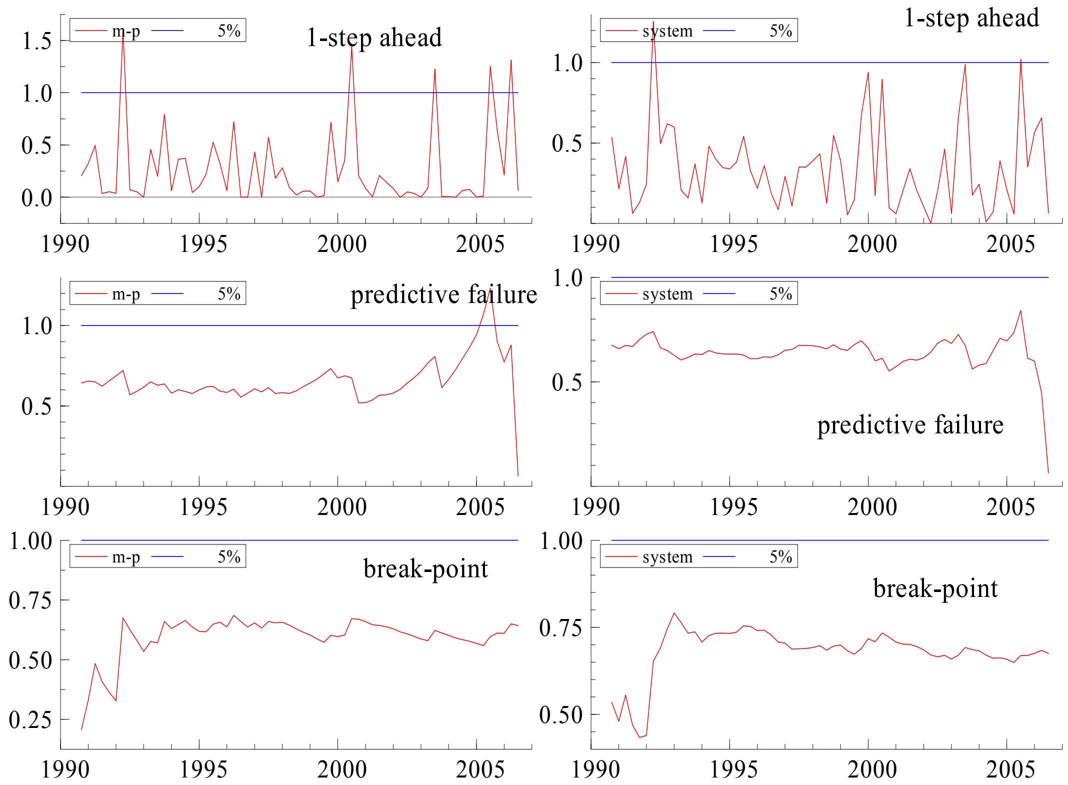
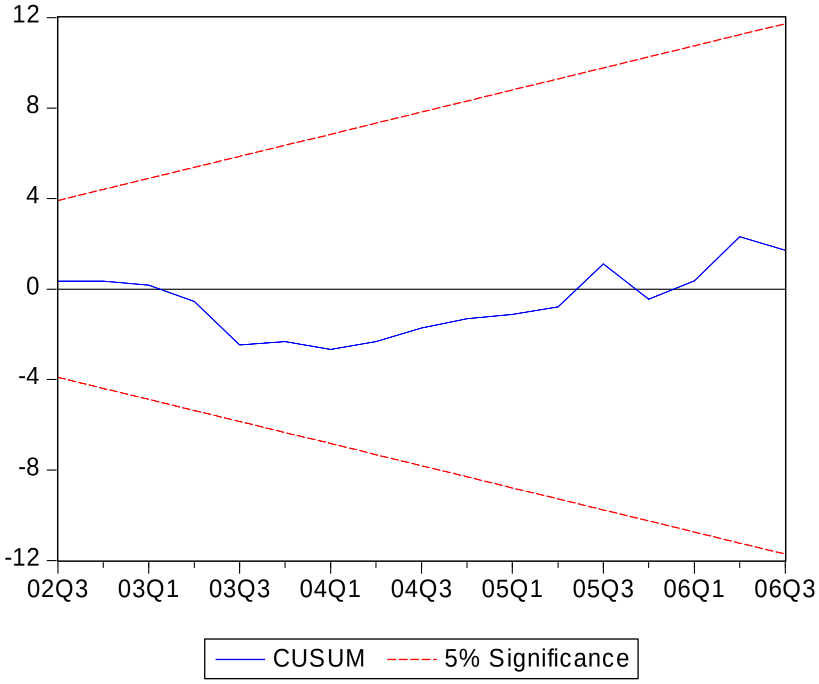


Figure 5

CUSUM and CUSUMQ Tests for the Short-Run Money Demand Equation



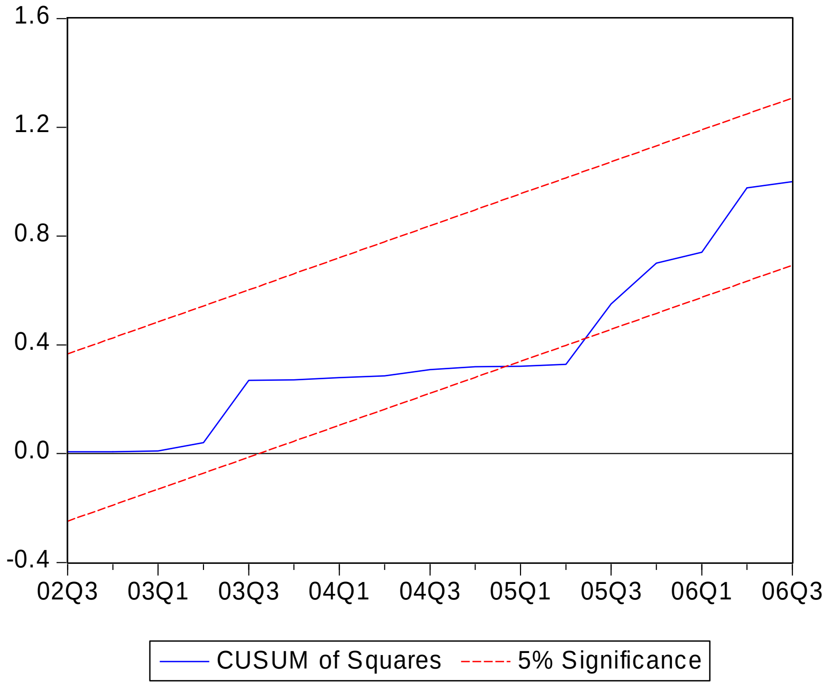


Figure 6
TVC Estimation: Total and Bias-Free Effects of Real Income
of Real Income

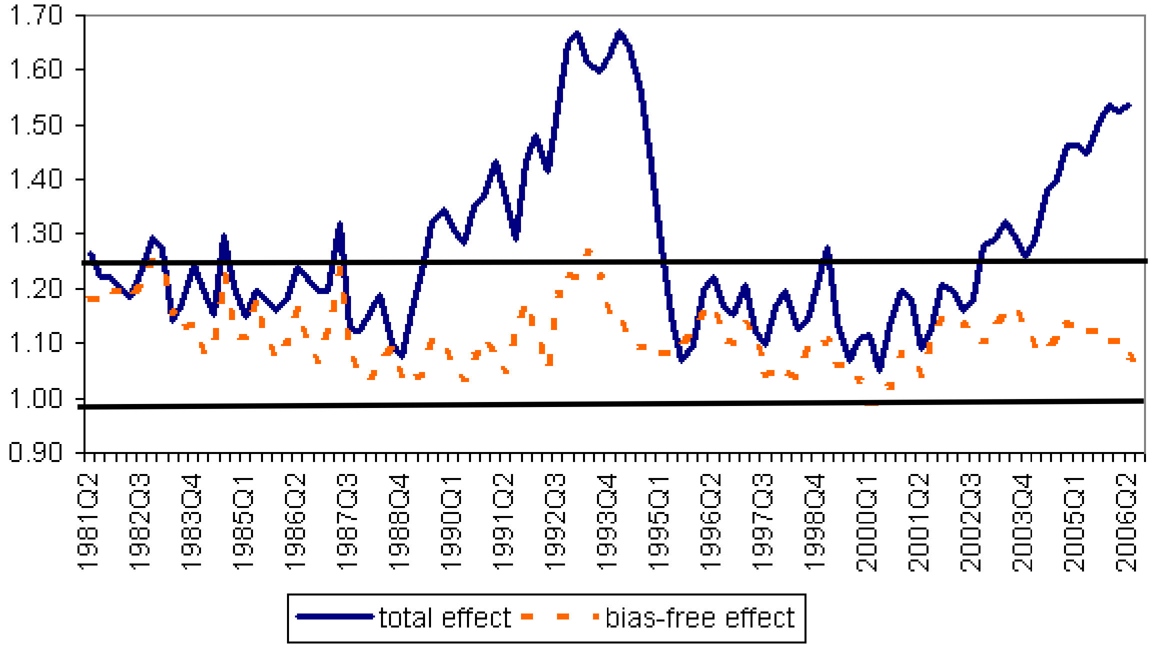


Figure 7 (Appendix)
TVC Estimation: Total and Bias-Free Effects of the constant

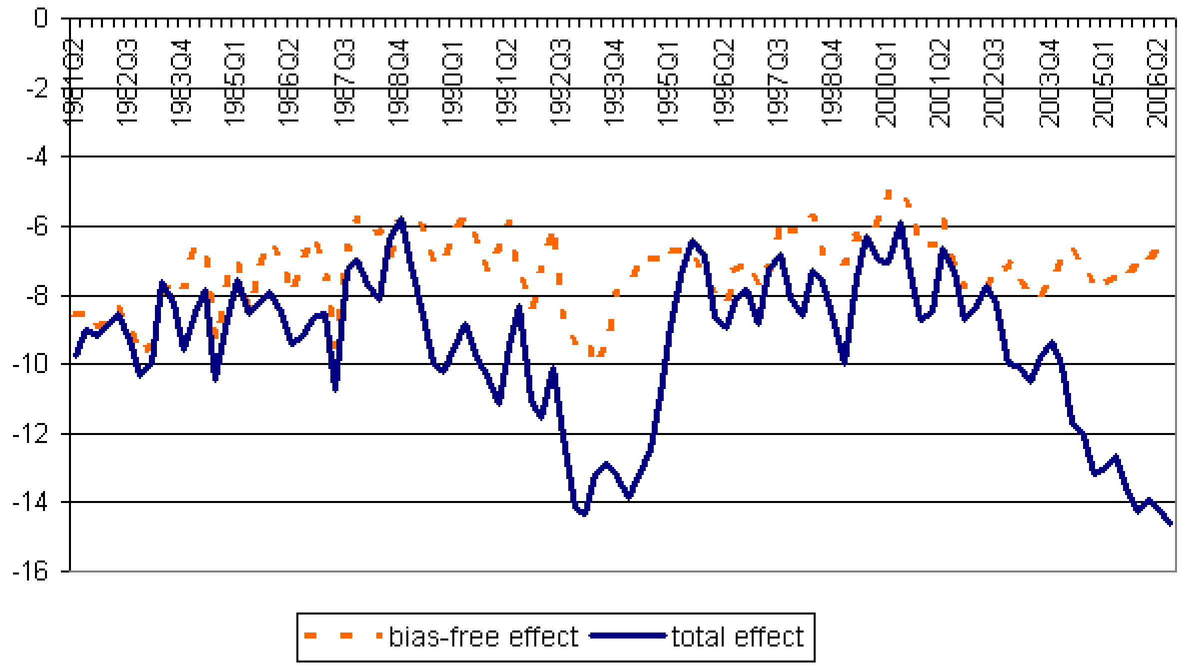
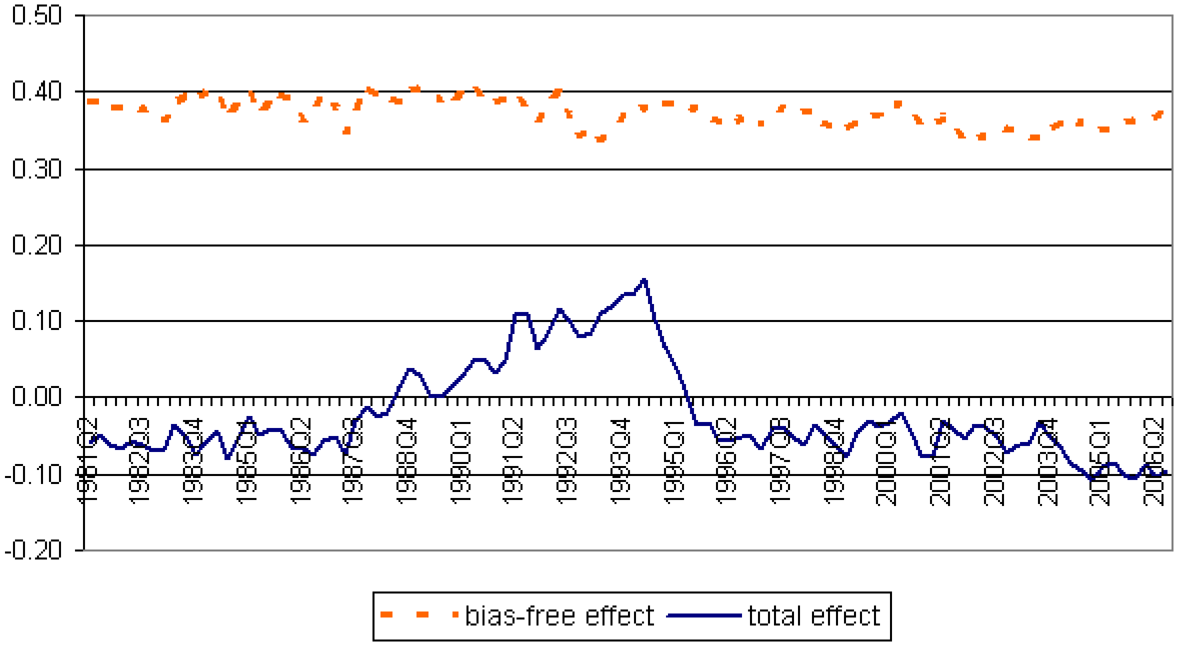


Figure 8 (Appendix)
TVC Estimation: Total and Bias-Free Effects of Wealth-to-Income Ratio



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