# ADMISSIBLE MONETARY AGGREGATES FOR THE EURO AREA

By

Jane M. Binner, Rakesh K. Bissoondeeal, C. Thomas Elger, Barry E. Jones, Andrew W. Mullineux

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*Dr. Jane Binner, Reader in Economics,*
*Economics and Strategy Group*
*Aston Business School*
*Aston University, Aston Triangle*
*Birmingham B4 7ET, UK*
*Tel: +44 (0)121 204 3036, Fax: +44 (0)121 204 3306*
*Email: j.m.binner@aston.ac.uk*

*Rakesh K. Bissoondeeal, Aston University*

*C. Thomas Elger, Lund University*

*Barry E. Jones, Binghamton University*

*Andrew W. Mullineux, University of Birmingham*

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The Research Director, Aston Business School, Aston University,
Birmingham B4 7ET

Telephone No: (0121) 204 3000 Fax No: (0121) 204 3326 http://www.abs.aston.ac.uk/

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**Abstract:** We use the Fleissig and Whitney (2003) weak separability test to determine admissible levels of monetary aggregation for the Euro area. We find that the Euro area monetary assets in M2 and M3 are weakly separable and construct admissible Divisia monetary aggregates for these assets. We evaluate the Divisia aggregates as indicator variables, building on Nelson (2002), Reimers (2002), and Stracca (2004). Specifically, we show that real growth of the admissible Divisia aggregates enter the Euro area IS curve positively and significantly for the period from 1980 to 2005. Out of sample, we show that Divisia M2 and M3 appear to contain useful information for forecasting Euro area inflation.

**Key Words:** Weak Separability Tests, IS Curve, Euro Area, Divisia Aggregates, Forecasting
**JEL Codes: E41, C43, C51**

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## 1. Introduction

We identify admissible monetary aggregates for the Euro area using a non-parametric weak separability test proposed by Fleissig and Whitney (2003).[1] Weak separability is a key theoretical condition required for the existence of economic monetary aggregates as discussed in Barnett (1980, 1982), Swofford and Whitney (1991, 1994), Barnett and Serletis (2000), and Barnett and Binner (2004).[2] We construct Divisia monetary aggregates for admissible groupings of Euro area monetary assets and evaluate their potential as indicator variables.[3] In this regard, Nelson (2002) finds evidence that real monetary base growth has positive and significant "direct effects" on aggregate demand for the US and UK; *i.e.* effects beyond those captured indirectly through short-term real interest rates. Reimers (2002) and Stracca (2004) provide evidence for direct effects of Divisia money on Euro area aggregate demand for the period from 1980 to 2000.[4] We provide related evidence for the sample period from 1980 to 2005. We also evaluate the potential for Divisia monetary aggregates to be used to forecast inflation in the Euro area in a pure out of sample forecasting exercise based on Drake and Mills (2005), who study the same issue for the US.

In our weak separability tests, we consider the four monetary assets included in the Euro area M3 monetary aggregate, which is currently monitored by the ECB.[5] These assets are as follows: currency (CC); overnight deposits (OD); other short term deposits (SD); and marketable instruments (MI).[6] We find that the M3 monetary assets are weakly separable from total private consumption and that the M2 monetary assets (CC, OD, and SD) are

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[1] This work builds on earlier studies of the Euro area by Spencer (1997), Swofford (2000), and Reimers (2002). See also Belongia and Chrystal (1991), Drake and Chrystal (1994, 1997), and Elger, Jones, Edgerton, and Binner (2006), which study the UK, and Belongia and Chalfant (1989), Swofford and Whitney (1991, 1994), Fisher and Fleissig (1997), and Jones, Dutkowsky, and Elger (2005), which study the US.

[2] Our notion of admissibility comes from Barnett (1982). Specifically, he referred to a weakly separable group of monetary assets as being "admissible as an indicator".

[3] Specifically, our monetary aggregates are based on the superlative Törnqvist discrete-time approximation of the continuous-time Divisia index; see Anderson, Jones, and Nesmith (1997). In the literature, these monetary aggregates are often referred to simply as Divisia monetary aggregates.

[4] Elger, Jones, Edgerton, and Binner (2006) find similar evidence for household-sector Divisia monetary aggregates for the UK.

[5] We note, however, that the ECB has recently given the broad M3 monetary aggregate a smaller role in its monetary policy strategy (ECB, 2003). The Governing Council confirmed (ECB, 2003, p. 79) that it continues to employ a two pillared approach. However, it "…also decided to no longer review the reference value on an annual basis in order to stress the longer-term nature of the reference value for monetary growth as a benchmark for assessing monetary developments." ECB (2003, p. 87) states that "…the [President's Introductory] statement will [after identifying short to medium-term risks to price stability] proceed to monetary analysis to assess medium to long-term trends in inflation in view of the close relationship between money and prices over extended horizons."

[6] See ECB (1999) for a more detailed description of the components of M3. SD consists mainly of time and savings deposits. MI consists of repurchase agreements, money market fund shares, and money market paper and debt securities issued with maturities of up to 2 years.

weakly separable from total private consumption and the remaining asset (MI) over the period from 1991 to 2005. We find, however, that the M1 monetary assets (CC and OD) are not weakly separable from total private consumption and the other monetary assets.

Based on the weak separability test results, we construct admissible Divisia monetary aggregates for the M2 and M3 asset groupings. Belongia (1996), Lucas (2000), Schunk (2001), Stracca (2004), Duca and VanHoose (2004), Drake and Mills (2005), and Belongia and Ireland (2006) provide recent discussions on the merits of Divisia monetary aggregates. In particular, Belongia (1996) showed that the qualitative conclusions of several important empirical studies were reversed when Divisia aggregates were used instead of conventional "simple sum" aggregates. He argued that (unlike Divisia aggregates) conventional aggregates do not internalize pure substitution effects. He emphasized, however, that the composition of the monetary aggregates must be based on weak separability tests.[7] Divisia monetary aggregates are currently produced by the Federal Reserve Bank of St. Louis (Anderson, Jones, and Nesmith, 1997) and the Bank of England (Hancock, 2005).

Recent work on monetary policy rules build on small-scale macroeconomic models that include an IS-curve relating the output gap to the real interest rate. Commonly used backward-looking empirical IS-curve specifications (e.g. Rudebusch and Svensson, 2002) neglect money and, thus, a potentially important channel for monetary effects on output.[8] Nelson (2002) recently investigated the theoretical and empirical grounds for critiquing such IS-curve specifications that exclude money. In particular, he finds that real monetary base growth enters backward-looking IS-curve specifications "sizably, positively, and significantly" for the US and UK. Reimers (2002) finds similar evidence for real Divisia money growth for the Euro area over the period 1980 to 2000. Stracca (2004) provides additional evidence favourable to Divisia money in a VAR model.[9]

We find that the admissible Euro area Divisia monetary aggregates have direct effects on aggregate demand building directly on the IS curve specification from Reimers (2002) for a long sample period from 1980 to 2005 and a shorter one from 1991 to 2005. At a minimum, therefore, we can conclude that Divisia monetary aggregates appear to contain additional in-

[7] Weak separability also implies that the monetary aggregate is unaffected by pure shifts in the composition of spending on non-monetary goods and, therefore, depends on total income, but not on the composition of expenditures (see Swofford and Whitney, 1991, p. 752).

[8] McCallum and Nelson (1999), McCallum (2001), and Ireland (2004) discuss the micro-foundations for the New Keynesian IS curve and the conditions under which money can be excluded from it.

[9] Specifically, Stracca (2004) considers a VAR model containing three lags each of output gap, inflation, real interest rates, and either real money growth or an error-correction term, which can be thought of as embedding both an IS curve relation and a Phillips curve relation.

formation for aggregate demand in the Euro area economy beyond that contained in short-term real interest rate variables.

A number of recent studies have investigated whether or not monetary aggregates in general and Divisia monetary aggregates in particular are useful in forecasting inflation out of sample: see, for examples, Stock and Watson (1999), Schunk (2001), Drake and Mills (2005), and Elger, Jones, and Nilsson (2006). Stock and Watson (1999) investigate whether or not monetary aggregates could be used to improve upon inflation forecasts for the US (at the four quarters horizon) based on Phillips curve models, which could be motivated by appealing to the quantity theory of money. They find that monetary aggregates provide marginal improvements for some measures of inflation over some sample periods, but lead to a serious deterioration in the accuracy of forecasts of CPI for the 1970s and early 1980s. Moreover, they find (p. 305) that their best performing money models are comparable to a univariate autoregressive model of inflation.

Drake and Mills (2005) use a model, which builds on Stock and Watson (1999), to forecast nominal GDP growth and inflation for the US using simple sum M2 and M2+ (M2 plus stock and bond mutual funds), Divisia M2, and an empirically weighted monetary aggregate. They find that simple sum M2 provides the best forecasts of nominal income, but that the empirically weighted monetary aggregate provides the best inflation forecasts especially at longer forecast horizons. We evaluate forecasts of Euro area inflation, as measured by the GDP deflator, using the same basic framework as Drake and Mills (2005). We find that Divisia M2 and M3 produce better out-of-sample forecasts of inflation than a univariate model at most forecast horizons. In addition, we find that forecasts based on these admissible Divisia aggregates are better at all forecast horizons than corresponding forecasts based on simple sum M3. Thus, Divisia aggregates appear to provide useful information for forecasting inflation in the Euro area.

The remainder of the paper is organised as follows. Section 2 provides some background and describes our weak separability tests. Section 3 presents the empirical results from our weak separability tests on Euro area data. Section 4 provides evidence supporting direct effects of Divisia money in the Euro area. Section 5 contains our forecasting results. Section 6 concludes the paper.

## 2. Monetary Aggregation and Weak Separability

### *2.1 Background*

The theory of monetary aggregation (Barnett, 1978, 1980, 1982) is based on an optimization framework in which monetary assets are treated as durable goods in the (representative) consumer's utility function. Let **m** denote a vector of real monetary assets and let **z** denote all other variables in the utility function, so that utility is given by $u(\mathbf{m},\mathbf{z})$. The consumer is assumed to maximize $u$ subject to a budget constraint. The user cost prices of the monetary assets are defined by Barnett (1978). The utility function, $u$, is *weakly separable* in **m** if there exists a macro-function, $U$, and a sub-utility function, $V$, such that

$$u(\mathbf{m},\mathbf{z}) = U\left(V(\mathbf{m}),\mathbf{z}\right). \tag{1}$$

Under weak separability, the marginal rates of substitution between any pair of assets in the separable group of assets, **m**, are functions only of the quantities of those assets. Consequently, the optimal quantities of those assets depend only upon their user costs and group expenditure. Weak separability also implies the existence of an economic monetary aggregate for the separable asset grouping; see Barnett (1980, 1982, 1987) for further discussion.

### *2.2 Non-parametric Approach to Testing Weak Separability*

Weak separability can be tested in either a parametric or a non-parametric framework. The parametric approach requires postulating a functional form and estimating the unknown parameters of that functional form. In contrast, the non-parametric revealed preference approach (Varian 1982, 1983) does not require a particular functional form and, therefore, avoids problems associated with model misspecification (see Barnett and Choi, 1989 and Swofford and Whitney, 1994).

Non-parametric weak separability tests are extensions of standard revealed preference tests of utility maximization. Varian (1982) proved that a dataset consisting of observed quantities and prices for a set of goods can be rationalized by a well-behaved utility function if and only if it satisfies the Generalized Axiom of Revealed Preferences (GARP). Varian (1983) derives necessary and sufficient conditions for a dataset to be rationalized by a well-behaved utility function, which is weakly separable in a particular sub-group of the goods.

We begin by setting notation. Let $\mathbf{m}^i = (m_1^i,...,m_n^i)$ denote the $i^{\text{th}}$ observed real quantities for a set of $n$ monetary assets and let $\boldsymbol{\pi}^i = (\pi_1^i,...,\pi_n^i)$ denote the corresponding observed nominal user costs for these assets, where $i = 1,...,T$. Further, let $\mathbf{z}^i = (z_1^i,...,z_m^i)$ denote the

observed quantities of all other variables in the utility function (including monetary assets not in **m**) with corresponding prices $\mathbf{p}^i = (p_1^i, ..., p_m^i)$. Varian (1983, p. 105, Theorem 3) proved that the following two conditions are equivalent:

(*i*) There exists a concave, monotonic, continuous weakly separable (in **m**) utility function, which rationalizes the data $(\mathbf{p}^i, \mathbf{z}^i)$ and $(\boldsymbol{\pi}^i, \mathbf{m}^i)$

(*ii*) There exist numbers $U^i, V^i, \lambda^i, \mu^i > 0$ $(i = 1, ..., T)$ such that;

$$U^i \le U^j + \lambda^j \mathbf{p}^j (\mathbf{z}^i - \mathbf{z}^j) + \lambda^j (V^i - V^j) / \mu^j \quad \forall i, j \tag{2}$$

$$V^i \le V^j + \mu^j \boldsymbol{\pi}^j (\mathbf{m}^i - \mathbf{m}^j) \quad \forall i, j. \tag{3}$$

There are two necessary conditions for weak separability: First, the combined price and quantity data for both sets of goods (**m** and **z**) must satisfy GARP, otherwise the data cannot be rationalized by a well behaved utility function, weakly separable or otherwise. Second, the price and quantity data for the separable group of goods $(\boldsymbol{\pi}^i, \mathbf{m}^i)$ must also satisfy GARP, since otherwise no feasible solution exists for the constraints in (3). We will refer to those constraints as *Afriat inequalities*.

If these necessary conditions are satisfied, then weak separability can be tested as follows: Use a numerical algorithm to construct *Afriat indexes* (positive numbers, $V^i$ and $\mu^i$, which satisfy the Afriat inequalities). Then, replace the quantities, $\mathbf{m}^i$, with the group quantity index, $V^i$, and replace their user cost prices, $\boldsymbol{\pi}^i$, with the group price index, $1/\mu^i$, within the combined dataset for all goods (see Fleissig and Whitney, 2003, p. 134). Specifically, let $\tilde{\mathbf{p}}^i = (p_1^i, ..., p_m^i, 1/\mu^i)$ and $\tilde{\mathbf{z}}^i = (z_1^i, ..., z_m^i, V^i)$ denote these new price and quantity vectors. If the necessary conditions are satisfied and the data $(\tilde{\mathbf{p}}^i, \tilde{\mathbf{z}}^i)$ satisfies GARP, then the dataset satisfies the necessary and sufficient conditions for weak separability.

### *2.3 Fleissig and Whitney's LP Test*

The Afriat indexes used in the weak separability test are not unique and, therefore, the test is biased toward rejecting weak separability (Swofford and Whitney, 1994). Moreover, the algorithm used to construct the Afriat indexes affects the power of the test. In this paper, we use a numerical algorithm proposed by Fleissig and Whitney (2003) to construct these in-

dexes.[10] The idea behind their algorithm is that a natural starting point is to use a superlative quantity index such as the Törnqvist index to obtain estimates of the group quantity index, $V^i$, since a superlative index provides a second-order approximation to the true unknown aggregator function (Diewert, 1976). The Törnqvist index may, however, require small adjustments in order to actually satisfy the Afriat inequalities (as a group quantity index) due to several factors including third and higher-order approximation errors and measurement errors in the data (Fleissig and Whitney, 2003, p. 135).

Fleissig and Whitney (2003) provide a linear programming (LP) algorithm, which minimizes the adjustments (in absolute value terms) needed in order for the Törnqvist quantity index to satisfy the Afriat inequalities. Fleissig and Whitney (2003, p. 138) refer to the resulting index as an "adjusted Törnqvist index with error". Complete technical details of the LP algorithm are provided in the Appendix. Fleissig and Whitney (2003) demonstrate that the weak separability test based on the LP algorithm is fairly robust to moderate measurement errors on data simulated from a weakly separable Cobb-Douglas utility function.[11,12]

## 3. Weak Separability Tests

### *3.1 Data*

The data for the Euro area used in this study was provided to us by Livio Stracca (ECB). The dataset contains quarterly observations on monetary assets, interest rates, and Euro area GDP from 1980:2 to 2005:1 and on Euro area consumption from 1991:1 to 2005:1.

We use quarterly Euro-area data on four monetary assets and total private consumption for the period from 1991:1 to 2005:1 in our weak separability tests. The monetary assets are the components of the M3 monetary aggregate (CC, OD, SD, and MI), which are defined in the introduction. The monetary asset stocks are converted to real terms using the private consumption deflator (PCON). In addition, the real monetary asset stocks and real consumption (CON) are converted to per-capita terms using an estimate of the Euro area population. The interest rate on CC is zero. The interest rates on OD and SD are denoted by ROD and

[10] See Jones, Dutkowsky, and Elger (2005) and Elger, Jones, Edgerton, and Binner (2006) for empirical applications based on Fleissig and Whitney (2003).

[11] Varian (1985), de Peretti (2005), Jones and de Peretti (2005), and Fleissig and Whitney (2005) explore stochastic extensions of the standard GARP test, which can account for measurement errors in the data.

[12] Barnett and Choi (1989) found that Varian's original weak separability test, which used a different algorithm to construct Afriat indexes, was highly biased towards rejecting separability on data generated from a Cobb Douglas utility function with no stochastic components. Since the tests are identical in all other respects, the improvement in the performance of the test can be attributed entirely to the use of Fleissig and Whitney's LP algorithm.

RSD respectively. The interest rate on MI is proxied by RST, which is the 3 month inter-bank lending rate.

Following Barnett (1978), nominal user costs of the monetary assets are defined as $(R - R_i)/(1+R)$ multiplied by the price index, PCON, where $R$ is a benchmark interest rate and $R_i$ is the rate of return on the $i^{th}$ monetary asset. $R$ is proxied by RST plus a liquidity premium of 0.8% per annum. Following Stracca (2004), the liquidity premium is based on the average spread between a long-term government bond yield and RST.

These monetary asset quantity and user cost variables are essentially updated versions of those used by Stracca (2004) to which the reader is referred for additional discussion and details.[13]

### *3.2 Test Results*

We begin by testing the observed prices and quantities for all goods (consumption and the four monetary assets) for GARP. This necessary condition is satisfied for the full sample period 1991:1 to 2005:1. Thus, the complete dataset is found to be consistent with maximization of a well behaved utility function.

We consider four possible groupings of the monetary assets in our weak separability tests, which we denote by M1, M2, M3, and MX. These four sub-groups represent all possible combinations of the monetary assets provided that CC and OD are included in all sub-groups. The test results are reported in Table 1 along with the definitions of the sub-groups.

**Table 1. Asset Groupings and Weak Separability Test Results**

| Groupings | Weak Separability |
|---|---|
| M1 = (CC, OD) | 92 |
| M2 = (CC, OD, SD) | Y |
| M3 = (CC, OD, SD, MI) | Y |
| MX = (CC, OD, MI) | 21 |

**Note:** A "Y" indicates that the asset grouping is weakly separable. A number indicates the number of GARP violations for the data (0%, 2%) when weak separability is rejected.

The quantity and user cost data for all four asset groupings satisfy GARP. Thus, we construct Afriat indexes for each asset grouping using Fleissig and Whitney's LP algorithm

[13] See also Calza, Gerdesmeier, and Levy (2001).

and test for weak separability accordingly. We found that M2 and M3 are weakly separable for the full sample period, while weak separability is rejected for M1 and MX.[14]

As discussed in Section 2.3, Fleissig and Whitney's LP algorithm computes adjusted Törnqvist indexes, which satisfy the Afriat inequalities. They interpret differences between the Törnqvist index computed directly from the data and the adjusted Törnqvist index computed by their algorithm as resulting from approximation errors in the index and from measurement errors in the data. These differences are depicted in Figure 1 for the M3 monetary assets, which were weakly separable over the full sample period.

**[Figure 1 about here]**

In the figure, the solid line denotes the Törnqvist quantity index (in real per-capita terms) and the dashed line denotes the adjusted Törnqvist index (*i.e.* the Afriat index from the LP algorithm). The figure shows that the Törnqvist index requires only very small adjustments in order to satisfy the Afriat inequalities as a group quantity index. The corresponding results for M2 (not shown) are very similar.[15] In theory, these superlative indexes have the ability to provide a second-order approximation to the true unknown quantity aggregate, so that the tracking errors of the indexes should be of only third and higher orders. Our findings can be interpreted (following Fleissig and Whitney, 2003, p. 135) as implying that the tracking errors are indeed very modest and have a correspondingly modest impact on the properties of the indexes.

For the remainder of the paper, we will refer the Törnqvist indexes calculated for the components of M2 and M3 simply as Divisia M2 and Divisia M3.[16]

## 4. Does Divisia Money Enter the IS Curve for the Euro Area?

In this section, we provide evidence that the admissible Divisia M2 and M3 monetary aggregates have direct effects on aggregate demand in the Euro area.

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[14] Studies in monetary economics often emphasize the effects of including time deposits in the asset grouping being tested for weak separability. For example, earlier research by Swofford and Whitney (1987) and Belongia (2000) found that aggregates including a monetary asset with a time component, *i.e.* small time deposits for the US and CDs for Germany and Japan, led to rejections of weak separability. Similarly, Jones, Dutkowsky and Elger (2005) test for weak separability of M2, which contains small time deposits, and M2M and MZM, which are zero-maturity aggregates that do not. Their findings are relatively favourable for MZM. See also Belongia (1996). For our Euro area dataset, it is not possible to make such a fine distinction regarding time deposits. The reason is that the SD component contains both time and savings deposits. The MI component contains some zero-maturity assets (for example, money market mutual fund shares), but it also contains debt securities issued with maturities of up to 2 years. It is not possible to further disaggregate SD and MI over our sample period.

[15] Jones, Dutkowsky, and Elger (2005) obtained similar findings for US monetary data, although they provide summary statistics rather than graphs to demonstrate their results.

[16] Our Divisia M3 monetary aggregate is essentially an updated version of the one constructed by Stracca (2004).

### *4.1 IS Curve Specification*

We consider the following two IS curve specifications for the Euro area, which are based on Reimers (2002):

$$y_t = \beta_0 + \beta_1 y_{t-1} + \beta_2 r_{t-1} + \varepsilon_t \tag{4}$$

$$y_t = \beta_0 + \beta_1 y_{t-1} + \beta_2 r_{t-1} + \beta_3 \Delta_4 \left(m - p\right)_{t-2} + \varepsilon_t \tag{5}$$

In these equations, the variable $y_t$ denotes the output gap and the variable $r_t$ denotes the short-term real interest rate. The real interest rate is defined as $r_t \equiv \sum_{j=0}^{3} R_{t-j} - \Delta_4 p_t$, where $R_t$ denotes a short-term nominal interest rate (expressed as a quarterly fraction), $p_t$ denotes the natural log of a price index, and $\Delta_4$ takes the difference between the current value of a variable and its fourth lag: *i.e.* $\Delta_4 x_t = x_t - x_{t-4}$.[17] Annualized real money growth, which is included in the IS curve specification containing a money term (5), is defined as $\Delta_4 \left(m - p\right)_t = \Delta_4 m_t - \Delta_4 p_t$, where $m_t$ is the natural log of a nominal monetary aggregate.

### *4.2 Data*

The IS curves are estimated using quarterly data. Let $gdp_t$ denote the natural log of real GDP in quarter $t$. Output gap for the Euro area is estimated using two different methods. First, we apply the Hodrick-Prescott (HP) filter to $gdp_t$ and treat output gap as the cyclical component produced from the filter. Second, we de-trend $gdp_t$ by regressing it against a constant, $t$, and $t^2$ and treat the residuals from the regression as a measure of output gap, following Nelson (2002). These computations are based on the sample period from 1980:2 to 2005:1 for which we have Euro area GDP data. We measure $R_t$ as the 3 month inter-bank lending rate and $p_t$ as the log of the GDP deflator.

The two measures of output gap are shown in Figure 2. In the figure, the solid line denotes the cyclical component from the HP filter and the dashed line denotes the residuals from the quadratic de-trending regression (QD). The figure shows that the two methods of estimating output gap produce very similar results, especially in more recent periods.[18]
We estimate the models with real money growth using both Divisia M2 and Divisia M3.

**[Figure 2 about here]**

[17] See Svensson (1999) and Rudebusch and Svensson (2002).
[18] Reimers (2002) uses the HP filter and an extended exponential smoothing filter. The latter produces results that are very similar to the QD method.

### *4.3 Estimation Results*

Estimation results for (4) and (5) appear in Table 2. We estimate the IS curve models for two sample periods: 1991:1-2005:1 and 1980:2 to 2005:1. The shorter sample period corresponds to the sample period used in our weak separability tests. In the table, we show estimates for both measures of the output gap and with and without a real money growth term (based on either Divisia M2 or Divisia M3).

We begin with results for the shorter sample period, which are reported in Panel A of the table. The coefficient on lagged output gap is between 0.87 and 0.96 and is strongly significant in all cases indicating that the output gap is highly serially correlated as is also evident in Figure 2. The coefficient on the real interest rate is negative for the standard IS curve without money using either measure of output gap, but it is insignificant at the 5% level in both cases. The coefficient on the real interest rate is positive in all four specifications with money, but continues to be insignificant at the 5% level in all cases.

The real money growth term is statistically significant at the 5% level in the IS curve for both Divisia M2 and M3 for both measures of the output gap and the coefficient on money is positively signed. Including real money growth also leads to moderate improvements in $R^2$ in all cases. Thus, we find that Divisia M2 and M3 have direct effects on aggregate demand corroborating similar findings in Reimers (2002) and Stracca (2004).

The findings are very similar for the longer sample 1980:2-2005:1, which are reported in Panel B of the table. The main difference is that for the longer sample period the real interest rate becomes significant or marginally significant (at the 5% level) in the IS curve with money if output gap is based on quadratic de-trending, although its value is still positive.

**Table 2. IS Curve Estimations**

***A. 1991:1 – 2005:1 Sample Period***

| | Standard IS Curve | | Real Divisia Money Growth Term Included | | | |
|---|---|---|---|---|---|---|
| Constant | 0.0003<br>(0.32) | 0.0008<br>(0.825) | **-0.0058**<br>**(-3.18)** | **-0.0041**<br>**(-2.51)** | **-0.0055**<br>**(-2.82)** | **-0.0039**<br>**(-2.23)** |
| $y_{t-1}$ | **0.952**<br>**(23.32)** | **0.892**<br>**(15.70)** | **0.929**<br>**(25.23)** | **0.882**<br>**(17.00)** | **0.923**<br>**(24.10)** | **0.875**<br>**(16.46)** |
| $r_{t-1}$ | -0.028<br>(-1.11) | -0.029<br>(-1.31) | 0.025<br>(0.95) | 0.011<br>(0.48) | 0.021<br>(0.76) | 0.007<br>(0.29) |
| $\Delta_4 (m-p)_{t-2}$ | ------- | ------- | **0.114**<br>**(3.89)** | **0.092**<br>**(3.45)** | **0.111**<br>**(3.40)** | **0.090**<br>**(3.05)** |
| Output Gap<br>Money Measure | QD<br>------- | HP<br>------- | QD<br>M2 | HP<br>M2 | QD<br>M3 | HP<br>M3 |
| $R^2$<br>DW | 0.915<br>1.15 | 0.820<br>1.31 | 0.935<br>1.47 | 0.853<br>1.61 | 0.931<br>1.38 | 0.847<br>1.53 |

***B. 1980:2 – 2005:1 Sample Period***

| | Standard IS Curve | | Real Divisia Money Growth Term Included | | | |
|---|---|---|---|---|---|---|
| Constant | 0.0003<br>(0.27) | 0.0004<br>(0.42) | **-0.0074**<br>**(-3.83)** | **-0.0051**<br>**(-2.88)** | **-0.0075**<br>**(-3.75)** | **-0.0050**<br>**(-2.76)** |
| $y_{t-1}$ | **0.948**<br>**(27.83)** | **0.846**<br>**(15.10)** | **0.926**<br>**(29.85)** | **0.835**<br>**(15.88)** | **0.919**<br>**(29.19)** | **0.827**<br>**(15.60)** |
| $r_{t-1}$ | -0.016<br>(-0.66) | -0.013<br>(-0.59) | **0.054**<br>**(2.04)** | 0.036<br>(1.51) | 0.050<br>(1.92) | 0.033<br>(1.37) |
| $\Delta_4 (m-p)_{t-2}$ | ------- | ------- | **0.144**<br>**(4.73)** | **0.103**<br>**(3.71)** | **0.147**<br>**(4.58)** | **0.103**<br>**(3.54)** |
| Gap Measure<br>Money Measure | QD<br>------- | HP<br>------- | QD<br>M2 | HP<br>M2 | QD<br>M3 | HP<br>M3 |
| $R^2$<br>DW | 0.897<br>1.55 | 0.715<br>1.78 | 0.917<br>1.90 | 0.753<br>2.03 | 0.916<br>1.87 | 0.750<br>1.99 |

**Notes:**

1. HP denotes cyclical component from HP filter. QD denotes residuals from a quadratic de-trending regression.
2. T statistics are in parentheses. Bold entries are significant at the 5% level.
3. DW is the Durbin-Watson test statistic.

## 5. Does Divisia Money Help Forecast Inflation for the Euro Area?

In this section, we investigate the relative performance of different monetary aggregates in an inflation forecasting framework. The framework for our analysis is a bi-variate direct forecast model, which is based on Drake and Mills (2005).[19]

### *5.1 Model for Forecasting Inflation*

Let $p_t$ be the natural log of the price level in quarter *t* and let $\pi_t^k = (4/k)(p_t - p_{t-k})$ be the corresponding *k* quarter inflation rate. Let $x_t^k$ be the equivalently defined *k* quarter nominal money growth rate. Drake and Mills (2005) produce forecasts of $\pi_{t+k}^k$ from lags of $\pi_t^k$ and $x_t^k$ at a variety of different horizons (*k*). Building on their framework, we produce *k* quarter inflation forecasts from estimates of the following model:

$$\pi_t^k = a + \sum_{i=0}^{q-1} b_i \, \pi_{t-i-k}^k + \sum_{i=0}^{r-1} c_i \, x_{t-i-k}^k + \varepsilon_t \ , \tag{6}$$

where $\varepsilon_t$ is an error term in the regression.

### *5.2 Data and Forecast Method*

We compute *k* quarter inflation rates from the GDP deflator for the Euro area. Based on the results of our weak separability tests, we construct forecasts using *k* quarter nominal money growth rates calculated from Divisia M2 and Divisia M3.

For comparison purposes, we also construct forecasts based upon *k* quarter growth rates of the nominal simple sum M3 monetary aggregate. The comparison between simple sum and Divisia for inflation forecasting is not meant to be interpreted as a test of the use of Divisia aggregates. Rather, the goal is to provide a comparison between the most widely monitored aggregate for the ECB, simple sum M3, and the ones we are investigating. The conceptual advantages of Divisia over conventional monetary aggregates are widely acknowledged. Recent discussions can be found in, for example, Lucas (2000), Duca and Van-Hoose (2004), and Belongia and Ireland (2006). Specifically, the use of a simple sum aggregate would be justified only if the monetary assets are all assumed to be perfect substitutes for each other in the provision of monetary services, which is not a reasonable assumption for broad asset groupings.

[19] See also Stock and Watson (1999) and Marcellino, Stock, and Watson (2006) for further details and discussion regarding direct forecast methods.

Following Drake and Mills (2005), we produce forecasts at four different horizons: $k = 4, 6, 8,$ and $12$. Our forecasts are based on an expanding information window technique in which the forecast model is re-estimated to take advantage of all information that would have been available to the forecaster at the time each forecast was made, but which does not use any future information. The following algorithm details the expanding information window technique we use to calculate forecasts and forecast errors for each forecast horizon *k*:

**Do** $T = 1994:1$ to $2005:1-k$

1. Estimate (6) using all available observations *t* up to and including *T*.
2. Compute $\pi_{T+k}^{k,forecast} = \hat{a} + \sum_{i=0}^{q-1} \hat{b}_i \pi_{T-i}^{k} + \sum_{i=0}^{r-1} \hat{c}_i x_{T-i}^{k}$, where "^" denotes parameter estimates obtained in Step 1 of the loop.
3. Compute the forecast error $\mu_{T+k}^{k} = \pi_{T+k}^{k,forecast} - \pi_{T+k}^{k}$

**End do**

Drake and Mills (2005) produce forecasts for the US using four lags of both the $\pi$ and $x$ variables: *i.e.* $r = q = 4$. Analysis of our data indicated that a shorter lag length of one to two is more appropriate for the Euro area.[20] We report results for forecasts using two lags of both variables so that $r = q = 2$, although we found that our qualitative results are quite robust to lag length.[21]

As is clear from the algorithm, the data from 1980:2 to 1994:1 is reserved for initial parameter estimation. For $k = 8$, the initial forecast for $\pi_{1996:1}^{8}$ is based on estimates of equation (6) using an effective sample of 39 observations from 1984:3 to 1994:1 (earlier observations are either needed to construct 8 quarter growth rates or are lost due to lagging of variables on the right hand side of the equation). The algorithm produces 37 total forecasts at the 8 quarter forecast horizon. The last forecast for $\pi_{2005:1}^{8}$ is based on an effective sample of 75 observations from 1984:3 to 2003:1. Thus, we have effectively divided the total data set in

[20] In particular, evaluation of the Schwartz information criteria (SIC) prior to estimation in Step 1 of the algorithm results in the selection of lag lengths of 1 or 2 for the $\pi$ and $x$ variables in nearly all cases.

[21] We produced comparable results for lags lengths of 1 through 4 for both variables (*i.e.* $r = q$=1 to 4). The qualitative results are very similar for different lag lengths, except at the 12 quarter forecast horizon. For $k = 12$, we found that the inclusion of Divisia money growth improves the forecasting performance of the model for lag lengths of 1 and 2, but harms it for lag lengths of 3 and 4. We also found that the best RMSE are always produced for models with lag lengths of either 1 or 2 and that RMSE are always worse for lag lengths of 3 or 4 than for the corresponding model with a lag length of 2.

half, reserving the second half of the dataset for forecast evaluation and the first half for initial in-sample estimation.

In the results section, we present root mean squared errors (RMSE), which are defined as follows:

$$RMSE_k = \left[ \frac{1}{N} \sum_{t=1994:1+k}^{2005:1} \left( \mu_t^k \right)^2 \right]^{1/2}, \tag{7}$$

where $N = 45 - k$ is the number of out-of-sample forecasts for horizon $k$.

### *5.3 Forecast Results*

Table 3 summarizes our forecast results. For evaluation purposes, we also present RMSE obtained from a univariate benchmark model, which excludes the $x$ terms from equation (6).

For $k$ = 4 (annual inflation), the univariate model produced lower RMSE than any of the models containing a nominal money growth term. For Divisia M2 and M3, the RMSE are fairly similar to the RMSE of the univariate model, although their inclusion leads to a moderate deterioration in forecasting performance. In contrast, the inclusion of simple sum M3 leads to a more serious deterioration in forecasting performance.[22] Specifically, simple sum M3 leads to a 34% increase in RMSE over that of the univariate model, but Divisia M2 and M3 lead to only 6 and 8% increases in RMSE respectively over the univariate model.

For $k$ = 6 and 8, we find exactly the opposite result. All models that contain a nominal money growth term produced lower RMSE than the univariate model. Specifically, for $k$ = 8, Divisia M3 leads to a 31% reduction in RMSE versus the univariate model and, similarly, simple sum M3 leads to a 22% reduction in RMSE over the univariate model. At the longest forecast horizon ($k$ = 12), the models containing a nominal Divisia money growth term produced lower RMSE than the corresponding univariate models, but the inclusion of simple sum M3 growth did not. For $k$ = 6, 8, and 12, the best model is always based on Divisia M3. We also find that the RMSE for forecasts based on simple sum M3 always exceed those for forecasts based on the admissible Divisia M2 and M3 aggregates. In contrast, Drake and Mills (2005) found that Divisia M2 performed poorly relative to simple sum M2 for the US.

[22] Although in-sample fit (as judged by, for example, sum of squared errors) cannot be harmed by including uninformative variables into the regression model, out-of-sample forecasting performance (as, for example, judged by RMSE) can be harmed. The reason is that inclusion of uninformative variables can contribute to the problem of in-sample over fitting.

**Table 3. Root Mean Squared Errors for Inflation Forecasts**

| $k$ | Divisia M2 | Divisia M3 | Sum M3 | Univariate |
|---|---|---|---|---|
| 4 | 6,658 | 6,792 | 8,425 | **6,277** |
| 6 | 6,470 | **6,220** | 6,839 | 7,481 |
| 8 | 7,057 | **6,324** | 7,101 | 9,110 |
| 12 | 12,399 | **11,222** | 15,709 | 12,951 |

**Notes:**
1. RMSE are multiplied by 1,000,000.
2. Two lag specification ($r = q = 2$).
3. Bold entries indicate the smallest RMSE for each forecast horizon.
4. The total number of out-of-sample forecasts, $N$, for each forecast horizon, $k$, is $N = 45\text{-}k$.

Finally, we investigated how relative forecasting performance varies over time. Here, we focus on results for $k = 8$, where the monetary aggregates seem to be most valuable. We found that the inclusion of nominal money growth harms the forecasting performance of the model for forecasts made after the launch of the Euro currency (*i.e.* for forecasts based upon in-sample estimations using observations for 2002:1 and beyond, which are used to produce forecasts of 8 quarter inflation for 2004:1 through 2005:1). This result could possibly indicate problems with the consistency of the monetary aggregate data prior to and immediately following the launch of the Euro currency.[23] Excluding these 5 forecasted values, there are a total of 32 forecasted values. We computed separate RMSE for the first 16 and for the last 16 of these forecasts and compared results. The inclusion of money growth reduces RMSE substantially for the first 16 forecasts regardless of which monetary aggregate is used, although the result is most pronounced for Divisia M3. The inclusion of Divisia M3 leads to lower RMSE relative to the univariate model for the last 16 forecasts as does the inclusion of simple sum M3 (to a lesser extent), but the inclusion of Divisia M2 leads to slightly higher RMSE than the univariate model for the last 16 forecasts. Thus, it appears that although nominal money growth contains useful information for forecasting inflation, much of the evidence supporting this finding is for the earlier forecasts considered in our exercise.

Figure 3 depicts the relationship between 8 quarter inflation, $\pi_t^8$, and the 8 quarter nominal money growth rates for Divisia and simple sum M3, $x_t^8$. In panels A and B of the figure, the dashed lines denote inflation and the solid lines denote money growth. Panel A features Divisia M3 and Panel B features simple sum M3. Panel C shows the difference between the Divisia M3 growth rate and the simple sum M3 growth rate to facilitate compari-

[23] Such inconsistency is apparent, for example, in the quantity data for the CC component of M3.

son. We shade dates corresponding to recessions in order to highlight possible differences between the series during recessions, expansions, and at business cycle turning points.[24] The graph shows that Divisia M3 has a lower growth rate than simple sum M3 throughout the expansion of the 1980s and the recession of the early 1990s, but conversely grows more rapidly during the expansion of the mid to late 1990s. During the most recent recession, Divisia growth is lower than simple sum M3 growth, but is again higher in the most recent expansion period. Thus, there is at least some evidence that differences between Divisia and simple sum growth are systematically related to the business cycle in the 1990s and beyond.

**[Figure 3 about here]**

## 6. Conclusions

Divisia monetary aggregates have been widely used in academic research and are regularly published by several central banks including the Bank of England for the UK and the Federal Reserve Bank of St. Louis for the US. Stracca (2004) studies the properties of a synthetic Divisia monetary aggregate for the Euro area. Using updated data, we tested various groupings of the Euro area monetary assets in M3 for weak separability. Empirical research has often stressed that both the composition and construction of monetary aggregates matter for gauging their value in empirical settings (see, for examples, Swofford and Whitney, 1991, Belongia, 1996, Schunk, 2001, and Duca and VanHoose, 2004). Moreover, the widely acknowledged theoretical superiority of the Divisia monetary aggregate rests on the aggregation-theoretic admissibility property of weak separability of the components of the aggregate. We find that both the M2 and M3 asset groupings as defined by ECB satisfy the weak separability criteria.[25]

We construct Divisia monetary aggregates for M2 and M3 and test for direct effects of Divisia money on Euro area aggregate demand, following an approach developed by Nelson (2002), Reimers (2002), and Stracca (2004). We find evidence that both Divisia M2 and M3 have direct effects on aggregate demand over a long period from1980 to 2005 and a shorter period from 1991 to 2005. These results indicate that, at a minimum, the admissible Divisia monetary aggregates appear to contain additional information for aggregate demand in the Euro area economy beyond that contained in short-term real interest rate variables.

[24] We determine peaks and troughs from the two output gap measures previously depicted in Figure 2, which correspond to HP filtered data and quadratic de-trending in logs. The peak of 1992:1 corresponds exactly to the peak from the Business Cycle Dating Committee of CEPR (2003). The trough of 1993:4 differs from the CEPR trough of 1993:3 by just one quarter. Thus, our choice of dating seems plausible. CEPR also dates a peak at 1980:1 and a trough at 1982:3, but we omit this from our figures, since it comes at the beginning of our sample period.

[25] The finding that the several asset groupings are weakly separable mirrors similar findings for the UK (*e.g.* Elger, Jones, Edgerton, and Binner, 2006) and for the US (*e.g.* Jones, Dutkowsky, and Elger, 2005).

Next, we evaluated the potential for these Divisia aggregates to be used to forecast inflation as measured by the GDP deflator. We find that Divisia M2 and M3 led to improvements in inflation forecasts for the Euro area over a univariate model at most forecast horizons. In addition, forecasts based on Divisia M2 and M3 were superior to corresponding forecasts based on simple sum M3. Thus, the admissible Divisia monetary aggregates are potentially valuable for forecasting Euro area inflation. Although beyond the scope of the current study, an exhaustive study that evaluates a wide range of leading indicators for inflation in the Euro area, along the lines of Stock and Watson (1999), is clearly merited. With respect to Euro area monetary aggregates, further research might be profitably directed towards exploring more sophisticated aggregation procedures as suggested by Barnett (2003) or towards incorporating risk bearing assets into the money measures.[26]

[26] For example, Drake, Fleissig and Mullineux (1999) use an asymmetrically ideal model to estimate substitution elasticities between financial assets held in the UK personal sector. Innovatively, they extended the set of assets to include "risky" assets as well as the traditional "monetary" components of M3 or M4. They find evidence of substitutability between "risky" and "monetary" assets and that as a risk aversion increases, substitutability decreases. See also Elger and Binner (2004) for related analysis of the UK.

**Appendix. Afriat Indexes from Linear Programming (LP) Procedure**

Let $QT^i$ denote the $i^{\text{th}}$ observation of a Törnqvist quantity index and let $PT^i = \boldsymbol{\pi}^i \mathbf{m}^i / QT^i$ denote the $i^{\text{th}}$ observation of its dual price index (*i.e.* total expenditure divided by the quantity index). The procedure is to minimize

$$F = \sum_{i=1}^{T} (V_+^i + V_-^i + \mu_+^i + \mu_-^i) \tag{A1}$$

in $V_+^i,\ V_-^i,\ \mu_+^i,\ \mu_-^i$ for $i = 1,...,T$, subject to the following constraints:

$$QT^i + V_+^i - V_-^i \le QT^j + V_+^j - V_-^j + (1/PT^j + \mu_+^j - \mu_-^j)\boldsymbol{\pi}^j(\mathbf{m}^i - \mathbf{m}^j) \quad \forall\, i \ne j, \tag{A2}$$

$$QT^i + V_+^i - V_-^i > 0 \quad \forall\, i \tag{A3}$$

$$1/PT^i + \mu_+^i - \mu_-^i > 0 \quad \forall\, i \tag{A4}$$

$$V_+^i, V_-^i, \mu_+^i, \mu_-^i \ge 0 \quad \forall\, i\,. \tag{A5}$$

The Afriat indexes produced by the procedure are as follows: $V^i = QT^i + V_+^i - V_-^i$ and $\mu^i = 1/PT^i + \mu_+^i - \mu_-^i$, which implies that $V^i$ can be interpreted as an adjusted Törnqvist index with $V_+^i$ and $V_-^i$ representing the absolute value of the positive and negative adjustments respectively (since both are constrained to be non-negative). We solved this LP problem in FORTRAN using the IMSL subroutine DSLPRS.

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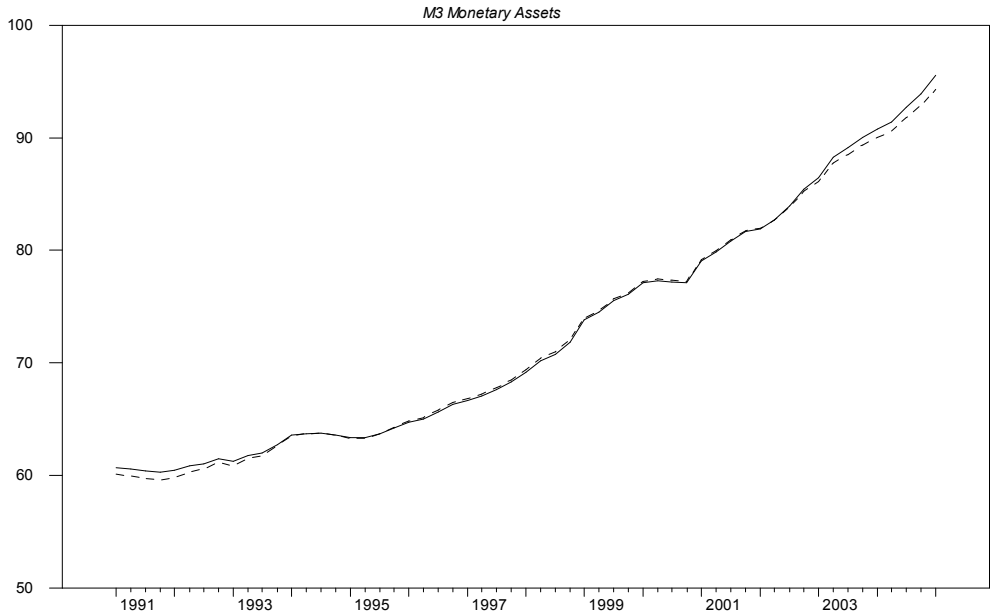
**Figure 1. Real (Per-Capita) Tornqvist Index vs. Afriat Index**

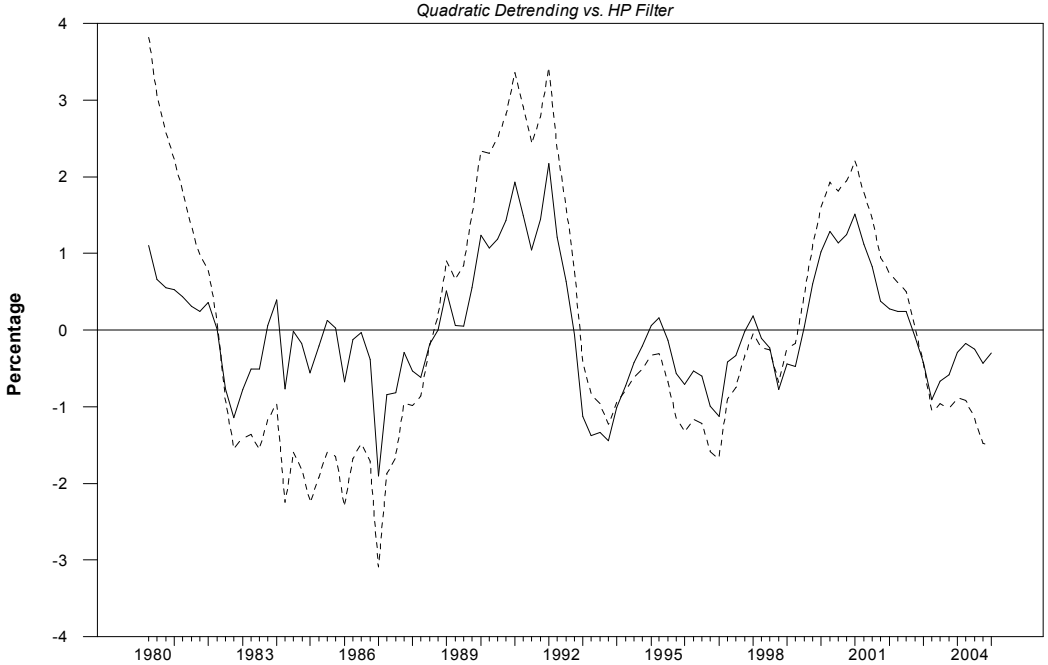
*M3 Monetary Assets*




Solid line denotes Törnqvist Index, dashed line denotes Afriat Index from the LP algorithm.

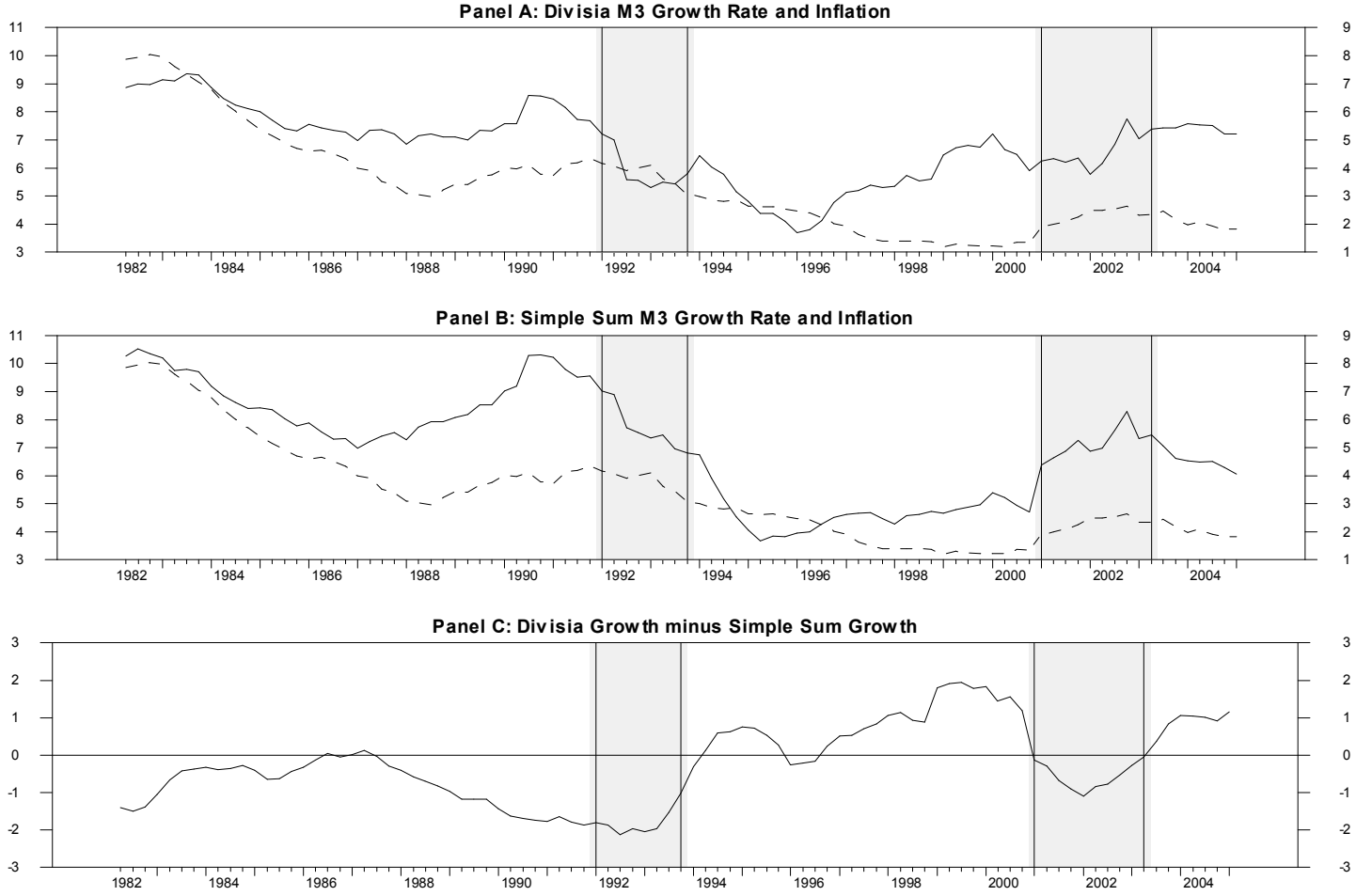
**Figure 2. Two Measures of Output Gap**

*Quadratic Detrending vs. HP Filter*




Solid line denotes cyclical component from HP filter, dashed line denotes residuals from quadratic de-trending regression. Output gap measures are multiplied by 100 to denote percentages.

## Figure 3: 8 Quarter Inflation vs. 8 Quarter Nominal Money Growth




In panels A and B, dashed line denotes $\pi_t^8$ (right scale), solid line denotes $x_t^8$ (left scale) both multiplied by 100. Shaded areas denote recessions from peak to trough.