ADMISSIBLE MONETARY AGGREGATES AND U.K. INFLATION TARGETING

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Abstract

This study shows how to construct “admissible” monetary aggregates using a procedure to adjust the simple sum, Divisia and empirical monetary aggregates to be consistent with weak separability. The corresponding “admissible” monetary aggregates have considerable leading indicator information and provide the most accurate predictions of inflation over the Bank of England’s two year forecast horizon.

Key Words: weak separability, revealed preference, nonparametric

JEL Categories: C14, C43, E51, E52

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1. INTRODUCTION

Monetary policy objectives in the United Kingdom have changed considerably over the last 20 years. Specifically, the abandonment of formal broad monetary targeting in 1986 was followed by unsuccessful phases of exchange rate targeting from 1987 to 1992, and culminated with the present objective of inflation targeting following Sterling's exit from the ERM in September 1992. The policy of Inflation Targeting was further bolstered with the granting of operational independence for the Bank of England in May 1997. The Treasury assigned the Bank of England the task of hitting the inflation target of 2.5% (plus or minus 1%) based upon a retail price index excluding mortgage interest payments (RPIX).[1]

Given that inflation is a lagging indicator, the Bank of England constructs a probability density function to forecast inflation outcomes up to two years ahead. Thus the Bank's Monetary Policy Committee requires leading indicators to target inflation and utilizes simple sum monetary aggregates, yield differentials between nominal and inflation-indexed bonds and other economic indicators.

A major concern of the Bank of England and other central banks is that simple sum monetary aggregates have, in the past,

[1] The U.K. Chancellor recently changed the Inflation Target to 2% for the Consumer Price Index to bring the U.K. into line with the Euro-zone monetary policy conducted by the European Central Bank.

failed to maintain a stable and predictable relationship with key economic variables such as nominal income and its decomposition into prices (inflation) and real income (output). The failure of the simple sum monetary aggregates as a policy tool has largely been attributed to financial innovation, specifically the introduction of monetary assets by the banking system that are close but less than perfect substitutes for highly liquid assets. A serious problem with the simple sum aggregate is that it treats very different assets, for example currency and building society deposits, as perfect substitutes and assigns these assets equal weights of unity in the aggregate.[2] For any monetary aggregate to accurately predict economic activity, it must allow for less than perfect substitution between assets with weights that vary over time according to economic conditions.[3] Such monetary aggregates can be constructed using a Divisia superlative index suggested by Barnett (1980, 1982) or estimated empirically from nominal income or price relationships, as in Feldstein and Stock (1996) and Drake and Mills (2004) for the U.S., and Drake and Mills (2001) for the U.K.

No matter how a monetary aggregate is constructed, however, Barnett (1980, 1982) advocates using an "admissible" monetary

[2] U.K. studies typically find less than perfect substitution between monetary assets and that the instability of broad money demand during the 1980s may be attributable in large part to the use of conventional official simple sum aggregates; Belongia and Chrystal (1991), Drake and Chrystal (1994,1997) and Drake, Fleissig and Swofford (2003).

[3] Formal targeting of the growth rates of simple sum monetary aggregates were abandoned by the Bank of England in 1986 for £M3 and by the U.S. Federal Bank for all monetary aggregates in 2000. Many Central Banks now construct monetary aggregates using a superlative index. The Bank of England introduced the sectorial Divisia M4 project in 1994 while the Federal Reserve Bank of St. Louis published its Monetary Service Index in 1997.

aggregate which must satisfy the conditions for weak separability. While the nonparametric procedure of Varian (1983) has been used by, inter-alia, Belongia and Chrystal (1991), Patterson (1991), Fisher, Barnett and Serletis (1992), Fisher (1992), Belongia (1996), Swofford and Whitney (1987, 1988), Drake (1996), Drake and Chrystal (1994, 1997), to evaluate if groups of monetary assets are weakly separable from other goods, this does not necessarily produce "admissible" monetary aggregates. These studies suggest constructing "admissible" monetary aggregates from weakly separable sub-groups of monetary assets using a Divisia index, but a potential problem is that these constructed monetary aggregates may not themselves be consistent with weak separability.

In this paper we use the three step procedure developed by Fleissig and Whitney (2003) to determine if a constructed or estimated monetary aggregate is an "admissible" aggregate by testing if it is consistent with weak separability. The test first evaluates samples over which the utility function of monetary assets and consumption goods are consistent with utility maximization. The procedure is then applied over such periods to determine if various monetary aggregates (simple sum, Divisia, and empirically weighted) are consistent with weak separability. If any of these aggregates violate weak separability, the third stage of the analysis determines how much the aggregate must be adjusted to satisfy weak separability. Thus, all adjusted monetary aggregates are "admissible" monetary aggregates.

The ultimate goal is to evaluate and determine if the

Divisia, simple sum, empirically weighted and "admissible" monetary aggregates are suitable for policy purposes in the context of inflation targeting. The most significant result from this study is that the "admissible" monetary aggregates give considerably more accurate RPIX inflation forecasts two years ahead compared to the simple sum, Divisia, and empirically weighted monetary aggregates.

2. MONETARY AGGREGATION AND WEAK SEPARABILITY

In a general consumer optimization framework, the agent derives utility from both consumer goods and service flows from monetary assets which are included in the utility function:

$$u = U(\mathbf{c},\mathbf{m}) \tag{1}$$

where **c** and **m** are vectors of service flows from consumption goods and monetary assets. The utility function is often tested for consistency with utility maximizing behavior or the Generalized Axiom of Revealed Preference (GARP). Further structure of the utility function, specifically weak separability, can be examined only if the utility function is consistent with GARP.

The objective of this study is to find if there exists a sub-utility function V(**m**) of the monetary assets that is consistent with a weakly separable utility function:

$$u = U(\mathbf{c},V(\mathbf{m})) \tag{2}$$

and satisfies the necessary and sufficient conditions for weak separability of Varian (1983).

Varian's Separability Theorem. The following conditions are equivalent.

(i) there exists a weakly separable concave, monotonic, continuous non-satiated utility function that rationalizes the data;

(ii) there exist numbers U^i, V^i, $\lambda^i>0$, $\mu^i>0$, that satisfy the separability inequalities for i,j=1,...,n:

$$U^i \le U^j + \lambda^j p^j(x^i - x^j) + (\lambda^j/\mu^j)(V^i - V^j)$$

$$V^i \le V^j + \mu^j q^j(y^i - y^j)$$

(iii) the data (q^i,y^i) and $(p^i,1/\mu^i; x^i,V^i)$ satisfy GARP for some choice of (V^i,μ^i) that satisfies the Afriat inequalities.

Note that condition (iii) is equivalent to evaluating GARP with V^i as the 'group quantity index' and $1/\mu^i$ as the 'group price index' for the separable y-goods. In this study, the various monetary aggregates are the 'group quantity indices' with their associated user cost being the 'group quantity indices.

In applications, the researcher must empirically determine if the observed price and quantity data are consistent with GARP. The nonparametric test of Varian (1982) is often used to evaluate if utility function U(**c**,**m**) is consistent with GARP.[4] If the utility function U(**c**,**m**) is found to be consistent with GARP, then further empirical tests are necessary to establish if it is possible to form an “admissible” monetary aggregate V(**m**) that is consistent with a weakly separable utility function U(**c**,V(**m**)).

One approach to finding a sub-utility function is to apply Varian’s (1983) nonparametric procedure which finds an arbitrary

[4] An advantage of the nonparametric procedure is that violations of revealed preference cannot be attributed to using an incorrect functional form because the test does not require specifying a parametric utility function. A shortcoming of the non-parametric approach is that it is non-stochastic, see Barnett and Choi (1989), Bronars (1987) and Fleissig and Whitney (2003).

solution for V(**m**). Researchers who use Varian's (1983) procedure, and find that monetary assets are weakly separable from goods, typically suggest aggregating these assets using a Divisia index.[5] While Varian's procedure finds a solution for the monetary aggregate V(**m**) that may have negative values but is still consistent with weak separability, there is no guarantee that the constructed Divisia aggregate satisfies weak separability, i.e., condition (iii) above may not be satisfied by the Divisia index. An alternative is to use the more powerful nonparametric procedure of Fleissig and Whitney (2003) which extends Varian's approach by using economic theory to find the monetary sub-utility function. Their LP procedure uses a superlative index to approximate V(**m**) and tests if it satisfies weak separability. An important result from their simulations is that the superlative index often requires a small adjustment to satisfy weak separability.

Given that V(**m**) is a monetary aggregate, we also construct empirically weighted monetary aggregates using weights estimated from a long run relationship between the monetary asset components and either prices or nominal GDP. This empirically weighted approach to monetary aggregation follows Drake and Mills (2001, 2004) and is discussed in more detail in section 4. For completeness, we also use the simple sum monetary aggregate for V(**m**). All of these empirical aggregates are checked for consistency with weak separability using the procedure of

[5] Studies that use U.K. data include Belongia and Chrystal (1991), Patterson (1991), Drake (1996), Drake and Chrystal (1994, 1997),and Drake, Fleissig and Swofford (2003).

Fleissig and Whitney (2003).

3. DATA

The quarterly data cover the period 1977:1 through 2003:3 and relate to the U.K. Household sector. All quantity data are seasonally adjusted and converted into real per household terms using the GDP deflator and data on the total number of households obtained from *The Office of Population and Census Studies*. The three consumer goods are:

NDUR - nondurable goods
SER - services
DUR - stock of durable goods.[6]

Liquidity service flows from monetary assets are assumed to be proportional to the real per household stock of monetary asset holdings.[7] The asset categories are:

NC - Notes and coins
NIBS - Non-interest-bearing sight deposits
IBS - Interest bearing sight deposits
TD - Bank Time Deposits
BSD - Building Society Deposits[8]

These assets correspond broadly to U.K. M4, the official broad money aggregate adopted in the U.K. following the abandonment of £M3 (approximately M4 less BSD) targeting in the

[6] The stock of durables goods are calculated using data on expenditures on durables, combined with unpublished data on depreciation rates for durables obtained from the Office for National Statistics. Quantities for non-durables and services are real per household expenditures.
[7] Personal sector holdings of the assets were constructed on a stock-flow consistent and break adjusted basis by the Bank of England as part of a sectoral Divisia M4 project. The annual percentage interest rate series data were transformed into quarterly returns by dividing by 400.

[8] Cash individual savings accounts (ISAs) were introduced by the Government in the second quarter of 1999 as part of an initiative to stimulate savings. Since Cash ISA deposits are not available over most of the sample, they are omitted from the analysis.

mid 1980s. Since NC and NIBS have identical user costs, they make up a Hicksian composite good and can be added together. This composite asset category is henceforth referred to as Non-Interest Bearing M1 (NIBM1).

The interest rate series reflect the rates paid to the Household Sector on the component assets, such as bank interest bearing sight and time deposits. The own rates of return on notes and coins and non-interest bearing sight deposits are taken to be zero although the opportunity cost of holding these assets is not zero. Fisher, Hudson, and Pradhan (1993) provide details on the own rates of return for the interest bearing assets. The appropriate formula for the user cost (RP_{it}), or one period holding cost, of monetary assets is $RP_{it}=P_t(R_t-r_{it})/(1+R_t)$ where R_t is the yield available on a benchmark asset, P_t is a price index and r_{it} is the market yield on the i^{th} monetary asset. This formula was derived by Barnett (1978) and Donovan (1978).[9]

4. EMPIRICALLY WEIGHTED AGGREGATES

The abandonment of monetary aggregate targeting was largely associated with the breakdown of previously stable empirical relationships between the monetary aggregates and policy variables such as prices (inflation) and nominal income.

[9]This user cost is used by Belongia and Chalfant (1989), Barnett, Fisher and Serletis (1992), Fisher (1992), Belognia and Chrystal (1991), Patterson (1991), Swofford and Whitney (1987,1988), Drake and Chrystal(1994,1997), Drake (1996), Belongia (1996), and Drake, Fleissig and Swofford (2003). The return on the benchmark asset is from the Bank of England's Divisia database. Following Patterson (1991) and Drake, Fleissig and Swofford (2003), the envelope approach is used to construct the benchmark return which is taken to be the max of all the returns (including the benchmark asset) in each period plus epsilon to eliminate negative rental prices.

Empirical evidence suggests that the instability of broad U.K. money demand during the 1980s may have been attributable in large part to the use of conventional official simple sum aggregates which assume that the component assets are perfect substitutes for each other (Patterson, 1991, Belongia and Chrystal, 1991, and Drake and Chrystal, 1994, 1997). As a consequence, both central banks and researchers have increasingly tended to focus on weighted aggregates such as Divisia monetary aggregates.

An alternative approach for constructing monetary aggregates, suggested by Feldstein and Stock (1996) and Drake and Mills (2001, 2004), is to determine the weights for the monetary component assets empirically so that the monetary aggregate adjusts over time to provide a stable leading indicator for economic variables. The weights for the monetary assets can be estimated using a switching regression or time varying parameter model as in Feldstein and Stock (1996), or from the long run relationship between the component monetary assets and either nominal GDP or prices as in Drake and Mills (2001, 2004)[10].

We follow Drake and Mills (2001, 2004) in deriving the weights for the component monetary assets from the long run relationship between the monetary components and either RPIX, the Retail Price Index (RPI) or Nominal GDP. We utilize RPIX as the appropriate measure of the U.K. price index in order to be consistent with the U.K. policy of Inflation Targeting which was based on RPIX after 1992:4. However, this measure of retail

[10] The switching regression approach of Feldstein and Stock (1996) has been applied to Canadian monetary data by Siklos and Barton (2001).

prices explicitly excludes the cost of living element associated with mortgage interest payments. Hence, for completeness we also use the more comprehensive all items retail price index. The required historical data is not available to permit an analysis using the Consumer Price Index recently adopted by the U.K. government in the context of the revised inflation target.

4.1 Long Run Empirical Relationships

Prior to testing for a long-run cointegrating relationship between the monetary asset components, and either RPIX, RPI or Nominal Income (NGDP), the order of integration of these variables and the monetary asset components is evaluated using the Augmented Dickey Fuller (ADF) test (see Appendix 1). Since the levels of the variables tend to be strongly trended, the ADF test fails to reject the null of a unit root for all variables. When the variables are expressed in first differences, however, the ADF tests fail to accept the null of a unit root for all variables. Hence, the results from the ADF tests suggest that all the series are integrated of order one I(1) and we can therefore proceed to test for a long-run cointegrating relationship between the log of monetary assets and either the log of prices (LRPIX, LRPI) or log nominal income (LNGDP).

In order test for long-run cointegrating relationships, the multivariate maximum likelihood procedure of Johansen (1988) is used. In all cases, the Johansen maximum eigenvalue test suggests a unique cointegrating relationship between the log of the monetary asset components and the log of the policy variable of interest, RPIX, RPI and Nominal GDP as shown in Appendix 2.

Appendix 2 also provides details on the component asset weights implied by the long run empirical relationships. Prior to constructing the empirically weighted monetary aggregates based on these cointegrating relationships, the long run weights are normalized to sum to unity. In each case, the empirically weighted aggregates are derived as the exponential of the sum of normalized log asset weights multiplied by the respective nominal asset quantities, as in Drake and Mills (2001, 2004). The three empirical monetary aggregates are:

EW_NGDP: Empirical weighted aggregate estimated from the long run relationship between the nominal monetary assets and nominal income

EW_RPIX: empirically weighted aggregate estimated from long run relationship between nominal monetary assets and RPIX

EW_RPI: empirically weighted aggregate estimated from the long run relationship between nominal monetary assets and RPI

5. NONPARAMETRIC TESTS FOR ADMISSIBLE MONETARY AGGREGATES

The utility function of the goods and monetary assets is first evaluated for consistency with revealed preference and the nonparametric test of Varian (1982) is applied to the utility function:

$$u = U[NDUR, SER, DUR, NIBM1, IBS, TD, BS]$$

The data violate revealed preference over the sample 1977:1-2003:3.[11] Further testing, however, revealed that the largest

[11] Drake, Fleissig and Swofford (2003) did not find GARP violations over

sample period for which there are no GARP violations was over the period 1992:4-2003:3. Finding this GARP consistent period is significant because it corresponds with the period of inflation targeting introduced by the U.K. government in October 1992.

As the data are only consistent with utility maximization over the period 1992:4-2003:3, we now empirically evaluate the separability conditions of Varian (1983) over this sample to determine if the weakly separable utility function $u = U(\mathbf{c}, V(\mathbf{m}))$ is consistent with utility maximization. Since the monetary sub-utility function $V(\mathbf{m})$ also has the properties of a utility function, Varian's (1983) necessary condition for the weak separability is that the sub-utility function:

$$V(\mathbf{m}) = \mathbf{V}(NC+NIBS, IBS, TD, BS) \qquad \mathbf{(3)}$$

also satisfies GARP. The procedure of Fleissig and Whitney (2003) requires first testing if the sub-utility function satisfies the necessary condition for weak separability. Applying Varian's (1982) procedure, the monetary data satisfy GARP over the period 1992:4-2003:3. Given that the data satisfy both necessary conditions for weak separability, the sufficient condition is now evaluated.

The sufficient condition for the weak separability test requires evaluating if the sub-utility function of the monetary assets and consumer goods is consistent with utility maximization.

$$u = U[NDUR, SER, DUR, \mathbf{V}(NIBM1, IBS, TD, BS)] \qquad \mathbf{(4)}$$

It is important to note that all the monetary assets are

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a smaller sample and the data set did not utilize the Bank of England's benchmark rate.

now a single aggregate. Since V(**m**) represents the monetary group quantity index, Fleissig and Whitney (2003) suggest using a superlative index such as the Divisia index for V(**m**). To be consistent with utility maximizing behavior, the solution to their linear programming setup requires that the superlative index is positive and that expenditure on the monetary assets for the weakly separable group holds. Since there are multiple feasible solutions and the superlative index may not satisfy the inequalities, they suggest minimizing the deviations around the superlative index and the inverse of the corresponding implicit user cost for the aggregate (see Appendix 3).

While economic theory suggests using a superlative index to approximate V(**m**), other monetary aggregates, such as simple sum or the empirically weighted monetary aggregates discussed above, could also potentially satisfy weak separability. Therefore we also use these alternative monetary aggregates which are adjusted, if necessary, to pass weak separability using the procedure of Fleissig and Whitney (2003).

It turns out that all the monetary aggregates require small adjustments in order to pass weak separability as each aggregate either over or under predicts a feasible solution over the GARP consistent sample for weak separability.[12] Note that all adjusted aggregates are "admissible" aggregates because they are consistent with weak separability. The adjustments are required

[12] The objective function from the LP solutions are from minimizing both the deviations around the chosen monetary aggregate and the inverse of the implicit user cost (see Appendix 3). The objective function from RPIX was 9.2 (EW_NGDP), 9.8 (EW_RPIX), 10.3 (EW_RPI), 10.9 (simple sum) and 11.1 (Divisia Index).

because weak separability imposes restrictions on optimizing behavior with respect to other goods in the utility function which is not captured by the unadjusted monetary aggregates. Thus it is possible that changes in the relative prices of consumer goods may cause agents to re-optimize their consumption decisions and portfolio holdings so that the unadjusted monetary aggregates violate the weak separability conditions at some data points (see Drake, 1996).

The empirical aggregates are based on the long-run empirical relationship between monetary assets and either a price index or nominal GDP. The Divisia index, however, provides a nonparametric second order approximation to the unknown monetary aggregator function and is derived from the first order conditions of a consumer optimization. The traditional method of simple sum aggregation assumes that the assets are perfect substitutes for each other. All of the empirical monetary aggregates, including those that satisfy weak separability, are also evaluated for their forecasting accuracy.

6. FORECASTING TESTS

To assess the leading indicator properties of the alternative monetary aggregates, their relative performance is evaluated in an out-of-sample forecasting analysis. This forecasting analysis is conducted in both cumulative and marginal terms. The cumulative test assesses how lagged annualised average growth rates of a monetary aggregate over some time horizon, forecasts annualised average growth rates of a policy variable (i.e., RPIX, RPI, etc) over different forecast horizons. The alternative marginal forecasting test evaluates how well lagged one period growth rates of a monetary aggregate forecast the one period growth rate of a policy variable at different forecasting horizons, for example, four or eight quarters ahead.

Clearly, the latter is a somewhat more demanding forecasting test. Given that it takes time for changes in the growth rate of a monetary aggregate to affect inflation, however, the marginal forecasting tests are arguably more relevant for central banks such as the Bank of England which tend to forecast marginal inflationary pressures at time horizons out to two years ahead and beyond.

The analysis is initially conducted in the context of the so-called cumulative forecast tests using the forecasting model:

$$\pi_{t+k}^{k} = a + \sum_{i=1}^{q} b_i \pi_{t-i}^{k} + \sum_{i=1}^{r} c_i x_{t-i}^{k} + e_{t+k} \qquad \textbf{(5)}$$

where $\pi_t^k = (4/k)(p_t - p_{t-k})$ is k-period inflation, p_t relates to either the log of RPIX or the log of RPI, and x_t^k is a similarly defined growth rate of the indicator variable (either empirically weighted, Divisia Index, simple sum or "admissible" monetary aggregate) and e_{t+k} is a random error term.[13] This approach follows that of Drake and Mills (2001, 2004), and modifies the forecasting equation of Stock and Watson (1999) by using k-period growth rates as regressors instead of one-period rates. The lag lengths were set at q=r=4 and K=4, 8 and 12.

[13] Given the presumed theoretical link between nominal monetary growth and either nominal GDP growth or inflation, all the monetary aggregates, including the weak separability adjusted aggregates, are expressed in nominal terms for the purposes of the forecasting tests.

Since monetary economic theory generally suggests using a monetary aggregate to forecast inflation or nominal GDP, it is important to ascertain the contribution of a monetary aggregate to forecasting inflation as well as to discriminate between alternative aggregates. Hence, to evaluate the contribution that a monetary aggregate has to forecasting inflation, all forecasts are compared to a baseline forecast where inflation forecasts depend only on lagged inflation. Specifically, for the baseline forecasts all lagged nominal monetary growth terms are excluded from Equation (5) with $c_i=0$ for all i. For ease of interpretation, all of the Root Mean Square Errors (RMSE) from the respective monetary aggregate forecasts are divided by the corresponding baseline forecast RMSE. Thus values in Table 1 of less (greater) than unity show that the monetary aggregate has improved (lowered) the forecasting accuracy. For example, the one-year RMSE for RPIX for the monetary aggregate EW_NGDP relative to the baseline forecast is .97 so that including the aggregate improves the forecasting accuracy by 3%. We first focus on the RPIX and RPI inflation forecasts using the unadjusted monetary aggregates before contrasting these results with the corresponding adjusted "admissible" monetary aggregate forecasts.

6.1 Unadjusted Monetary Aggregate Inflation Forecasts

Including any monetary aggregate has unambiguously improved both the RPIX and RPI inflation forecasting accuracy as shown in

Table 1. The largest reductions in the relative RMSE for RPIX are between 25%-30% for the Divisia and simple sum aggregates over two and three year horizons. Empirical aggregates EW_NGDP and EW_RPIX reduce the RMSE for RPIX by 7%-19% over the two to three year horizons. Thus, including the Divisia Index and simple sum aggregates generally lower the forecast errors of RPIX inflation relative to the baseline forecasts by more than the other aggregates. Over the one year horizon, the monetary aggregates only lower the relative RMSE for RPIX by 3% to 5%, and this probably reflects the well established lag between prior increases in monetary growth and subsequent inflation.

It is interesting to note, given the U.K. government's decision to opt for the RPIX inflation target, that the relative RMSE are considerably smaller for RPI inflation, with the exception of the one year Divisia Index forecast. More specifically, including a monetary aggregate reduces the relative RMSE for RPI by over 30% in six forecasts compared to the single case for the simple sum RPIX forecast over the two year horizon. In addition, while the gains in RPI forecasting accuracy are larger for the Divisia index and simple sum at the three year horizon, the empirical aggregates tend to predict better at the one and two year horizons. These results support the findings of Drake and Mills (2001, 2004) that empirically weighted monetary aggregates can provide significant leading indicators of future inflationary pressures.

Table 1
Cumulative Unadjusted RMSE Forecasts[a,b]

Forecast	EW_NGDP	EW_RPIX	Divisia	Simple

	Horizon	Aggregate	Aggregate	Index	Sum
	1	.97	.95	.95	.97
RPIX	2	.89	.81	.73	.70
	3	.91	.93	.75	.71
	Forecast Horizon	**EW_NGDP Aggregate**	**EW_RPI Aggregate**	**Divisia Index**	**Simple Sum**
	1	.75	.75	.98	.95
RPI	2	.41	.49	.50	.57
	3	.80	.93	.27	.27

[a]All RMSE over the one, two and three year forecast horizons are divided by the corresponding baseline forecast that excludes all monetary data.

[b]A value less (greater) than unity shows that a monetary aggregate improves (lowers) the inflation forecasting accuracy relative to the baseline forecast.

RPIX = retail price index excluding mortgage interest payments
RPI = retail price index

EW_NGDP = empirical weighted aggregate estimated from the long run relationship between the nominal monetary assets and nominal income

EW_RPIX = empirically weighted aggregate estimated from long run relationship between nominal monetary assets and RPIX

EW_RPI = empirically weighted aggregate estimated from the long run relationship between nominal monetary assets and RPI.

6.2 Adjusted Monetary Aggregate Inflation Forecasts

The procedure of adjusting the monetary aggregates to be consistent with weak separability decreases the relative RMSE for both RPIX and RPI as shown in Table 2. Furthermore, the relative RMSE are now similar across forecast horizons for the adjusted monetary aggregates compared to the greater diversity for the unadjusted aggregates. As with the unadjusted aggregates, the adjusted “admissible” monetary aggregates generally reduce the relative RSME more for the RPI than RPIX, especially for the two and three year horizons.

In contrasting the results in Table 1 with those in Table 2, it is clear that the procedure for adjusting monetary aggregates to be consistent with weak separability can produce considerable improvements in forecasting accuracy. In the case of the empirical aggregates at the three year horizon, for example, the improvement in RPIX forecasting accuracy from adjusting the aggregates is from 9% to 23% (EW_NGDP) and from 7% to 23% (EW_RPIX). Similarly, the relative RPI forecasting accuracy improves for the empirical aggregates from 20% to 74% (EW_NGDP) and from 7% to 74% (EW_RPI). Adjusting the Divisia and simple sum aggregates to be consistent with weak separability tends to lower the RMSE for RPI but with no significant changes in the RMSE for RPIX.

In summary, these results demonstrate the significance of using the "admissible" monetary aggregates first advocated by Barnett (1980, 1982). This is an important result in the sense that, while Barnett demonstrated the theoretical advantages of using "admissible" monetary aggregates, such aggregates have not been utilized by central banks. Furthermore, there have been no empirical studies that demonstrate the empirical or policy relevance of using "admissible" monetary aggregates that have been evaluated for consistency with weak separability in an inflation forecasting environment. In particular, this study finds that for the U.K., the weak separability adjustments to the empirical monetary aggregates often lead to considerably better long run forecasts. Hence, from a policy perspective, the new adjusted "admissible" monetary aggregates can provide additional valuable leading indicators of inflationary pressures at horizons up to three years.

Table 2
Cumulative Adjusted "Admissible" RMSE Forecasts[a,b]

	Forecast Horizon	EW_NGDP Aggregate	EW_RPIX Aggregate	Divisia Index	Simple Sum
	1	.95	.91	.95	.95
RPIX	2	.72	.71	.73	.73
	3	.77	.77	.77	.77

	Forecast Horizon	EW_NGDP Aggregate	EW_RPI Aggregate	Divisia Index	Simple Sum
	1	.95	.96	.95	.95
RPI	2	.50	.48	.49	.49
	3	.26	.26	.25	.25

[a]All RMSE over the one, two and three year forecast horizons are divided by the corresponding baseline forecast that excludes all monetary data.

[b]A value less (greater) than unity shows that a monetary aggregate improves (lowers) the inflation forecasting accuracy relative to the baseline forecast.

RPIX = retail price index excluding mortgage interest payments
RPI = retail price index

EW_NGDP = empirical weighted aggregate estimated from the long run relationship between the nominal monetary assets and nominal income

EW_RPIX = empirically weighted aggregate estimated from long run relationship between nominal monetary assets and RPIX

EW_RPI = empirically weighted aggregate estimated from the long run relationship between nominal monetary assets and RPI.

6.3 Marginal Inflation Forecasting Tests

Since the Bank of England forecasts inflationary pressures two or more years ahead, the contribution that a monetary aggregate has on the marginal inflation forecasting accuracy is also examined and compared to the cumulative results. The marginal impact that a monetary aggregate has on inflation forecasting is examined using the forecasting model:

$$\pi^k_{t+k-j} = a + \sum_{i=1}^{q} b_i \pi_{t-i} + \sum_{i=1}^{r} c_i x_{t-i} + e_{t+k} \qquad \textbf{(6)}$$

where K refers to the forecasting horizon, $\pi^k_{t+k-j} = p_{t+k} - p_{t+k-j}$,

$\pi_t = p_t - p_{t-1}$, p_t refers to the log of the price index (RPIX or RPI), x_t is the similarly defined one period growth rate of the relevant monetary aggregate, and e_{t+k} is a random error term. The results for the marginal forecasting tests, relative to the baseline forecasts, are provided in Table 3.[14]

Table 3
Marginal Inflation Forecasting Tests[a,b]

	One Year		Two Year		Three Year	
Unadjusted Aggregates	RPIX	RPI	RPIX	RPI	RPIX	RPI
EW_NGDP	.41	.48	.34	.25	.27	.42
EW_RPIX	.42	-	.35	-	.45	-
EW_RPI	-	.46	-	.43	-	.41
Simple Sum	.54	.58	.25	.21	.42	.48
Divisia Index	.48	.59	.21	.11	.48	.42
Adjusted Admissible	RPIX	RPI	RPIX	RPI	RPIX	RPI
EW_NGDP	.45	.55	.10	.17	.43	.32
EW_RPIX	.44	-	.10	-	.42	-
EW_RPI	-	.55	-	.17	-	.31
Simple Sum	.44	.55	.07	.16	.37	.24
Divisia Index	.44	.54	.07	.16	.37	.24

[a]All RMSE over the one, two and three year forecast horizons are divided by the corresponding baseline forecast that excludes all monetary data.

[b]A value less (greater) than unity shows that a monetary aggregate improves (lowers) the inflation forecasting accuracy relative to the baseline forecast.

RPIX = retail price index excluding mortgage interest payments
RPI = retail price index

EW_NGDP = empirical weighted aggregate estimated from the long run relationship between the nominal monetary assets and nominal income

EW_RPIX = empirically weighted aggregate estimated from long run relationship between nominal monetary assets and RPIX

EW_RPI = empirically weighted aggregate estimated from the long run relationship between nominal monetary assets and RPI.

Including a monetary aggregate considerably improves the accuracy of the marginal inflation forecasts with large decreases

[14] In all cases, j=1, and for the one and two year horizons (k=4 and 8) the lag orders are set at q=8 and r=12, while for the three year period (k=12), the lags are set at q=4 and r=12, due to degrees of freedom problems.

in the relative RMSE's of between 41% and 93% over all horizons. More significantly, however, in the context of the Bank's two year RPIX inflation targeting horizon, the relative RMSE's are decreased by over 90% for all of the adjusted monetary aggregates. While the EW_RPIX aggregate has a RMSE that is 65% lower than the baseline forecast over the two year horizon, the adjusted "admissible" EW_RPIX aggregate generates a RMSE which is 90% smaller than the baseline forecast. The most significant gains in forecasting accuracy, however, are for the adjusted Divisia index and simple sum aggregate, which both have RMSE's that are 93% lower compared to the baseline forecast.

Based on the substantial reductions recorded in the relative RMSEs, it is clear that there is also considerable leading information content in respect of lagged monetary growth over the three year forecasting horizon. Furthermore, given the U.K.'s strong commitment to RPIX inflation targeting in the post-1992 period, the adjusted "admissible" aggregates clearly have significant longer leading indicator properties. In the case of the Divisia aggregate, for example, the relative RMSE is 48% of the baseline forecast, while for the adjusted Divisia aggregate the relative RMSE is only 37% of the base forecast.

Turning now to the RPI marginal inflation forecasting results, the unadjusted Divisia aggregate has by far the lowest relative RMSE of 11% of the baseline forecast over the two year horizon. Nonetheless, it is clear that, in general, the "admissible" monetary aggregates give a marked improvement in the marginal inflation forecasting accuracy over all forecast horizons. The relative RMSE of the empirical aggregate EW_RPI over the two year horizon, for example, declines from 43% of the base forecast, to only 17% for the adjusted EW_RPI aggregate. Furthermore, as was evident in the cumulative forecasting tests, the process of weak separability adjustment tends to reduce the diversity in the forecasting accuracy across the aggregates.

Hence, these marginal forecasting results reiterate the potential significance of using the "admissible" monetary aggregates advocated by Barnett (1980, 1982). If anything, the support for the use of the "admissible" adjusted monetary aggregates is stronger on the basis of the marginal as opposed to the cumulative inflation forecasting tests. More specifically, the improvements in forecasting accuracy are more dramatic in the marginal forecasting tests, especially in the context of the two year RPIX inflation forecasts.

7. CONCLUSIONS

Monetary policy in the U.K. has changed considerably since 1992, given the commitment to inflation targeting based on the Retail Price Index excluding mortgage interest payments (RPIX). In particular, since inflation is a lagging economic indicator, the Bank of England now sets policy based on inflation predictions two years ahead. In this context, this study highlights the policy relevance of using "admissible" monetary aggregates first advocated by Barnett (1980, 1982). More specifically, constructing "admissible" monetary aggregates gives far more precise predictions of RPIX inflation over the Bank's forecast horizon compared to the simple sum, Divisia Index and empirical aggregates.

The "admissible" monetary aggregates were constructed by using a procedure to adjust the simple sum, Divisia Index and empirical monetary aggregates to be consistent with a weakly separable utility function that also includes consumer goods. Hence, this study differs from the typical approach where a Divisia monetary aggregate is constructed from a weakly separable subset of monetary assets, but where the Divisia aggregate itself may not be consistent with a weakly separable utility function. Both the cumulative and marginal out-of-sample RPIX inflation forecasts find that most of the adjusted "admissible" monetary aggregates strongly out-predict the unadjusted counterparts at the two and three year forecasting horizon. These improvements are most notable in the case of the marginal forecasts at the two year horizon, while the cumulative forecast tests also reveal considerable forecasting gains with respect to RPI inflation, especially for the empirical weighted aggregates.

Thus our results strongly indicate that the Bank of England should utilize "admissible" monetary aggregates as part of the information set used to forecast future inflationary pressures. This contradicts the recent trend where central banks have tended to place less emphasis on the information content of monetary aggregates, largely due to the previous problems experienced with monetary growth targeting and money demand instability. The results demonstrate how changes in consumer optimizing behaviour, in response to chances in the relative price of goods, can affect portfolio holdings and ultimately the construction and predictions of monetary aggregates, as stated in Belongia (1996). These changes in consumer optimization are typically not captured by the unadjusted monetary aggregates.

The wide diversity in the forecasting accuracy of the unadjusted aggregates across different inflation measures and different forecasting horizons tends to support Barnett's (1997) conjecture that monetary aggregates that are not consistent with weak separability (and hence are non-admissible) may perform well over certain periods of time and in certain countries, but will inevitably be prone to periodic instabilities. In contrast, we find considerable convergence and consistency in the forecasting accuracy across all the adjusted "admissible" monetary aggregates.

As emphasised previously, a Divisia and simple sum aggregate constructed from a weakly separable group of monetary assets may still require small adjustments to ensure consistency with weak separability. The alternative approach of estimating empirical aggregates from a long run cointegrating relationship between monetary assets and a price index or nominal GDP, also failed to provide "admissible" aggregates without small adjustments to avoid violating the weak separability conditions. Hence, the key finding of this paper is that using a procedure to adjust the alternative monetary aggregates to be consistent with weak separability is not only theoretically consistent with optimal consumer behaviour, but also generally improves the accuracy of inflation forecasting.

Appendix 1

Augmented Dickey-Fuller Tests*

	Without Trend	With Trend
Levels		
LNIBM1	-1.784	-2.181
LIBS	-2.750	-0.647
LTD	-2.871	-2.576
LBSD	-3.588*	-1.742
LNOMGDP	-6.859*	-3.284
LRPI	-3.560*	-3.379
LRPIX	-2.178	-1.166
First Differences		
DLNIBM1	-3.233*	-3.473*
DLIBS	-3.275*	-8.947*
DLTD	-3.372*	-4.203*
DLBSD	-3.657*	-5.085*
DLNOMGDP	-3.788*	-5.361*
DLRPI	-3.639*	-4.922*
DLRPIX	-6.853*	-6.744*

*Significant at the 5% level
All variables are in logarithms

Lag order in the ADF tests determined on the basis of Information Criteria

NIBM1 - Notes and coins + Non-interest-bearing sight deposits
IBS - Interest bearing sight deposits
TD - Bank Time Deposits
BSD - Building Society Deposits

Appendix 2

Johansen Cointegration Results
Maximal Eigenvalue Test*

Dependent Variable	Null Hypothesis	Alternative Hypothesis	Test Statistic	95% Critical Value
LNGDP	r = 0	r = 1	42.600	37.860
	r<= 1	r = 2	27.954	31.790
	r<= 2	r = 3	21.005	25.420
	r<= 3	r = 4	18.749	19.220
LRPIX	r = 0	r = 1	42.639	37.860
	r<= 1	r = 2	29.835	31.790
	r<= 2	r = 3	23.058	25.420
	r<= 3	r = 4	13.533	19.220
LRPI	r = 0	r = 1	41.449	37.860
	r<= 1	r = 2	23.487	31.790
	r<= 2	r = 3	19.736	25.420
	r<= 3	r = 4	14.075	19.220

*The VAR lag length is set at 4 and justified on the basis of quarterly data, although Information Criteria typically implied a lower order lag length.

Normalised Cointegrating Vector

	LNGDP	LRPI	LRPIX
LNGDP	-1.000	-1.000	-1.000
LNIBM1	0.261	0.395	0.314
LIBS	-0.079	-0.128	-0.108
LTD	0.279	0.366	0.339
LBSD	0.383	0.066	0.171
Trend	0.006	0.005	0.004

The coefficient for LIBS can be set to zero since a Wald test finds that the coefficient for LIBS is not statistically significantly different from zero LNGDP (CHSQ(1)=2.367 p-value=.124), LRPI (CHSQ(1)=1.639 p-value=.200), and LRPIX (CHSQ(1)=1.390 p-value=.237).

Appendix 3

Weak Separability

The LP solution from Theorem 1 of Fleissig and Whitney (2003) is:

$$\text{Min } Z = \sum_{i=1}^{n} Q_p^i + \sum_{i=1}^{n} Q_n^i + \sum_{i=1}^{n} \mu_p^i + \sum_{i=1}^{n} \mu_n^i$$

subject to

$$QV^i + Q_p^i - Q_n^i \leq QV^j + Q_p^j - Q_n^j + \mu^j q^j (y^i - y^j)$$

$$\mu^i = QV^i / inc^{yi} + \mu_p^i - \mu_n^i$$

$$\mu^i \geq \varepsilon_\mu^i$$

$$QV^i + Q_p^i - Q_n^i \geq \varepsilon_{QV}^i$$

$$Q_p^i \geq 0$$

$$Q_n^i \geq 0$$

$$\mu_p^i \geq 0$$

$$\mu_n^i \geq 0$$

a. For this data set, QV^i is either a non-negative simple sum, empirical or Divisia aggregate of the monetary assets (q^i). Fleissig and Whitney (2003) add a non-negative quantity index constraint $QV^i \geq 0$ to the linear programming setup and Q_p^i and Q_n^i measure positive and negative the deviations from the monetary aggregate.

b. The implicit user cost is μ^i. To obtain a feasible solution for their linear program that is consistent with expenditure (inc^{yi}) on the separable goods (y^i) and thus more likely to satisfy weak separability, the corresponding constraint is equivalent to minimizing deviations around the inverse of the implicit user cost for the monetary aggregate. Thus μ_p^i and μ_n^i measure the positive and negative deviations around the inverse of the implicit monetary user cost.

c. The weak separability conditions of Varian (2003) require $\mu^i > 0$ and to obtain a feasible solution for the linear program the standard approach is to set $\mu^i \geq \varepsilon_\mu^i$ where ε_μ^i is a small positive number.

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