U.S. MONEY DEMAND: STRUCTURAL SHIFTS OR HETEROGENEOUS AGENTS?

STUART LANDON*

This paper examines whether observed "structural shifts" in the money demand function could be the result of agent heterogeneity due to different household income levels. Following the methodology of Stoker [1986], income distribution variables are found to be significant determinants of money demand, and once changes in the distribution of income are accounted for, there is no evidence of parameter instability. A money demand function incorporating income distribution effects is shown to perform as well or better than several standard alternatives on the basis of diagnostic tests, non-nested hypothesis tests, within-sample prediction errors and out-of-sample forecasting.

I. INTRODUCTION

A major objective of the empirical money demand literature has been the specification and estimation of a relatively parsimonious money demand function which is stable over time and satisfies basic goodness-of-fit tests, is characterized by reasonable dynamics, and can accurately forecast out of sample. As noted in Judd and Scadding [1982] and Rasche [1987] (and the references therein), most of the estimated demand for money functions produced have been characterized by structural shifts and relatively slow adjustment (or large serial correlation coefficients). What causes these results and how they should be interpreted are the subject of considerable controversy.

The present study proposes an alternative specification for the money demand function which is parsimonious, implies rapid adjustment of real money holdings, shows no sign of instability, cannot be rejected by several measures of goodness of fit, and forecasts better than several alternative specifications. The important innovation in the money demand function estimated below is the incorporation of agent heterogeneity as reflected in different household income levels. The impact of income distribution on estimates of the money demand function was raised, but not investigated, by Goldfeld [1973], while the potential importance of income distribution to the estimation of aggregate macroeconomic equations in general was made clear by Stoker [1986].

If the aggregate demand for a good is specified to be a function of aggregate or average income only, micro-level Engel curves must be linear (and parallel). If they are non-linear (or non-parallel), so that marginal demand propensities differ for agents with different incomes, a reallocation of income from one income group to another which leaves average income unchanged will alter total demand. If this is not accounted for during estimation, the estimated coefficients of the aggregate demand function will be biased. This bias could lead to incorrect estimates of demand elasticities and could potentially result in estimates which are characterized by slow adjustment (or large serial correlation coefficients), as in Stoker [1986] and Buse [1992], or parameter instability.

* University of Alberta. I gratefully acknowledge the comments of Paul Boothe, Adolf Buse, Brad Reid, Connie Smith and two anonymous referees.

Economic Inquiry
Vol. XXX, July 1992, 496–510

Barnett and Serletis [1990] examine the issue addressed in this paper by taking a demand systems approach to money demand. Using Barnett's [1979] version of the Rotterdam model, they estimate demand functions for Divisia indices of each of three monetary sub-groups of the Federal Reserve's L aggregate (M1, M2 less M1, and L less M2).[1] These three money demand functions have as arguments the user cost of each of the three sub-aggregates as well as an income variable which, for the case considered, is equal to a Divisia index of the components of L.[2] Barnett and Serletis test exact aggregation over consumers by including the Divisia second moment of the components of the income variable as an additional explanatory variable in the demand system. Their results indicate that there is no significant gain to the inclusion of distribution effects (Divisia variances) in the demand functions for these three sub-categories of monetary aggregates.

The present paper differs from Barnett and Serletis in two principal ways. First, I aim to provide an alternative explanation for the "shifts" in the money demand function that have been the focus of much empirical research in the money demand literature. To this end, the specification of the demand for money function used here is designed to remain as close as possible to that used elsewhere in the literature. In particular, I use a single equation approach, and most of the explanatory variables included have been employed in previous studies. Because the models estimated below remain similar to those in the existing literature on shifting money demand functions, the discussion can focus on the impact of income distribution effects. The second difference between the approach taken here and that of Barnett and Serletis is that the importance of the distribution of income for money demand is tested using Stoker's [1986] quantile test which explicitly incorporates income distribution data.

The paper is organized as follows. An aggregate money demand function consistent with both linear and non-linear Engel curves is derived in section II. Section III describes the data, provides estimates of the money demand function, and gives the results of several diagnostic tests. In section IV several common alternative money demand specifications are estimated. These are then compared to the estimates of section III on the basis of diagnostic tests, non-nested hypothesis tests, fit during extraordinary periods, and forecasting ability. Section V provides a brief summary and conclusion.

II. AGGREGATING MONEY DEMAND[3]

The real money demand of an individual (or household) is generally assumed to be a function of the individual's income and a vector of other variables which may be time varying, but which are identical across individuals (i.e. interest rates). Estimated money demand functions, on the other hand, usually relate average or aggregate money holdings to average or aggregate income. This approach implicitly assumes that a redistribution of income from one individual to another which leaves average income unchanged will have no effect on aggregate money demand. However, if micro-level demand for money functions are non-linear in income (or linear and non-parallel), a redistribution of this type will alter total money demand.

To derive an aggregate money demand function which is consistent with both linear and non-linear micro-level demand

1. See Barnett and Serletis [1990] for a discussion of Divisia indices.

2. This specification requires that the components of L enter the utility function and that they are weakly separable from the other arguments of this function.

3. The analysis in this section closely follows Stoker [1986] and Buse [1992].

for money functions, begin with the real money demand function of an average individual in income class i during period t:[4]

$$(1) \qquad M_{it} = Bz_t + V(y_i),\ i = 1,...N,$$

where

- y_i = average real income of individuals belonging to income class i,[5]
- z_t = a vector of variables common to all individuals,
- N = the number of cells in the income distribution.

Letting P_{it} be the proportion of individuals in income class i, average money demand across all income classes in period t is

$$(2) \qquad \overline{M}_t = \sum_i P_{it}M_{it} = Bz_t + \sum_i P_{it}V(y_i).$$

Equation (2) can only be simplified to a function of average income $\bar{y}_t$ (which equals $\sum_i P_i y_i$) if $V(y_i)$ is linear in y_i.[6]

By re-formulating equation (2), it is possible to construct an estimable money demand function which relates average money demand to average income while also accounting for potential non-linearities in micro-level money demand functions. Using vector notation, the last element of equation (2) can be rewritten as

$$(3) \qquad \overline{V}_t = V'P_t$$

where

- $\overline{V}_t$ = the average income dependent component of money demand,
- V = an N-element vector of the income dependent components of money demand for each income class,
- P = an N-element vector of the proportion of individuals in each income class.

Let $X = (i\ Y)$ where i is an N-element vector of ones and Y is an N-element vector of the average income of individuals in each income class. Defining R as $X(X'X)^{-1}X'$, it is possible to form the orthogonal decomposition of $\overline{V}_t$:

$$(4) \qquad \overline{V}_t = V'P_t = V'RP_t + V'(I-R)P_t$$
$$= V'X(X'X)^{-1}X'P_t + \tilde{V}'P_t$$
$$= \alpha + \gamma\bar{y}_t + \tilde{V}'P_t.$$

The parameters α and γ are given by $V'X(X'X)^{-1}$ and are the outcome of a cross-section regression of V on X which yields the residual vector $\tilde{V}$.[7] The matrix product $X'P_t$ equals $(1\ \bar{y}_t)$ since $i'P_t = 1$ and $Y'P_t = \bar{y}_t$. Only if individual money demand functions are linear would the marginal effect of income on money demand be the same for all income classes and the residual ($\tilde{V}$) from the cross-section regression of V on X be zero.

Substitution of (4) into (2) yields a function relating average money demand to

4. In writing equation (1) we chose to remain as close as possible to the empirical money demand literature that has found evidence of shifts in the money demand function (Goldfeld [1976] and Rasche [1987] for example) while incorporating potential non-linear micro-level income effects. Both Goldfeld and Rasche justify their specifications of the money demand function by reference to transactions models of money demand. It is implicitly assumed that this type of function at least locally approximates the money demand behaviour of utility-maximizing agents as derived, for example, in Lucas [1988].

5. The average for each class is assumed to be time invariant. Since the proportion of households in each income class can vary through time, this does not imply that average real income per household across all income classes is time invariant.

6. This follows because $V(\cdot)$ is not indexed by i and, therefore, linear micro-level demand functions would be parallel. If $V(\cdot)$ were linear but varied across individuals, so that individual demand functions were linear but non-parallel, average money demand could not be written as a function of average income only. Linear micro-level demand functions which are not parallel across income classes can be thought of as linear approximations to a non-linear $V(\cdot)$. Conversely, a non-linear $V(\cdot)$ can be used to proxy linear, but non-parallel, micro-level demand functions.

7. The time invariance of the y_i, the elements of Y, is necessary for α, γ and $\tilde{V}$ to be time invariant.

average income which is consistent with non-linear micro-level money demand functions:

(5) $\overline{M}_t = \alpha + Bz_t + \gamma\overline{y}_t + \tilde{V}'P_t + \varepsilon_t$

where ε_t is a random error.[8] Equation (5) implies that the bias in aggregate coefficient estimates which follows from the non-linearity of micro-level demand functions can be accounted for by adding the proportion of the population in each income class to the list of explanatory variables. The coefficients on these P_t variables reflect movements in money demand due to shifts in the distribution of income. The coefficient on the average income term, on the other hand, accounts for movements in money demand due to changes in average income, holding the distribution of income constant.

The extent of non-linearity in micro-level money demand functions can be determined by testing whether $\tilde{V}$ is significantly different from zero in equation (5). The a priori imposition of this zero restriction when it is actually untrue would subject estimates of α, B and γ to the usual excluded variable bias.

In the orthogonal decomposition of $\overline{V}_t$ used above, $V'R$ and $V'(I-R)$ (which equals $\tilde{V}'$) are orthogonal and, therefore, $\tilde{V}'$ must be orthogonal to i and Y. These two orthogonality restrictions must be satisfied when estimating and testing the parameters of equation (5). As a result, a test of the significance of the income distribution effects in the aggregate money demand function, that is that $\tilde{V} = 0$, has only $N - 2$ degrees of freedom since only $N - 2$ elements of the N-element vector $\tilde{V}$ are independent.

As proposed by Stoker [1986], a simple method of satisfying these two orthogonality restrictions is to exclude two income classes from P_t. This forces the cross-section regression of V on X to pass through the observations corresponding to these two excluded classes and yields the estimating equation

(6) $\overline{M}_t = \alpha^* + B^*z_t + \gamma^*\overline{y}_t + \tilde{V}^{*\prime}P_t^* + \varepsilon_t^*$,

where P_t^* does not include two elements of P_t. The vector $\tilde{V}^*$ measures the extent to which the demand for money of the income classes included in P_t^* differs from that of the two excluded classes. If distributional effects are unimportant, the demand for money of the classes included in P_t^* should be insignificantly different from that of the excluded classes and $\tilde{V}^*$ should be zero. Thus, a test of whether $\tilde{V}^*$ is zero can be used to determine the significance of income distribution effects on money demand.

III. ESTIMATES OF A MONEY DEMAND FUNCTION WITH DISTRIBUTIONAL EFFECTS

Equation (6) is an estimable money demand function which, other than the incorporation of income distribution variables, is similar to that estimated in much of the money demand literature. The dependent variable in this equation, however, is the level of the real quantity of M1 per household (*RM*1) rather than the log of aggregate M1 as is often used. I use household levels rather than logs so that the micro-level demand functions [equation (1)] can be summed to yield the aggregate money demand function [equation (2)].[9]

8. See Stoker [1986] and Buse [1992] for a discussion of the source of ε_t.

9. The data on M1 include observations for 1952 through 1958 which have been made consistent with later observations using an adjustment proposed in Rasche [1987]. Use of data without this adjustment as well as with a further adjustment for the introduction of NOW accounts (also suggested by Rasche) has almost no effect on the estimates. Goldfeld and Sichel [1987] also splice pre- and post-1959 data and find it makes no difference to their results. If aggregate, rather than per household, data is used, the coefficient estimates reported below are affected only marginally (though the fit of the money demand function is not as precise).

Following general practice in the money demand literature, one element of z_t is assumed to be the opportunity cost of holding money. This is proxied by the three-month U.S. Treasury bill yield (*R*).[10] Real personal income per household (*RPI*) is used as the average income measure since it is the income measure which is most consistent with the income distribution data.[11]

The available real income distribution data give the proportion of households in each of six income classes: those with incomes (in constant 1986 dollars) under \$5,000 (*PU5*); \$5,000 to \$9,999 (*P5T10*); \$10,000 to \$12,499 (*P10T125*); \$12,500 to \$14,999 (*P125T15*); \$15,000 to \$24,999 (*P15T25*); and \$25,000 and over (*P250*). As noted in section II above, the two orthogonality restrictions which follow from the derivation of equation (5) can be satisfied by dropping two income classes from the estimating equation. Following Stoker [1986], the estimates given below all exclude the middle two classes.[12]

I include the total number of households (*H*) as an explanatory variable for two reasons. An increase in population density is likely to lead to an increase in the number of banking facilities, lower the cost of financial transactions and reduce the demand for real money balances. In addition, technical change in the provision of banking services over the sample period is likely to have been highly correlated with the growth in the number of households (and may, in fact, not be independent of this growth). As a result, *H* is assumed to be an element of the z_t vector in the micro-level money demand function and, therefore, appears as an explanatory variable in the estimated aggregate money demand function.

Two shift dummies are also included as regressors to allow for possible structural shifts in the money demand function. These allow the intercept of the money demand function to shift at the beginning of 1974 (*D74*) and again at the beginning of 1982 (*D82*). There is still considerable controversy concerning the exact timing of these shifts. The beginning of 1974 was chosen on the basis of the evidence in Goldfeld [1976], Hafer and Hein [1982] and Judd and Scadding [1982] while the beginning of 1982 was chosen on the basis of evidence provided by Rasche [1987]. (The dates of these shifts were not modified once estimation had begun.)

Equation (6), incorporating the variables described above, was estimated using annual data for the 1953 to 1986 period. The sample period (similar to that in most of the literature) and periodicity of the data were constrained by the available income distribution data. Estimates

10. As pointed out in Barnett [1978; 1980], the interest rate is not the user cost of money implied by economic theory. Estimates using the correct user cost were not significantly different from those using a simple interest rate except that the *F*-statistic for a test of the hypothesis that the income distribution terms are jointly zero became larger in all cases. The results reported below are all for estimates which employ the simple interest rate since this is more consistent with the "shifting" money demand function literature than is the true user cost. There were also no statistically significant changes in the coefficient estimates if a constant maturity U.S. Government five-year bond yield is used in place of the Treasury bill rate.

11. Both personal income and the money supply are deflated using the Consumer Price Index since this index is used in the derivation of the constant dollar income distribution data and, in addition, it is the price index most consistent with the household demand for money. If real GNP is used, as is more common in the money demand literature, in place of real personal income, the significance of the distribution variables and the magnitude of the interest elasticity do not change appreciably, but the income elasticity of money demand falls.

12. Since the two orthogonality restrictions are not explicitly incorporated in the estimating equation, the estimated coefficients will vary depending upon which two income classes are dropped. The sensitivity of the estimated coefficients to the particular income classes dropped was examined by re-estimating the model with the highest two and then the lowest two income classes excluded. In both cases the included distribution variables remained jointly significant, and the interest and aggregate income coefficients did not change significantly.

were obtained using mid-year (June) observations for all but the income variables in order to avoid the introduction of a moving average error through averaging. The annual value of the aggregate personal income variable was used in order to remain consistent with the income distribution data.[13] (Exact definitions and sources of the data are provided in Appendix A.)

The money demand function was initially estimated using the current value and one lag of all the explanatory variables (except the shift dummies) as well as a lagged dependent variable. Tests of the restriction that the coefficients on the lagged variables are zero either individually or jointly could not be rejected at a 95 percent confidence level.[14] Columns I.1 and I.2 of Table I provide estimates of the money demand function with these zero restrictions imposed as well as with zero restrictions imposed on all lagged variables except the lagged dependent variable. Columns I.3 and I.4 give estimates of these same money demand functions, but with zero restrictions imposed on the two shift dummy variables as well. Though statistically insignificant at the 95 percent confidence level, the lagged dependent variable is included in two of the four versions of the model in Table I for comparison with previous studies which have used a partial adjustment specification of this type.[15]

The estimates in Table I explain a large proportion of the movement in the dependent variable, and an Lagrange multiplier test for serial correlation proposed by Godfrey [1978] cannot reject the hypothesis of no serial correlation in all four cases. (Thus, there is no evidence of the spurious correlation problem described by Granger and Newbold [1974].) Furthermore, the coefficient on the lagged dependent variable is not large nor particularly significant in the two equations in which it is included. The failure to find serial correlation is not characteristic of much of the money demand literature (see Rasche [1987] for example), but is characteristic of other studies incorporating income distribution effects (Stoker [1986] and Buse [1992]).

A Breusch-Pagan [1979] test for heteroskedasticity (also a general test for misspecification) could not reject the hypothesis of homoskedastic errors for all four equations.

13. As in Goldfeld [1973], the use of annual averages rather than mid-year observations does not significantly alter the coefficient estimates. They are also not altered significantly by the use of data from March, September or December rather than June. The F-statistic for the inclusion of the income distribution variables using data from each of these three months, and the model from column I.4 of Table I, are, respectively, 18.83, 14.60 and 8.97 (while the 5 percent critical value is 2.75).

14. This test is essentially equivalent to testing for a common factor of zero as noted in Hendry and Mizon [1978] and follows the methodology proposed therein. A general distributed lag specification encompasses a wide variety of specific dynamic models, as noted in Hendry, Pagan and Sargan [1984], including the standard partial adjustment model. A lag length of one was chosen ex ante since the data employed is annual, and with only thirty-two available observations estimating a general model with two lags is likely to be asking too much of the data. The appropriate lag structure and, in particular, the appropriate partial adjustment mechanism, has received considerable attention in the literature (see Goldfeld [1976], Goldfeld and Sichel [1987], and Rasche [1987]). Rather than starting with a general lag structure (Rose [1985] is an exception), the principal issue in this literature has been whether real or nominal money balances adjust according to a partial adjustment mechanism.

15. The assumption that money demand is homogeneous of degree one in prices was examined by adding the price index to the equations of Table I. In none of these four cases was this variable statistically significant. Several studies of money demand have included the actual inflation rate as an explanatory variable. In the models of Table I, this variable is not significant except when the equation includes a lagged dependent variable. This may indicate, as suggested by Goldfeld and Sichel [1987], that the restrictions imposed by the real partial adjustment mechanism may not be warranted. MacKinnon and Milbourne [1984] and Cuthbertson and Taylor [1987] have suggested that unanticipated inflation may be an important determinant of money demand. Due to the considerable controversy surrounding the definition of unanticipated inflation, we have not pursued this direction of analysis. Using annual data Rasche [1987] found no evidence to suggest that it is important.

TABLE I
Real M1 Demand with Income Distribution Effects

	I.1	I.2	I.3	I.4
Constant	4554.4 (1.78)	5930.3 (2.37)	4566.3 (1.85)	6430.2 (2.68)
R	-14.76 (2.71)	-17.53 (3.27)	-14.30 (2.75)	-17.29 (3.31)
RPI	.36 (4.55)	.43 (6.11)	.36 (5.22)	.41 (6.17)
PU5	-.31 (.01)	-7.38 (.19)	4.03 (.12)	-14.96 (.43)
P5T10	-93.53 (1.75)	-120.13 (2.28)	-96.51 (1.92)	-120.30 (2.33)
P15T25	-26.48 (1.40)	-29.95 (1.54)	-27.07 (1.49)	-33.68 (1.79)
P250	-55.13 (2.83)	-67.66 (3.65)	-53.19 (2.86)	-67.83 (3.79)
$RM1_{-1}$	.21 (1.63)		.21 (1.94)	
H	-26419 (4.81)	-33029 (8.61)	-27591 (5.63)	-35318 (11.71)
D74	-33.63 (.58)	-19.17 (.32)		
D82	-13.82 (.26)	-52.57 (1.07)		
R^2	.992	.992	.992	.991
Godfrey LM Test for AR1 (χ^2 test with one degree of freedom)	2.45[a]	.41[a]	1.96[a]	.06[a]
Breusch-Pagan LM Test for Heteroskedasticity	16.66[b] (10)	14.01[b] (9)	14.65[b] (8)	13.22[b] (7)
F-Test of Zero Restrictions on the Distribution Variables	8.07 (4,23)	18.05 (4,24)	19.68 (4,25)	25.78 (4,26)

Note: The numbers in parentheses under a coefficient estimate are the absolute values of the *t*-statistics. Those under a test statistic are the degrees of freedom for the test.

[a]Cannot reject no serial correlation at 95 percent.

[b]Cannot reject homoskedasticity at 95 percent.

Several authors, in particular Cooley and LeRoy [1981], have raised the possibility that the interest rate may be endogenous as a result of Federal Reserve behaviour. A test of the hypothesis that the interest rate and the errors in the money demand equation are independent was carried out using the methodology proposed in Hausman [1978]. For the equations given in Table I, this test could not reject the hypothesis of independence.[16]

As indicated in Table I, a test that the income distribution variables are jointly insignificant is decisively rejected.[17] Furthermore, there is no indication that the distribution variables or the number of households are simply proxying a trend movement in money demand. With the addition of a trend to the models of Table I, the distribution variables and the number of households remain significant (though in one case the latter is significant at slightly less than the 95 percent confidence level).[18]

As noted above, a large part of the money demand literature has concluded that the money demand function shifted in the mid-1970s and again in the early 1980s. However, in Table I the two shift dummies are never individually or jointly significant. In addition, F-tests for structural change at the end of 1973 or the end of 1981 cannot reject the hypothesis of parameter stability for any of the four models in this table.[19] These results suggest that evidence of structural shifts in the money demand function may be the result of aggregation bias. In other words, changes in the quantity of money demanded during the mid-1970s and early 1980s were partly the result of shifts in the distribution of income, the effect of which on money demand could not be adequately proxied by aggregate income due to the non-linearity of individual money demand functions. An examination of the income distribution data provided in Appendix B supports this finding. In the early to mid-1970s, at approximately the same time as the money demand function is supposed to have shifted, the distinct upward trend in the distribution of income came to an end. Furthermore, in the early 1980s, at which time the money demand function is also thought to have shifted, there was a brief downward shift in the income distribution.

IV. A COMPARISON WITH ALTERNATIVE SPECIFICATIONS[20]

The relative usefulness of the money demand specification described and estimated in the previous section can be ex-

16. The instruments used in this test were all the explanatory variables except the interest rate, all explanatory variables lagged, lagged prices, a trend, and lagged real GNP. Estimation of the money demand function using instrumental variables did not produce any significant changes in the estimated coefficients. Most other money demand studies have found the same result. See, for example, Goldfeld [1976], Rasche [1987] and Rose [1985].

17. As noted at the end of section II, the coefficients on the income distribution variables measure the difference between the real per household level of money demand for the income classes included in P_t^* and that of the excluded classes. The statistical insignificance of the estimated coefficient on $PU5$, for example, indicates that money demand by individuals in this class is insignificantly different from that which would be predicted for this income level by a money demand function that is consistent with the demand for money by the two income classes excluded from P_t^*.

18. For the models in columns I.3 and I.4 of Table I, the test statistics for the significance of the income distribution variables following the introduction of a trend are, respectively, 13.23 (4,24) and 12.90 (4,25). The t-statistics on the trend variable in the two cases are −.70 and −1.28.

19. The test statistics for the end-of-1973 break are, for columns I.1 through I.4 of Table I respectively: .71 (8,15); .66 (7,17); .69 (9,16); and .73 (8,18). The test statistics for a break at the end of 1981 are: 1.79 (5,19); 1.70 (5,20); 1.53 (5,20); and 1.86 (5,21). The numbers in parentheses give the degrees of freedom for the tests.

20. The alternative models introduced in this section were specified on the basis of the existing literature and were not the product of a specification search. These specifications were particularly influenced by Goldfeld [1973; 1976] and Rasche [1987]. There are a large number of alternative specifications which could have been used, and thus the comparisons made here are for illustrative purposes only.

amined by comparing it to some common alternatives using the same data set and household specification. Table II contains estimates of several money demand functions which do not include income distribution variables, but which incorporate various combinations of shift dummies for the beginning of 1974 and 1982 and, as suggested in Rasche [1987], a trend shift dummy (*T82*) starting at the beginning of 1982.[21] The two shift dummies are jointly significant in all instances, as is the trend shift dummy, and the hypotheses of homoskedasticity and noserial correlation cannot be rejected in all five cases.[22] In addition, parameter stability cannot be rejected for any of these models for the 1974 break, though it is rejected for the 1982 break in models II.1, II.2 and II.4.[23]

The estimates in Tables I and II are similar with respect to some simple diagnostic tests while the models given in Table I and those in columns II.3 and II.5 of Table II show no sign of parameter instability (which cannot be accounted for with shift parameters). Several approaches can be taken to further compare these alternative specifications. These include: non-nested hypothesis tests, a comparison of model fit over periods of possible money demand instability, and forecasting ability over the same periods.

Since the models of Table II are not nested within the specifications of Table I and vice versa, the *J*-test of Davidson and MacKinnon [1981] was used to test models I.3 and I.4 of Table I against the alternative models in Table II.[24] As indicated by the test statistics in Table III, the two Table I specifications reject the alternative Table II specifications in every case and are only rejected themselves by the model in column II.5 of Table II, the model which includes the largest number of structural shift parameters.

A further comparison of the income distribution augmented money demand functions of Table I with the alternative specifications of Table II involves examining their fit and forecasts over problem periods which have previously been identified in the literature: 1974 to 1976 and 1982 to 1986. Columns 1 and 2 of Table IV contain the root mean squared residual for these two periods (as a percentage of the mean of the dependent variable for the period) for all the models which appear in Tables I and II. The root mean squared residuals of the models in Table I are very similar to those of Table II for 1974 to 1976, but tend to be slightly smaller for the 1982 to 1986 period (except relative to model II.5). In particular, the models in columns I.3 and I.4 of Table I, neither of which contain structural shift dummies, both compare favorably with models which explicitly allow for shifts in the money demand function.

Columns 3 and 4 of Table IV present the root mean squared errors of forecasts for 1974 to 1976 and 1982 to 1986.[25] The fore-

21. Estimates which do not include any shift dummies or income distribution variables reject both homoskedasticity and the hypothesis of non-serially correlated errors unless a lagged dependent variable is included. In this latter case, however, the parameter estimates are characterized by an implausibly small income elasticity and slow speed of adjustment. In addition, an *F*-test rejects parameter stability for a break at the beginning of 1974 as well as for a break at the beginning of 1982 in all versions of the model that exclude shift dummies and distribution effects.

22. The number of households is not included in the models of Table II because it was never significant and its inclusion did not alter the significance of the trend variable.

23. The inclusion of dummy variables in these equations implies that the tests for parameter stability are for the coefficients on the variables which have no dummy variables associated with them.

24. Model II.3 is nested within model I.1, but not in any of the other models of Table I.

25. These forecasts employ parameter estimates derived using pre-forecast period data only. That is, data for 1953 to 1973 was used to estimate the models' parameters to forecast the 1974 to 1976 period while only data for 1953 to 1981 was used to forecast the 1982 to 1986 period. As a result, the models corresponding to the specifications of Table II used to forecast the 1974 to 1976 period do not include any dummy variables and only include the 1974 shift dummy, where relevant, to forecast the 1982 to 1986 period.

TABLE II
Real M1 Demand With Structural Shifts and No Distribution Effects*

	II.1	II.2	II.3	II.4	II.5
Constant	1181.8	1323.5	439.63	730.87	1010.2
	(8.50)	(7.44)	(1.42)	(3.08)	(4.60)
R	-16.23	-17.87	-12.75	-12.48	-6.57
	(2.97)	(3.21)	(1.82)	(2.32)	(1.31)
RPI	.29	.27	.01	.22	.21
	(15.10)	(10.14)	(.62)	(5.96)	(5.87)
$RM1_{-1}$			.83	.30	.23
			(9.24)	(2.28)	(2.02)
T	-74.37	-68.08		-54.98	-54.63
	(20.75)	(11.66)		(6.00)	(6.04)
D74		-60.60	-160.95		-65.07
		(1.25)	(3.09)		(1.71)
D82		168.18	126.50		-1698.60
		(3.84)	(2.49)		(3.14)
T82	5.96			6.23	56.88
	(4.97)			(5.53)	(3.47)
R^2	.986	.986	.980	.988	.992
Godfrey LM Test for AR1	.04[a]	.01[a]	3.26[a]	1.91[a]	2.99[a]
Breusch-Pagan Test for Heteroskedasticity	4.87[b] (4)	6.47[b] (5)	6.72[b] (5)	5.81[b] (6)	11.25[b] (7)

*See note to Table I.

casts of the models of Table I for 1974 to 1976 are slightly larger than those of Table II, but are appreciably smaller than those of any of the models of Table II for 1982 to 1986.

The different models estimated above can be further compared on the basis of their income and interest elasticities (see Table V). The interest elasticities of all the models tend to be small (except in the case of equation II.3 which is characterized by extremely slow adjustment). These small interest elasticities are consistent with the recent empirical money demand literature (see Rasche [1987] for example). In the early empirical money demand literature it was standard to find estimates of the income elasticity which were significantly less than one. The addition of income distribution variables causes estimates of the aggregate income elasticity (those with respect to $\bar{y}$ alone) to be larger than one.[26]

26. As in Stoker [1986] and Buse [1992], the income elasticity reported in Table V is derived using estimates of the γ^* parameter. As a result, it is the elasticity corresponding to a change in income caused by a movement in households from one of the income classes excluded during estimation to the other excluded class. Using the estimates in Table I and approximating the mean for each income class, it can be shown that this reported elasticity is very similar to the elasticity which would be calculated using an estimate of the γ parameter in equation (5) as opposed to γ^* of equation (6). This follows because the coefficients on the included income distribution terms, though significant, are small in size relative to the level of real money holdings per household.

TABLE III

J–Test Statistics

Maintained Hypothesis (Models With Distribution Effects)	Alternative Hypotheses (Models Without Distribution Effects)				
	II.1	II.2	II.3	II.4	II.5
I.3	.66	.67	.28	.51	2.09[a]
I.4	.53	.46	1.77	1.40	2.96[a]

Maintained Hypothesis (Models Without Distribution Effects)	Alternative Hypotheses (Models With Distribution Effects)	
	I.3	I.4
II.1	4.79[a]	4.06[a]
II.2	4.75[a]	4.04[a]
II.3	6.65[a]	6.42[a]
II.4	3.80[a]	3.53[a]
II.5	2.32[a]	2.39[a]

Note: These are asymptotic t–statistics.

[a]At a 95 percent confidence level the maintained hypothesis is rejected.

This confirms the movement in the recent literature (Rasche [1987] and Lucas [1988]) away from small estimates of the income elasticity of money demand, and does this without having to examine the data ex post in order to determine the proper shift dummy variables to include.

V. SUMMARY AND CONCLUSIONS

The estimates of the money demand function reported in Table I incorporate income distribution effects which account for possible aggregation bias. These estimates cannot be rejected by several diagnostic tests, show no signs of parameter instability, and do not support the slow adjustment of money demand. In addition, the models of Table I compare favorably with alternative models using non-nested hypothesis tests, are able to account (without using shift dummies) for the periods in which the money demand function was believed to have shifted, and are able to forecast over these periods nearly as well or better than the other specifications examined. Particularly noteworthy is the ability of models I.3 and I.4 to fit the 1974–76 and 1982–86 periods without the use of ex post shift variables. While model II.5 performs slightly better over these periods, its specification relies on the ex post examination of the data to determine the timing of structural breaks. In contrast, equations I.3 and I.4 require no ex post information to provide a stable representation of money demand for the 1953–86 period.

TABLE IV
Comparison of Fit and Forecasts 1974–1976, 1982–1986
(As a percent of mean RM1 for the period.)

Equation	1 Root Mean Squared Residual, 1974–1976	2 Root Mean Squared Residual, 1982–1986	3 Root Mean Squared Forecast, 1974–1976	4 Root Mean Squared Forecast, 1982–1986
I.1	1.0	2.2	4.2	6.7
I.2	1.7	2.5	4.3	4.8
I.3	.9	2.2	4.2	5.6
I.4	1.5	2.8	4.3	4.4
II.1	1.2	3.9	3.5	11.5
II.2	1.6	4.1	3.5	10.6
II.3	.8	3.3	7.0	7.9
II.4	1.1	3.5	3.5	11.7
II.5	.6	2.2	3.5	10.7

TABLE V
Elasticity Estimates*

	Interest Elasticity		Income Elasticity	
Equation	Short Run	Long Run	Short Run	Long Run
I.1	-.031	-.039	1.35	1.70
I.2	-.037	-	1.60	-
I.3	-.030	-.038	1.34	1.70
I.4	-.036	-	1.53	-
II.1	-.034	-	1.10	-
II.2	-.037	-	1.01	-
II.3	-.027	-.158	.03	.177
II.4	-.026	-.037	.824	1.18
II.5	-.014	-.018	.778	1.01

*All elasticities are evaluated at the mean.

APPENDIX A
Data Definitions and Sources

D74 = 1974 structural shift dummy variable. Equal to one in 1974 and later, zero otherwise.

D82 = 1982 structural shift dummy variable. Equal to one in 1982 and later, zero otherwise.

H = number of households. The sum of families and unrelated individuals from Table 11 in U.S. Bureau of the Census, Current Population Reports, Series P-60, No. 159, *Money Income of Households, Families, and Persons in the United States: 1986*, U.S. Government Printing Office, Washington, D.C., 1988.

PU5 = the percentage of households with incomes less than $5,000 in constant 1986 dollars. Source is same as *H* above.

P5T10 = the percentage of households with incomes between $5,000 and $9,999 in constant 1986 dollars. Source is same as *H* above.

P10T125 = the percentage of households with incomes between $10,000 and $12,499 in constant 1986 dollars. Source is same as *H* above.

P125T15 = the percentage of households with incomes between $12,500 and $14,999 in constant 1986 dollars. Source is same as *H* above.

P15T25 = the percentage of households with incomes between $15,000 and $24,999 in constant 1986 dollars. Source is same as *H* above.

P250 = the percentage of households with incomes greater than $24,999 in constant 1986 dollars. Source is same as *H* above.

R = the nominal interest rate. The three-month U.S. Treasury Bill rate June average. This is taken from Statistics Canada CANSIM data base series B54401.

RM1 = real money balances per household. This is represented by nominal M1 deflated by the consumer price index and the number of households. The U.S. consumer price index is the June observation from the Statistics Canada CANSIM data base series D134010. The June observation for M1 was taken for 1959 to 1986 from the Statistics Canada CANSIM data base series B54324. The 1952 to 1958 June observations came from the U.S. Department of Commerce, Bureau of Economic Analysis, *Business Statistics 1971*, Washington, D.C., 1972. The 1952 to 1958 observations were adjusted using the method employed in Rasche [1987] to make them consistent with the 1959 to 1986 observations.

RPI = real personal income per household. This is U.S. personal income deflated by the consumer price index (for source see *RM1* above) and the number of households (see *H* above). U.S. personal income data comes from: 1952, U.S. Department of Commerce, Bureau of Economic Analysis, *Business Statistics, 1982*, Washington, D.C., 1983; 1953 to 1982, U.S. Department of Commerce, Bureau of Economic Analysis, *Business Statistics, 1984*, Washington, D.C., 1985; 1983 to 1986, U.S. Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business*, Washington, D.C., July 1987.

T = a linear trend.

T82 = a trend dummy for a structural shift in 1982 (equal to the product of *T* and *D82*).

APPENDIX B
Income Distribution Data

Year	Under $5,000 (percent)	$5,000–$9,999 (percent)	$10,000–$12,499 (percent)	$12,500–$14,999 (percent)	$15,000–$24,999 (percent)	Above $24,999 (percent)
1952	17.78	15.84	11.91	8.00	29.60	16.88
1953	17.81	14.19	10.24	6.93	30.75	20.10
1954	19.08	14.59	10.14	6.96	29.37	19.95
1955	17.38	13.92	9.37	6.56	29.88	22.78
1956	15.90	13.41	8.36	5.95	30.58	25.90
1957	16.04	13.67	8.12	5.78	31.25	25.03
1958	15.84	14.04	8.18	5.90	30.65	25.41
1959	15.19	13.62	7.66	5.52	29.20	28.91
1960	14.82	13.18	7.53	5.48	28.50	30.34
1961	14.59	13.40	7.36	5.36	27.09	32.04
1962	13.61	13.28	7.14	5.29	27.16	33.54
1963	13.13	13.02	6.18	5.94	25.87	35.92
1964	12.70	12.62	6.30	5.92	24.88	37.57
1965	11.62	12.37	6.04	5.72	24.45	39.83
1966	10.37	11.99	6.01	5.36	23.80	42.43
1967	10.83	11.90	4.96	5.37	23.38	43.48
1968	9.55	11.47	5.27	5.19	22.38	46.07
1969	9.74	11.38	5.40	5.12	21.22	47.33
1970	9.65	11.87	5.25	5.44	21.18	46.61
1971	9.33	12.32	5.40	5.70	21.33	45.94
1972	8.58	12.31	5.36	5.42	20.28	48.00
1973	7.91	12.36	5.85	5.32	20.25	48.24
1974	7.64	12.92	5.99	5.51	21.22	46.79
1975	8.18	13.81	6.38	5.52	21.45	44.75
1976	8.19	13.42	6.14	5.56	20.79	45.90
1977	7.86	14.07	5.94	6.01	20.20	45.90
1978	7.83	13.56	6.08	5.61	20.16	46.76
1979	8.32	13.30	6.17	5.30	21.28	45.71
1980	8.89	14.15	6.01	6.42	20.94	43.52
1981	9.42	14.25	6.52	6.35	21.18	42.15
1982	9.62	14.23	6.74	6.25	21.48	41.54
1983	9.89	13.83	6.42	6.20	21.30	42.30
1984	9.29	13.91	6.37	6.21	20.86	43.43
1985	9.29	13.49	6.59	5.63	20.96	44.01
1986	9.24	12.94	6.38	5.43	20.26	45.75

REFERENCES

Barnett, W. A. "The User Cost of Money." *Economics Letters* 1(2), 1978, 145–49.

______. "Theoretical Foundations for the Rotterdam Model." *Review of Economic Studies*, January 1979, 109–30.

______. "Economic Monetary Aggregates: An Application of Index Number and Aggregation Theory." *Journal of Econometrics*, September 1980, 11–48.

Barnett, W. A., and A. Serletis. "A Dispersion-Dependency Diagnostic Test for Aggregation Error: With Applications to Monetary Economics and Income Distribution." *Journal of Econometrics*, January/February 1990, 5–34.

Breusch, T. S., and A. Pagan. "A Simple Test for Heteroscedasticity and Random Coefficient Variation." *Econometrica*, September 1979, 1287–94.

Buse, A. "Aggregation, Distribution and Dynamics in the Linear and Quadratic Expenditure Systems." *The Review of Economics and Statistics*, February 1992, 45–53.

Cooley, T. F., and S. F. LeRoy. "Identification and Estimation of Money Demand." *American Economic Review*, December 1981, 825–44.

Cuthbertson, K. and M. P. Taylor. "The Demand for Money: A Dynamic Rational Expectations Model." *Economic Journal*, Supplement 1987, 65–76.

Davidson, R. and J. G. MacKinnon. "Several Tests for Model Specification in the Presence of Alternative Hypotheses." *Econometrica*, May 1981, 781–93.

Godfrey, L. G. "Testing Against General Autoregressive and Moving Average Error Models When the Regressors Include Lagged Dependent Variables." *Econometrica*, November 1978, 1293–1302.

Goldfeld, S. M. "The Demand for Money Revisited." *Brookings Papers on Economic Activity* 3, 1973, 577–638.

______. "The Case of the Missing Money." *Brookings Papers on Economic Activity* 3. 1976, 683–730.

Goldfeld, S. M., and D. E. Sichel. "Money Demand: The Effects of Inflation and Alternative Adjustment Mechanisms." *Review of Economics and Statistics*, August 1987, 511–15.

Granger, C. W. J., and P. Newbold. "Spurious Regressions in Econometrics." *Journal of Econometrics*, July 1974, 111–20.

Hafer, R. W., and S. E. Hein. "The Shift in Money Demand: What Really Happened?" *Federal Reserve Bank of St. Louis Review*, February 1982, 11–16.

Hausman, J. A. "Specification Tests in Econometrics." *Econometrica*, November 1978, 1251–71.

Hendry, D. F., and G. E. Mizon. "Serial Correlation as a Convenient Simplification, Not a Nuisance: A Comment on a Study of the Demand for Money by the Bank of England." *Economic Journal*, September 1978, 549–63.

Hendry, D. F., A. R. Pagan and J. D. Sargan. "Dynamic Specification," in *Handbook of Econometrics* Volume II, edited by Z. Griliches and M. D. Intriligator. Amsterdam: North-Holland, 1984, 1023–1100.

Judd, J. P., and J. L. Scadding. "The Search for a Stable Money Demand Function." *Journal of Economic Literature*, September 1982, 993–1023.

Lucas, R. E. "Money Demand in the United States: A Quantitative Review," in *Money, Cycles and Exchange Rates: Essays in Honor of Allan H. Meltzer*, edited by K. Brunner and A. H. Meltzer. Carnegie-Rochester Conference Series on Public Policy, Autumn 1988, 137–68.

MacKinnon, J. G. and R. D. Milbourne. "Monetary Anticipations and the Demand for Money." *Journal of Monetary Economics*, March 1984, 263–74.

Rasche, R. H. "M1-Velocity and Money-Demand Functions: Do Stable Relationships Exist?" in *Empirical Studies of Velocity, Real Exchange Rates, Unemployment and Productivity*, edited by K. Brunner and A. H. Meltzer. Carnegie-Rochester Conference Series on Public Policy, Autumn 1987, 9–88.

Rose, A. K. "An Alternative Approach to the American Demand for Money." *Journal of Money, Credit and Banking*, November 1985, 439–55.

Stoker, T. M. "Simple Tests of Distributional Effects on Macroeconomic Equations." *Journal of Political Economy*, August 1986, 763–95.