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ON THE DEMAND FOR AND SUPPLY OF MONEY: AN EMPIRICAL STUDY*

Grant E. SIMS and Akira TAKAYAMA

1. INTRODUCTION

The study of the monetary equilibrium relation has a long history of theoretical development and empirical investigation. Theoretically, it has been placed in a central importance in macro models through Keynes' (1936) reformulation of the Cambridge equation in terms of his liquidity preference theory. More recently, Friedman's monetarism has attracted a great deal of attention. Although there may be some strong disagreements with regard to what constitutes the basic doctrines of monetarism, there is little disagreement that the monetary relation is at the heart of its theory and empirical investigations.

Together with the development of macro models, empirical studies on the demand for and supply of money literally abound in the literature. The attention has been mainly focused on the demand for money. This is probably because Keynes and many of his followers assumed that the supply of money is exogenously given. This is also the case in many of the writings of Friedman (with notable exceptions such as Friedman [1972]). To illustrate the importance and popularity of empirical studies on the demand for money, it probably suffices to cite some interesting and useful surveys on this topic such as Laidler ([1977], pp. 119–152), Goldfeld (1973), Havrilesky-Boorman ([1978], pp. 167–222), Boorman ([1980], pp. 315–360), Harris ([1981], pp. 397–428), and Judd-Scadding (1982).

In contrast to the popularity of studies on the demand for money, the supply of money has attracted interest only recently. For example, Harry Johnson in his survey (1962) remarked that money supply theory has been thoroughly neglected in monetary analysis (with some exceptions as pointed out by Brunner ([1971], pp. 89–91, for example). However, since Johnson's survey article, a number of theoretical and empirical advances have been made. For useful surveys on this topic, see, for example, Fand (1967), Teigen (1970), Raasche (1972), Takayama-Drabicki (1976), and Wrightsman (1976).

Reading through these surveys and much of the relevant literature cited, one would be struck with a diversity of empirical studies (most of which show reasonable to excellent statistical success), and be impressed but confused with a

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catalogue of complex results, some of which are contradictory. For example, on the demand for money, some studies assert (either *a priori* or empirically) that the wealth elasticity of the demand for money is equal to unity, while other studies assume that it is equal to zero and income should replace wealth as a more relevant explanatory variable. Some studies indicate that the short-term interest rate explains more of the variation of the demand for money than does the long-term rate, while other studies indicate that the long-term interest rate is of greater importance. One may then get confused with regard to the question of what constitutes the correct specification of the demand for money.

Such a problem may be more serious with respect to the supply of money. Some studies attempt to explain the behavior of the money supply, an endogenous variable, in terms of other endogenous variable such as the commercial banks' holdings of free reserves and their loans to the public, in spite of the fact that these are systematically related through the commercial banks' balance sheet, etc. Other studies assume that the ratio of the banks' loans over demand deposits is exogenously given, while such a ratio should clearly depend systematically on a number of variables such as interest rates on the banks' loans, the Fed's discount rate, and the legal reserve ratios. Yet others attempt to explain the supply of money chiefly by the banks' free reserve behavior, ignoring their behavior on loans and also ignoring the dependence of the banks' free reserve behavior on such variables as the level of demand and time deposits and the legal reserve ratios. For a survey of these studies, we refer the reader to Takayama-Drabicki ([1976], pp. 341–347). A systematic and unified approach to the money supply formula which overcomes these difficulties of the previous studies would then be desirable. Takayama-Drabicki (1976) proposed on such formula, following the line of studies by Brunner-Meltzer (1964) and Takahashi (1971). However, it remains to be seen that the T-D formula performs well empirically.

The purpose of this paper is to investigate these problems on the demand for and the supply of money. The present paper thus intends to shed light on the proper specifications of the demand and supply of money functions. In the next section, we offer a brief survey of the literature on the demand for money, and in so doing we shall propose what we think to be the correct specification of the money demand function (at least for the period of our observation). In Section 3, we then actually estimate the proposed money demand function and thus test how our specification performs empirically and compare our results to the ones found in the literature. Among other results, we find that the wealth and the income elasticities of the demand for money are approximately 0.4 and 0.6, respectively. In our discussion, the homogeneity of the money demand function plays an important role. One possible justification for this is that the money demand function may be best described as the behavioral relation among *nominal* quantities of money, income and wealth (and other variables such as interest rates). As an example of such a view, we may recall the simple Cambridge quantity equation which relates the *nominal* quantities of money and income through transactions demand. Given such a view, homogeneity follows naturally: doubling the unit of the currency denomination should double all the nominal quantities in the money demand function. In this paper, we take a view that such a homogeneity should hold in principle, but that it is still an empirically testable hypothesis.

In Section 4, we propose the money supply equation, the Takayama-Drabicki formula ([1976], also Drabicki-Takayama [1984]) as modified to incorporate time deposits. It is shown that such a money supply formula performs well empirically, and that some of the estimates are comparable to the ones found in the literature. In Section 5, we estimate the demand and supply equations simultaneously by using the method of two stage least squares. We find that our estimates of the parameters of the demand and supply functions of money thus obtained are not much different from the ones obtained by the single equation approach in the previous sections, and as such we are not able to detect a significant simultaneity bias. The paper ends with an appendix concerning the derivation of the money supply equation.

The question of simultaneity bias is a well-known one in the monetary process. It can be argued easily that the estimates of parameters of the demand or the supply equation by the single equation approach are inadequate, since such an approach ignores the endogenous nature of money and interest rates being determined simultaneously by the demand and supply function (while the interactions with the "real" sectors of macro models may be ignored on the ground that the speed of adjustment in the money market would be relatively faster than those in the real sectors.) For example, Teigen's well-known study (1964), while ignoring the repercussions on the real sectors, indicates that simultaneity bias is significant in the monetary process. On the other hand, there now seems to exist a rather strong feeling in the profession that simultaneity bias is not so important in the monetary process. For example, Laidler ([1977], p. 117) writes, "there is quite a bit of evidence that the results for the demand for money are not usually greatly or importantly altered by taking explicit account of the supply side of the marker." Also, Booreman ([1980], p. 335) writes, "the results derived from simultaneous-equation models generally confirm the single-equation results." Although such conclusions may have to be viewed with caution as they are naturally based on particular specifications of the demand and the supply functions of money (and to the extent that we are skeptical of such specifications, the conclusion cannot be taken for granted), our study in Section 5 also indicates that simultaneity bias may not be too important in the monetary process.

Finally, we should remark on our observation period, which is from 1929 to 1958. This rather "ancient" period was chosen partially to facilitate comparison with most of the well-known important empirical studies. For example, the periods of observation in the studies by Latané (1954), Friedman (1959), Bronfenbrenner-Mayer (1960), Meltzer (1963), Brunner-Meltzer (1963), Teigen (1964), Heller (1965), Laidler (1966a), Laidler (1966b) and Chow (1966), respectively, end 1952, 1957, 1956, 1958, 1959, 1959, 1958, 1960, 1960, and 1958.

Also, we wish to avoid strongly manifested complications via recent international repercussions (by a relative marked increase in the importance of the foreign sector and through exchange rate fluctuations, currency substitution, the fluctuation of the Fed's liabilities to foreign monetary authorities, etc.) and also to avoid the complication due to high rate of inflation in the U.S. in the 1970's through early 1980's. Furthermore, changes in financial institutions and the appearance of new financial instruments vehicled by such laws as the Financial Institutions Act of 1975, the Depository Institutions Deregulation and Monetary Control Act of 1980, and the Gern-St. Germain Depository Institution Act of 1982 are rather remarkable. (For a good survey, see Ito [1985], for example. Judd-Scadding [1982] also contains a brief account of institutional changes.) In fact Judd-Scadding focus their attention on the search for a stable money demand function, and conclude, "the most likely cause of the observed instability of the demand for money after 1973 is innovation in financial arrangements." ([1982], p. 1014). These three factors should systematically shift both the money demand and supply functions, and we wish to postpone our study for more recent periods until we obtain a theoretically persuasive model to take account of such complications. As surveyed in Judd-Scadding (1982), most empirical studies on money demand (which tend to ignore such complications) do not perform well.[1] In addition, there have been considerable progress in theoretical and empirical studies on open macro models and international finance in the past decade or so, and we think that such a development should be incorporated in a systematic and unified way into the studies of the demand and supply of money over recent periods. By confining ourselves to the period in which such complications do not manifest themselves too strongly, we wish to focus our attention of finding proper specifications of the demand and supply equations of money during such a period.

2. A SURVEY OF SOME ISSUES ON THE DEMAND FOR MONEY AND THE PROBLEM STATED

A popular assumption in many textbooks underlying the specification of the demand for money is that it depends on current income and interest rates. The monetary equilibrium under such an assumption (in its simplest form) may be described as,

$$M = L(i, Y)\,, \tag{1}$$

where i represents the nominal rate (or rates) of interest, Y signifies (current)

[1] In this connection, it may be of some interest to note that Goldfeld (1976), in his extensive empirical study on the demand for money for a recent period (1952: II–1973: IV), concluded: "By this juncture it should be apparent that large unexplained error remains in the money-demand function" (p. 720), and "the paper is rather a failure. Specifications that seem most reasonable on the basis of earlier data are not the ones that make a substantial dent in explaining the recent data." (p. 725). In general discussions, J. Kareken and W. Salant pointed out the importance of international repercussions (p. 736).

nominal income, and M is the stock of nominal money. The dependence of the money demand function L on Y is mainly rationalized in terms of "transactions demand," and hence, we may call this specification the *transactions demand approach.*

Following the usual assumption in the literature, we may assume that the function L is homogeneous of degree one with respect to Y. This may be justified on the ground of the absence of money illusion, or doubling the denominations of the currency doubles both M and Y.[2] Viewed in this fashion, the homogeneity postulate of L is only an aspect of rational human behavior, and can be accepted without much difficulty; at least it becomes a testable hypothesis. In any case, given this postulate, (1) can equivalently be specified by either of the following two forms:[3]

$$M/p = L(i, y)\,, \tag{2-a}$$

$$M/Y = k(i)\,, \qquad k(i) \equiv L(i, 1)\,, \tag{2-b}$$

where p and y, respectively, signify the price level and real income (so that $Y \equiv py$). Note that k corresponds to the "Marshallian k," except that in (2-b) k is no longer constant, but rather sensitive with respect to changes in the interest rate. The inverse of k, $1/k(i)$, then corresponds to the "velocity of circulation." It is easy to see from (2-b), that the homogeneity postulate restricts the income elasticity of the

[2] The classical Cambridge form of the quantity theory postulates the money equilibrium relation as

$$M = kY\,, \qquad \text{where} \quad k \quad \text{is a constant}\,,$$

which is justified in terms of the transactions demand for money. In this case, $L = kY$ and the homogeneity postulate is clearly satisfied.

[3] By homogeneity, we have: $\alpha M = L(\alpha Y, i)$ for all $\alpha > 0$. Setting $\alpha = 1/p$ we obtain (2-a), and setting $\alpha = 1/Y$, we obtain (2-b). Following Keynes (1936, p. 199), it has been popular in textbooks and others to decompose the demand for money into active and idle balances, and write (1) in the form of

$$M = L_1(Y) + L_2(i)\,, \tag{1'}$$

where L_1 and L_2, respectively, signify the demand for active and idle balances. The Cambridge quantity equation is then often regarded as a special case of (1′) in which $L_2 \equiv 0$. However, there is a fundamental distinction between the Cambridge equation and (1′); i.e., the former satisfies the homogeneity postulate of the demand for money, while the latter does not. Doubling the denomination of the currency doubles M and Y, in which case (1′) no longer holds. Viewing the homogeneity as an aspect of rational human behavior, it may not be surprising that estimations of (1′) do not perform well empirically. Bronfenbrenner-Mayer ([1960], p. 812) call the classification of L into L_1 and L_2 "arbitrary." Booreman ([1980], pp. 331–332) states, "Virtually all work presented since Bronfenbrenner and Mayer study has wisely avoided the arbitrary classification of money balances into active and idle components···. Many economists believe that such a dichotomy is unreasonable since total money balances are simply one of many assets held for the services they provide and cannot be separated into unique components."

demand for money, $(\partial L/\partial Y)(Y/L)$, to be unity.[4]

Clearly, there is no essential difference between (2-a) and (2-b) given the homogeneity postulate, and there are a number of studies estimating these equations. For example, the pioneering work by Latané (1954) on the demand for money successfully estimated (2-b) in the following form,

$$M/Y = \alpha_0 + \alpha_1/i,$$

where he uses annual data for the period of 1919–1952. Note that Latané's specification *a priori* restricts the income elasticity of the demand for money to unity.

By way of contrast, another popular view in empirical studies is that the demand for money depends on wealth (instead of income) and interest rates. This specification was popularized by Meltzer's highly successful study (1963),[5] and may be termed the *wealth adjustment approach* (cf. e.g., Wrightsman [1976], pp. 206–223). Letting W denote the nominal stock of wealth, this approach specifies the money equilibrium relation as,

$$M = L(i, W). \tag{3}$$

Meltzer (1963) and Brunner-Meltzer (1963) found that W, measured as (non-human) wealth, explains variations in observed money demand better than current income.

Again, in the absence of money illusion, the function L in (3) is homogeneous of degree one in W, and accordingly we may rewrite (3) as,

$$M = \lambda(i)W, \quad \text{where} \quad \lambda(i) \equiv L(i, 1), \tag{4}$$

as pointed out by Meltzer ([1963], p. 223). The specification in (4) means that the wealth elasticity of the demand for money is equal to unity. Among others, Meltzer ([1963], p. 225) estimated the following log-linear form of (3),

$$\log M = \alpha_0 + \alpha_1 \log i + \alpha_2 \log W.$$

[4] The well-known Baumol-Tobin "square root law" of the transactions demand for money specifies the transactions demand for money L_1 by

$$L_1 = \frac{1}{2}\sqrt{\frac{2bT}{i}},$$

where T is the volume of expenditures financed in a given period, and b is the cost of switching between income earning assets and money. From this formula, it is easy to see that the elasticity of M with respect to T (when i and b are kept constant) is equal to one half. From such a consideration, some argue that the restriction of the income elasticity of the demand for money to be unity is "arbitrary" or "not supported by economic theory" (e.g., Booremman [1980], pp. 329–330, Harris [1981], p. 401). However, since both b and T are measured in terms of dollars, doubling the denomination of the currency doubles both b and T as well as L_1. Namely, the Baumol-Tobin formula is perfectly consistent with the homogeneity postulate and the unitary income elasticity of the demand for money specified in the text.

[5] Meltzer's study covers the period of 1900–1958, where he uses annual data.

Note that this form does *not a priori* restrict the wealth elasticity of the demand for money to unity, where α_2 measures such an elasticity. Meltzer finds that α_1 is significantly negative ($t = 13.5$) and that α_2 is approximately equal to unity ($\alpha_2 = 1.01$ with $t = 66.8$) where $\bar{R} = 0.994$. That the estimate of α_2 is approximately equal to unity is taken to be consistent with the homogeneity postulate (Meltzer [1963], p. 225).

Variations of (3) in which the variable (W) is replaced by "permanent income" (Y^p) have been studied by Friedman (1959) and others. Since no data exists on Y^p, Friedman used a proxy variable which is measured as a geometrically weighted sum of past and present levels of current income. While his statistical fit is impressive, his finding is rather striking: he finds no systematic relation between the demand for money and the interest rate, and his estimate shows the permanent income elasticity of the demand for money is equal to 1.8 (instead of unity).[6] Meltzer ([1963], pp. 234–238) specifically examines Friedman's study and finds that an equation in terms of nonhuman wealth fits the data better than the permanent income equation. On the other hand, Laidler (1966a) comes to the opposite conclusion on the relative merits of nonhuman wealth and permanent income as independent variables, while his results are hard to compare with Meltzer's findings because of Laidler's unusual form in which he expresses nonhuman wealth (cf. e.g., Harris [1981], pp. 405–407 for a brief survey). Friedman's (1959) procedure is subject to severe criticism. For one thing, it embodies two sets of theories: one is that the demand for money is a function of permanent income, and the other is that permanent income can be proxied by a weighted sum of past and present actual income. This then makes it difficult to discern which theory is (or is not) supported by empirical evidence (cf. Harris [1981], pp. 407–408). the second criticism is concerned with the procedure yielding interest insensitivity of the demand for money, which was pointed out and corrected by Laidler's (1966a) comparable study.[7] See also Laidler ([1977], p. 128).

While Friedman's study (1959) seems to have led many economists to infer his position to be that the demand for money is completely interest inelastic[8] (which was objected to by Friedman himself [1966]), virtually all studies agree that the demand for money is interest elastic. Thus Boorman ([1980], p. 332) summarizes, "in spite of these many differences, these studies . . . show that the interest rate measure is an important factor in explaining variations in the demand for money."

[6] Friedman's study (1959) covers the period of 1869–1957, where he uses annual *cyclically averaged* data. Unlike many empirical studies on the demand for money which measures M by M_1 (currency plus demand deposits), Friedman measures M by M_2 (M_1 plus time deposits). Although this is sometimes regarded as the reason why he found no systematic relation between the demand for money and the interest rate (which undoubtedly has an element of truth), Laidler's study (1966b) may indicate that this factor is not so important.

[7] Laidler (1966a) uses annual data for the period of 1892–1960, while Laidler (1966b) uses annual data for the period of 1919–1960, or of 1892–1960, and its subperiods.

[8] Friedman (1958) and Friedman-Schwartz (1963) also seem to have contributed to lead to such a belief.

Similarly, Laidler ([1977], p. 130) concludes that "there is an overwhelming body of evidence in favor of the proposition that the demand for money is negatively related to the rate of interest. Of all the issues in monetary economics, this is the one that appears to have been settled most decisively."

In spite of such unanimity of interest sensitivity of the demand for money, there is still a basic difference between the transactions demand equation (1) and the wealth adjustment equation (3), and this then suggests a third specification,

$$M = L(i,\, Y,\, W)\,, \tag{5}$$

which encompasses both (1) and (3), where Y and W, respectively, capture the transactions demand and the wealth adjustment components. Though there seems to be no disagreement that (5) is superior to (1) or (3), and though (5) has been used rather extensively in theoretical studies, empirical estimation of (5) encounters serious difficulties due to the correlated movement in Y and W (and hence multicollinearity). Having observed this, Meltzer ([1963], pp. 223–233) suggested that Y be deleted, asserting that the addition of income to the money demand equation adds little information. Since this suggestion is made on the basis of results that admittedly suffer from multicollinearity, his evidence is in no way conclusive that Y is not a significant determinant of money demand. In fact, Heller [1965, p. 294], concluded exactly the opposite, i.e., that the deletion of W rather than Y from the demand equation would yield a better empirical estimation.[9] Again, this assertion is inconclusive, having been based on the unreliable results due to multicollinearity. Therefore, from a statistical viewpoint, neither Meltzer's nor Heller's assertion is satisfactory to shed light on whether the demand for money is a function of Y or W, or both.

Citing the study by Meltzer (1963) and others (but ignoring Heller's [1965]), Laidler's survey work ([1977], p. 139) favors the inclusion of wealth. He concludes, "The evidence here seems to be fairly strong in favor of a wealth variable." On the other hand, Goldfeld ([1973], p. 613) remarked, "An issue that has been extensively examined in this literature is whether income or wealth (or perhaps permanent income) is the appropriate scale variable." Using quarterly data (for the period of 1952–1972), he favors the inclusion of income (rather than wealth). Contrary to Laidler's conclusion cited above, he remarks, "None the less, numerous writers continue to follow the transactions approach, which focuses on income as the primary scale variable." In spite of these conflicting contentions, we find that the deletion of either Y or W in the estimation of (5) simply to avoid

[9] Heller ([1965], p. 294) obtained the following equation:

$$\log M = 2.186 + 1.310 \log Y + 0.213 \log W - 0.115 \log i\,, \qquad R = 0.978\,,$$

where the standard error for the coefficient for $\log W$ equals 0.231. He then compares this estimate against the estimates obtained from equations in which W is deleted and also in which Y is deleted. (Incidentally, we may note that Heller's above estimated equation does not satisfy the homogeneity postulate: i.e., $1.31 + 0.213 \neq 1$.) The period of his observation is 1947–1958, where he uses *quarterly* data.

multicollinearity is not a sound empirical procedure. Furthermore, a "good fit" of (5) which deletes Y (respectively W) does not negate the theoretical importance of the transactions demand for money (respectively, the wealth effect of the demand for money).

Suppose that (5) is the correct specification of the demand for money. Then under the homogeneity postulate (i.e., doubling the denomination of the currency doubles, M, Y, and W, so that the function L is homogeneous of degree one in Y and W), we may rewrite (5) as the following equivalent two forms:

$$\text{(6-a)} \qquad M/Y = k(i, W/Y), \qquad \text{where} \quad k \equiv L(i, 1, W/Y),$$

$$\text{(6-b)} \qquad M/W = \lambda(i, Y/W), \qquad \text{where} \quad \lambda \equiv \lambda(i, Y/W, 1).$$

Hence to the extent that k depends on W/Y, the effect of i on k may not be well discernible (as is the case in Friedman [1959]), although this does not imply that k is independent of i. Also, note that to the extent that k or λ depends on the wealth-income ratio (W/Y), neither the income elasticity nor the wealth elasticity (of the demand for money) is equal to unity. Instead, under the homogeneity postulate, we have,[10]

$$\text{(7)} \qquad \eta_Y + \eta_W = 1,$$

where η_Y and η_W, respectively, signify the income and wealth elasticities of the demand for money. Hence, under the specification (5), it is more plausible to obtain $0 < \eta_Y < 1$ and $0 < \eta_W < 1$, while (with the homogeneity postulate) we would obtain $\eta_Y = 1$ under the transactions demand approach and $\eta_W = 1$ under the wealth adjustment approach, *a priori*. Note that (6-b) corresponds to the Tobin (1969) assumption.

We may further note that if we can accept the homogeneity postulate, (6) can provide a way to estimate the money demand function even in the presence of multicollinearity between Y and W. For example, assuming a log linear functional form, we may estimate:

$$\text{(6')} \qquad \log(M/Y) = \alpha_0 + \alpha_1 \log i + \alpha_2 \log(W/Y).$$

One weakness of this estimation procedure is that we *a priori* impose the homogeneity postulate, while such a postulate should remain to be an empirically testable hypothesis. We may note that if W is replaced by M lagged one period and i is composed of various interest rates, then (6′) is equivalent to a more recent specification by Hamburger (1977). Notice that he (unlike us) imposes homogeneity on money demand in the sense of (6-a) *a priori*.

The theoretical importance of the magnitudes of the income and the wealth

[10] Under the homogeneity postulate, Euler's equation can be written as

$$M = L_Y Y + L_W W, \qquad \text{where} \quad L_Y \equiv \partial L/\partial Y, \quad L_W \equiv \partial L/\partial W.$$

From this we at once obtain (7), where $\eta_Y \equiv L_Y Y/L$, and $\eta_W \equiv L_W W/L$.

elasticities has been highlighted in recent debates surrounding monetarism. One such issue began with Silber's (1970) "correction" of the standard IS-LM analysis, in which he argues that the effect of an increase in government spending financed by selling bonds may not be expansionary, as an increase in the public's bond holding shifts the LM curve to the left in the presence of the wealth effect in the money demand function. In response to a criticism of monetarism by Tobin (1972), Friedman asserts that this leftward shift of the LM curve "swamps" the shift of the IS curve ([1972], p. 916), thus placing the wealth effect in money demand in a central position of monetarism. Friedman then concludes that the relative magnitude of the shifts of the IS and the LM curves are an "empirical" question ([1972], p. 922). Thus the magnitude of the wealth effect in money demand becomes an important empirical question. Following this debate, Blinder-Solow (1973) proposed to analyze the long-run effects of an increase in government spending, in which they concluded that the long-run multiplier for the bond-financing case is greater than that for the money-financing case, *provided that* the long-run equilibrium is stable, and that the stability condition crucially depends on the magnitude of the wealth effect via money demand. They then left the stability question to be "an empirical question" ([1973], p. 330).[11]

Finally, we may take up the question with regard to what constitutes the "right" measure for interest rate (i). Although there is an overwhelming agreement with regard to the plausibility of including some interest rate in the money demand function, there is disagreement regarding the question of which measure of interest rate to use. Havrilesky-Boorman ([1978], pp. 191–192) state this by saying that Brofenbrenner-Mayer (1960), Laidler (1966a, b) and Heller (1965) "argue that some short-term interest rate is the more relevant variable since it measures the opportunity cost of holding money as the rate of return on what they consider to be money's closest substitutes," while others disagree with such a view.

Heller (1965) attempted to directly test this hypothesis by comparing the performance of long-term interest rate with that of a short-term rate. In these regressions the long-term rate never appeared statistically significant (at the 5 percent level), and thus he concluded (p. 297): "The short term rate is of greater importance than the long-term rate in the money function." Laidler ([1966b], p. 547) reached a similar conclusion that "there is little question of the superior explanatory power of the shorter interest rate." However, it may have to be noted that this conclusion is obtained when the dependent variable is M_2 (M_1 plus time deposits), and that when the dependent variable is M_1 (currency plus demand deposits) the long-term rate performs better than the short-term rate for most periods (p. 551). In this context, his results are opposite to those obtained by

[11] In an extensive review of Blinder-Solow's analysis, Infante-Stein (1976) found some serious weaknesses. Following their discussions, Takayama (1980) then proposed that the Blinder-Solow model requires important modifications. While his conclusions are not the same as the ones in Blinder-Solow, his stability condition of the long-run equilibrium again (as would naturally be expected) crucially depends on the wealth effect of money demand (cf. pp. 609 and 611).

Heller (1965), where Heller uses M_1 as the dependent variable. In fact, the conclusions obtained by Heller are directly challenged by Hamburger ([1966], pp. 608–609). Deleting the period of 1947–1951 in which the Fed pegged interest rates from Heller's regression, he found that both the long-term rate and the short-term rate appear equally important. In addition, we have a series of successful studies in which the long-term rate performs well in explaining the variation in M_1 (such as Latané [1954], Meltzer [1963] and Chow [1966]).

On the other hand, we may argue both the short-term and the long-term rates are important. In fact, most financial assets would be some sort of substitutes for money whether we adopt the "Chicago school" view or the "Yale school" view (e.g., Feige-Pearce [1977], pp. 441–442).[12] Also, given that both Y and W appear in our formulation, one would expect a short-term rate to affect liquidity and hence (more directly) transactions demand, and the long-term rate to affect portfolio decisions in the wealth adjustment process. We thus propose to use both short-term and long-term interest rates simultaneously as explanatory variables. This will also facilitate the comparison of our results with those obtained using the short-term rate and also with those obtained using the long-term rate, if our results are statistically significant.

We are now ready to unify a variety of threads of discussions mentioned above, and obtain the formula which we shall use for our empirical estimation of the money demand function. In short, the above discussions indicate that both income and wealth variables are important determinants of money demand, and that both short-term and long-term interest rates are important variables in explaining money demand. We thus propose to estimate the following money equilibrium relation.

$$M = L(i_S, i_L, Y, W)\,, \tag{8}$$

where i_S = the short-term interest rate, i_L = the long-term interest rate, Y = current nominal income, and W = (nominal) stock of non-human wealth.

The homogeneity postulate plays an important role here. First, it is an empirically testable hypothesis. We may then go a step further: i.e., if such a postulate does not hold empirically, we take it that it casts some doubt about the plausibility of our functional specification (since this means that doubling the monetary unit of account of all nominal variables would affect the behavior of economic agents, which in turn contradicts rational behavior).[13] On the other

[12] In this connection, the following passage from Hamburger's recent study ([1977], p. 273) may be of some interest: "monetarists have consistently objected to the transactions approach to money demand which limits the class of assets viewed as money substitutes to very short-term financial assets." We may also note that there is a considerable volume of empirical studies in the literature which test the substitutability of various financial assets (especially, that of "near-monies"). See Feige-Pearce (1977) for a survey. A fresh view-point in this regard was offered by Chetty (1969), which provoked a recent study by Sims-Takayama-Chao (1985).

[13] On the other hand, the satisfaction of the homogeneity assumptions does not necessarily validate out particular functional specifications, as we mentioned in the context of Meltzer's study (1963). In empirical estimations, as is well-known, we cannot "accept" a hypothesis under any circumstances.

hand, if we cannot reject the specified homogeneity, then we may impose such a property and estimate our money demand function with the restriction of homogeneity explicitly imposed.

Finally, we might note that our study will *not* introduce any lag structure in the money demand process, although such lags have been popular in recent empirical studies. Although the introduction of lags will undoubtedly increase the "fit" of regressions by the choice of proper lag structures for the period of observation, it is not clear how we can justify a particular lag structure empirically obtained from a theoretical view point, and thus, it is also not often clear whether the lag structure observed for a particular period of time remains valid outside such a period. Not only does the introduction of a rich lag structure quickly surpass econometric capability to derive useful statistical estimates of induced parameters, but it also tends to blur the focal points of the theory in question. Furthermore, unlike other markets such as the goods and the labor markets, it may not be so unreasonable to suppose that the monetary equilibrium relation can be brought about quite quickly, in which case lags are not so important. In this connection, we might also note that some of the important empirical studies discussed in this section do not incorporate any lags and yet obtain good results. We wish to make our study comparable to these studies, and, further, concentrate our efforts on the issues raised in this section.

3. ESTIMATION OF THE MONEY DEMAND EQUATION, AND DISCUSSION OF RESULTS[14]

For the purpose of estimation, we specify the functional form of L in (8) in the following log-linear form, which has been widely used in the literature for the estimation of money demand:

$$\log M = \alpha_0 + \alpha_1 \log i_S + \alpha_2 \log i_L + \alpha_3 \log Y + \alpha_4 \log W, \tag{8'}$$

where we use M_1 (currency plus demand deposits) for our measure of M. The variables M, Y, and W are measured (as defined in the previous section) in nominal magnitudes.[15]

[14] The data used in the present study comes from the following sources. The data for currency, demand deposits, time deposits and gross national products are from the U.S. Department of Commerce's *Historical Statistics*. The data for interest rates (the four-six month rate of commercial paper, the Moody's AAA long-term bond rate, and the Federal Reserve's discount rates) are from the *Economic Report of the President*. The data for the required reserve ratios for demand and time deposits for member banks and for the augmented monetary base are from the Federal Reserve's Board of Govenors' *Banking and Monetary Statistics*. The definition of non-human wealth follows Meltzer (1963) which in essence follows Goldsmith's data with adjustments.

[15] Goldfeld ([1973], p. 624) states, "Although some writers have used nominal magnitudes, the specification in real terms is most commonly used in empirical research and is suggested by economic theory," whereby "economic theory" he apparently meant the Baumol-Tobin inventory theoretic formulation. As we argued earlier (cf. footnote 4), we believe that the Baumol-Tobin theory is perfectly consistent with homogeneity. Furthermore, the specification in real terms will introduce unnecessary

The homogeneity postulate in terms of equation (8′) may be stated as,

$$\alpha_3 + \alpha_4 = 1\,, \tag{9}$$

where α_3 and α_4, respectively, signify the income and the wealth elasticities of the demand for money.

We wish to perform three investigations of the estimates of the parameters in the above system. First, we want to test for the homogeneity restriction which was discussed in the previous section. Second, if we cannot reject the homogeneity assumption, we want to estimate the equations under the restriction. Third, we want to compare these restricted estimates to unrestricted estimators as reported in the literature.

We first estimate (8′) *without* imposing the homogeneity restriction. We estimate (8′) using ordinary least square (OLS), and OLS with first order autocorrelation corrected for by the Cochrane-Orcutt method (CORC). Our results are reported below, where t-values are indicated in the parentheses. We use annual data for the period of 1929–1958.

(10-a) OLS

$$\begin{aligned}\log M = &-1.11 - 0.039\log i_S - 0.619\log i_L \\ &(-1.77)\;(-0.595)\qquad(-2.60) \\ &+0.557\log Y + 0.471\log W\,, \qquad R^2 = 0.9858 \\ &\;(3.05)\qquad\quad(2.36) \qquad\qquad\quad DW = 0.4887\end{aligned}$$

(10-b) CORC

$$\begin{aligned}\log M = &-1.51 - 0.079\log i_S - 0.345\log i_L \\ &(-2.65)\;(-1.54)\qquad(-1.83) \\ &+0.556\log Y + 0.486\log W\,, \qquad R^2 = 0.9450 \\ &\;(3.54)\qquad\quad(2.75) \qquad\qquad\quad DW = 1.03^{16}\end{aligned}$$

As can be seen, the coefficients are of the expected sign and all are significant, in general, except for the coefficient on the short-term interest rate, i_S. When the equation is estimated with the CORC technique the t-ratio for i_S is remarkably improved. However, it is not clear whether or not CORC was successful in

distortions in our statistical biases. To understand this, it suffices to note that the specification in real terms necessarily involves the use of a price index. However, the price index is only a *discrete* approximation of the Divisia index and is observed at a particular point in time, while income (Y) is a flow variable and prices do not remain constant during the period in which income is observed. This then tends to destroy any systematic theoretical relations such as homogeneity. In fact, this is well-known in other empirical studies such as the estimation of consumers' demand functions of commodities.

[16] This is the Durbin-Watson statistic calculated from the residuals of the regression:

$$Y^* = X^*\beta + \varepsilon\,,$$

where $Y^* \equiv Y - \hat{\rho}Y_{t-1}$, where $\hat{\rho}$ is the estimated coefficient of first order correlation from the regression:

$$Y = X\beta + u\,.$$

This formulation corresponds to the DW-statistics reported under all equations estimated with the CORC technique.

removing autocorrelation from the OLS residuals; the $DW = 1.03$ which may or may not indicate possible second or even higher order autocorrelation.[17] Therefore, results from CORC may be no better than those from OLS. It is interesting to note, however, that regardless of the estimation technique, the income and wealth elasticities are always positive and significant.

Our next task is to test whether or not the demand function (8′) is homogeneous of degree one with respect to both nominal income and wealth. That is, we wish to test the hypothesis regarding the parameters of (10);

$$H_0 : \alpha_3 + \alpha_4 = 1 .$$

H_0 was tested in equations (10-a) and (10-b) and the estimated F-statistics obtained were 0.2118 and 0.2869, respectively. The critical value of $F_{(1,25)}$ at the 95% confidence level is 4.24. Since our estimated statistics are well within the acceptance region, we cannot reject the hypothesis that the demand for money (at least for our sample period and specification) is linearly homogenous with respect to nominal income and wealth.

Two observations may be in order. First, we use annual data which tends to be more stable than quarterly data. Second, our homogeneity result may be somewhat "biased" because of possible multicollinearity between our two interest rates. The homogeneity restriction remains valid using OLS if the short-term rate is excluded but not if the long-term rate is excluded, although the income and wealth elasticities remain positive and significant.[18] However, as mentioned earlier, there is sufficient theoretical justification for including both short and long-term rates in the money demand function. It would be unjustifiable to exclude either of them for "statistical" reasons, just as it is unjustifiable to drop either income or wealth when there appears to be multicollinearity problems.

Given that we could not reject our theoretically derived homogeneity assumption, we estimated the money demand function under homogeneity; i.e., we estimated (8′), restricting $\alpha_3 + \alpha_4 = 1$. The results for the restricted demand equation are as follows:

[17] An obvious extension of our study would be to check the roubstness of our results based on estimates which are free of any autocorrelation, which is left to the interested reader.

[18] The OLS results and F-statistics for H_0: $\alpha_3 + \alpha_4 = 1$ are

$$\underset{}{\log M} = \underset{(-2.19)}{-0.811} \underset{(-6.59)}{-0.743 \log i_L} \underset{(3.04)}{+0.541 \log Y} \underset{(2.34)}{+0.457 \log W}$$

$$R^2 = 0.9856 , \quad F^* = 0.003 , \quad DW = 0.5266$$

and

$$\log M = \underset{(-4.46)}{-2.23} \underset{(-5.42)}{-0.190 \log i_S} \underset{(4.06)}{+0.749 \log Y} \underset{(1.81)}{+0.394 \log W}$$

$$R^2 = 0.9820 , \quad F^* = 9.749 , \quad DW = 0.3974 .$$

(11-a) OLS
$$\log M = -0.832 - 0.014 \log i_S - 0.699 \log i_L$$
$$\quad (-4.19) \; (-3.87) \qquad (-4.37)$$
$$+0.567 \log Y + 0.433 \log W, \qquad R^2 = 0.9857$$
$$(3.18) \qquad (2.43) \qquad DW = 0.5135$$

(11-b) CORC
$$\log M = -1.15 - 0.063 \log i_S - 0.404 \log i_L$$
$$\quad (-5.30) \; (-1.40) \qquad (-2.36)$$
$$+0.569 \log Y + 0.431 \log W, \qquad R^2 = 0.6538$$
$$(3.66) \qquad (2.78) \qquad DW = 1.19$$

It may not be surprising to note the similarities between equations (10-a) and (10-b) and their restricted versions (11-a) and (11-b) respectively. Again, it is necessary to point out that our CORC results may not be better since it is unclear whether or not we have removed autocorrelation in the demand equation's residuals. The DW-statistic $(=1.19)$ is in the region of indeterminacy.

On the basis of our results, we may conclude:

(a) The nominal demand for money depends significantly on both nominal income *and* wealth. Therefore, to drop either as an explanatory variable in empirical studies on the demand for money results in an inappropriate specification of the demand function;

(b) The nominal demand for money appears to be homogeneous of degree one with respect to (current) nominal income *and* wealth; i.e., the income and wealth elasticities of demand are both significantly positive and sum to one. We found that the wealth (resp. income) elasticity of the demand for money is approximately equal to 0.4 (resp. 0.6) (cf. equations (11-a) and (11-b)). The fact that the wealth elasticity is different from one makes a marked contrast to the popular assumption in the literature that it is equal to zero (the transactions demand approach) or one (the wealth adjustment approach).

Next, we may compare our results of the short-term and the long-term interest elasticities from our restricted specification to those results from some other representative studies in the literature, which are summarized in Table I. Needless to say, these comparisons should be made with caution since studies differ as to specification, assumptions, sample periods, etc.

Note that our estimate of the long-term interest elasticity obtained from OLS is not much different from other estimates in the literature in spite of the fact that we include both income (Y) and wealth (W) under the homogeneity restriction, as well as the short-term interest rate as explanatory variables. Our estimate of the short-term interest elasticity obtained from OLS, -0.014, is comparable to Goldfeld's result of -0.018 for the prime commercial paper and Teigen's result of -0.0141 for his post-war period.

TABLE 1. COMPARISON OF INTEREST RATE ELASTICITIES

	Short-term	Long-term
Latané (1954)		-0.7
Meltzer (1963)		$-0.7 \sim -0.9$
Brunner-Meltzer (1964)		$-0.652 \sim -0.526$
Chow (1966)		-0.75, -0.79
Laidler (1966b)		$-0.5 \sim -0.8$
Laidler (1966b)	$-0.18 \sim -0.20$	
Teigen (1964)	-0.0141 (1946–1959)	
	-0.0879 (1924–1941)	
Heller (1965)	-0.1	
Goldfeld (1976)	-0.018, -0.042	
	(commercial paper) (time deposits)	
Sims-Takayama (OLS)	-0.014	-0.699
(CORC)	-0.063	-0.404

4. THE MONEY SUPPLY FUNCTION

It is now well-known that the usual practice in most macro textbooks of taking the money supply as an exogenous variable is, conceptually, wrong. This can be seen very easily by simply considering the fact that the money supply depends on commercial banks' behavior regarding free reserves and loans to the public, which in turn depends on the interest rate, an endogenous variable in the money supply-demand process. Having recognized the endogeneity aspect of the money supply, it may not be surprising to see a number of works in the literature on the supply of money, especially in the last twenty years. Unfortunately, however, there is a great deal of complexity in alternative specifications of the money supply function, and one may easily get confused with regard to the question of what should constitute its proper specification. As mentioned earlier, one of the present authors, with John Drabicki, once surveyed the literature on the money supply, and then proposed what should be its plausible specification (see Takayama-Drabicki [1976]). Then such a formula has recently been utilized by Drabicki-Takayama (1984), for example, to analyze certain important theoretical problems. The approach taken in T-D (1976) is, in essence, to recognize the central importance of utilizing the balance sheets of both the commercial banks and the central bank. Most studies in the literature utilize neither of these balance sheets, or utilize only one of them, and thus unfortunately end up obtaining oversimplified (if not totally inadequate) money supply formulas. Such weaknesses were corrected in the Takayama-Drabicki formula ([1976], p. 338), which we shall use in the present study.

To facilitate the present empirical study which involves time deposits as well as demand deposits, we shall modify the Takayama-Drabicki formula (1976) in the following way, where we postpone its derivation to the Appendix.

$$M = \phi(i, i_F, \alpha, t, \gamma) S^c \equiv M(i, \alpha, t, \gamma, S^c) , \tag{12}$$

where M = currency plus demand deposits, S^c = the central bank's holding of securities, i = interest rate, i_F = the central bank's discount rate, α = the ratio of currency demand over M, t = the ratio of time deposits over demand deposits, and $\gamma \equiv \gamma^D + \gamma^T t$, and where γ^D and γ^T, respectively denote the required reserve ratios with respect to demand deposits and time deposits. Note that open market operations are facilitated by changes in S^c, and that (by the balance sheet of the central bank) S^c also signifies the augumented monetary base (cf. fn. 22 below).

It can rigorously be shown (cf. the Appendix) that

$$(13) \qquad \partial\phi/\partial i > 0\,, \quad \partial\phi/\partial i_F < 0\,, \quad \partial\phi/\partial\alpha < 0\,, \quad \partial\phi/\partial t < 0\,, \quad \partial\phi/\partial\gamma < 0\,.$$

I.e., the M supply curve is upward sloping in $(M - i)$ space where i is measured on the vertical axis; and a rise in the discount rate (i_F), the currency ratio (α), the ratio of time deposits to demand deposits (t), or in the required reserve ratio for either demand or time deposits (γ), *centris paribus*, shifts the M supply curve to the left. Namely, (13) conforms with the conventional wisdom. Also (12) indicates that the supply of money is unitary elastic with respect to S^c, i.e., $(\partial M/\partial S^c)(S^c/M) = 1$. Since both M and S^c are measured in dollars, this is not surprising: doubling the unit of the currency denomination doubles all nominal variables. Namely, the supply of money is homogenous of degree one with respect to S^c. Again, we shall test such a homogeneity in terms of data. If we would reject the null hypothesis of linear homogeneity, then the above money supply formulation, (12), should be subject to reconsideration.

For the purpose of testing this functional specification and obtaining estimates of the relevant parameters, we assume that (12) takes the following form:

$$(12') \qquad \log M = \beta_0 + \beta_1 \log i_S + \beta_2 \log i_F + \beta_3 \log \alpha + \beta_4 \log t + \beta_5 \log \gamma + \beta_6 \log S^c\,.$$

Note that we have assumed that commercial banks adjust their portfolios based on movements in short-term rates (which is probably not a bad assumption given the short-term nature of banks' portfolios). The expected signs of coefficients indicated by (13) are: $\beta_1 > 0$, $\beta_2 < 0$, $\beta_3 < 0$, $\beta_4 < 0$, $\beta_5 < 0$, and $\beta_6 > 0$.

The test for the linear homogeneity of money supply with respect to the augment monetary base, given that the supply function is written as (12′), is

$$H_0 : \beta_6 = 1\,.$$

If we fail to reject H_0, we may impose the linear homogeneity and we may estimate (12′) under the restriction of $\beta_6 = 1$.

We first estimate (12′) *without* imposing the homogeneity restriction. We estimate (12′) using ordinary least square (OLS), and OLS with first order autocorrelation corrected for by the Cochrane-Orcutt method (CORC). Our results are reported below, where we again use annual data for the period of 1929–1958.

(14-a) OLS

$$\log M = 1.63 + 0.445 \log i_S - 0.334 \log i_F - 0.232 \log \alpha$$
$$(5.68)\ (5.17) \qquad (-2.41) \qquad (-1.83)$$
$$-0.520 \log t - 0.445 \log \gamma + 0.907 \log S^c\,,$$
$$(-2.94) \qquad (-2.77) \qquad (15.25)$$
$$R^2 = 0.9912$$
$$DW = 0.8948$$

(14-b) CORC

$$\log M = 1.36 + 0.334 \log i_S - 0.191 \log i_F - 0.277 \log \alpha$$
$$(3.98)\ (4.01) \qquad (-1.60) \qquad (-2.13)$$
$$-0.357 \log t - 0.382 \log \gamma + 0.950 \log S^c\,,$$
$$(-1.95) \qquad (-2.63) \qquad (15.95)$$
$$R^2 = 0.9803$$
$$DW = 1.39$$

As can be seen, the coefficients are of the expected sign and all, in general are significant. As in the demand function, it is unclear whether or not the CORC results are any better than the results from OLS since the DW-statistic $(=1.39)$ is in the region of indeterminacy, and hence we cannot conclude that we were successful in removing autocorrelation.

Recall that the test for homogeneity of the money supply with respect to the augmented monetary base is equivalent to testing, $H_0: \beta_6 = 1$. H_0 was tested in equations (14-a) and (14-b) and the estimated F-statistics obtained were 2.41 and 2.84, respectively. The critical value of $F_{(1,23)}$ at the 95% confidence level is 4.28. Since our estimated statistics are within the acceptance region, we cannot reject the hypothesis that the supply of money (at least for our sample period and specification) is linearly homogeneous with respect to the augmented monetary base.

Given that we could not reject the (theoretically derived) homogeneity assumption, we estimate the money supply function under homogeneity, i.e., we estimate (12′), restricting $\beta_6 = 1$. The results for the restricted money supply equation are as follows:

(15-a) OLS

$$\log M = 1.590 + 0.402 \log i_S - 0.320 \log i_F - 0.291 \log \alpha$$
$$(5.41)\ (4.80) \qquad (-2.25) \qquad (-2.34)$$
$$-0.442 \log t - 0.565 \log \gamma + \log S^c\,,$$
$$(-2.54) \qquad (-3.91)$$
$$R^2 = 0.9903$$
$$DW = 0.7652$$

(15-b) CORC

$$\log M = 1.268 + 0.298 \log i_S - 0.153 \log i_F - 0.302 \log \alpha$$
$$(3.76)\ (3.87) \qquad (-1.36) \qquad (-2.37)$$

$$-0.279 \log t - 0.405 \log \gamma + \log S^c ,$$
$$(-1.67) \qquad (-2.98)$$
$$R^2 = 0.7846$$
$$DW = 1.47$$

Again, we must note that we are not sure whether CORC was successful in removing autocorrelation from our supply equation. It may not then be surprising that these results are similar to the ones from their unrestricted counterparts, (14-a) and (14-b), respectively, since we could not reject our homogeneity specification. Again, we will compare, to the extent possible, our results with the results from some other relevant empirical studies on the supply of money.

We obtain a range of the elasticity of money supply with respect to a short-term interest rate of 0.298 to 0.402. As Fand ([1967], p. 386) points out, other studies have obtained a range of 0.025 to 0.656, so that the estimates from our restricted specification are not out of the ordinary. Similarly, our range of the estimated elasticity of money supply with respect to the discount rate (-0.320 to -0.153) is similar to Fand's range of -0.468 to -0.004, and so on for our estimates via à vis those of similar studies.

In summary, we may conclude:

(a) The specification of the money supply function used in this study is a good specification in terms of explaining the variation in observed values of M for the period under consideration;

(b) The supply of money function is homogeneous of degree one with respect to the augmented monetary base.

5. SIMULTANEOUS EQUATION MODELS

Recall that the money demand and the money supply equations, in the unrestricted forms, are specified by (8′) and (12′). Hence, there should be little doubt that simultaneous bias, at least theoretically, exists since there are two endogenous variables, M and i_S in these two equations. We will therefore estimate the demand and the supply equations simultaneously by using two stage least squares (2SLS). We first estimate these equations in the forms which are not restricted by homogeneity. Then we test the homogeneity assumptions of these. If we cannot reject them, we further estimate these in the forms restricted by homogeneity.

We first report our results for the demand and the supply equations in the unrestricted forms.

(16-a) (2SLS)
$$\log M = -0.155 - 0.098 \log i_S - 0.434 \log i_L$$
$$(-2.25) \quad (-1.29) \qquad (-1.62)$$
$$+0.580 \log t + 0.492 \log W ,$$
$$(3.12) \qquad (2.42)$$
$$R^2 = 0.9854$$
$$DW = 0.4460$$

(16-b) (2SLS)

$$\log M = \underset{(5.22)}{2.11} + \underset{(4.63)}{0.757} \log i_S - \underset{(-3.15)}{0.779} \log i_F - \underset{(-1.90)}{0.302} \log \alpha$$

$$- \underset{(-3.30)}{0.828} \log t - \underset{(-3.03)}{0.649} \log \gamma + \underset{(10.67)}{0.839} \log S^c ,$$

$$R^2 = 0.9866$$
$$DW = 1.315$$

In general, the coefficients are of the expected sign and all are significant, and these coefficients are comparable to the results from their unrestricted counterparts, (10) and (14), respectively. Note that the t-ratio for the short-term interest elasticity of the demand for money is improved when 2SLS is used instead of OLS (cf. (10-a) with (16-a)). Note also, that the income and the wealth elasticities of money demand are again positive and significant.

The estimated F-statistic to test the homogeneity hypothesis of the money demand function, H_0: $\alpha_3 + \alpha_4 = 1$, is obtained as 1.16. Since the critical value of $F_{(1,25)}$ at the 95% confidence level is 4.24, we cannot reject the homogeneity hypothesis of the demand function. Also, the estimated F-statistic to test the homogeneity hypothesis of the money supply function, H_0: $\beta_6 = 1$, is obtained as 4.18. Since the critical value of $F_{(1,23)}$ at the 95% confidence level is 4.28, we cannot reject (only marginally) the homogeneity hypothesis of the supply function.

Given that we could not reject the homogeneity assumptions, we estimated the money demand and the money supply functions under homogeneity, i.e., we estimated, (8′) restricting $\alpha_3 + \alpha_4 = 1$, and (12′), restricting $\beta_6 = 1$, by using two stage least squares. The results for the restricted equations are as follows.

(17-a) (2SLS)

$$\log M = -\underset{(-4.87)}{0.832} - \underset{(-0.886)}{0.037} \log i_S - \underset{(-3.20)}{0.605} \log i_L$$

$$+ \underset{(3.25)}{0.637} \log Y + \underset{(1.86)}{0.363} \log W ,$$

$$R^2 = 0.9855$$
$$DW = 0.4810$$

(17-b) (2SLS)

$$\log M = \underset{(5.31)}{1.913} + \underset{(4.53)}{0.593} \log i_S - \underset{(-2.90)}{0.630} \log i_F - \underset{(-2.61)}{0.372} \log \alpha$$

$$- \underset{(-2.95)}{0.621} \log t - \underset{(-4.10)}{0.774} \log \gamma + \log S^c$$

$$R^2 = 0.9982$$
$$DW = 1.16$$

Again, in general, the coefficients are of the expected sign and all are significant, and these coefficients are comparable to the results from their restricted counterparts, (11) and (15).

Finally, we may examine whether or not simultaneity bias exists and whether it can be corrected for by using two stage least squares. There is little evidence that the simultaneous equation technique compensates for the bias, at least in the demand equation. A comparison of equations (11-a) and (17-a) indicates little change in the standard errors of the estimated coefficients and no apparent improvement in the autoregressive schemes. The supply equation, on the other hand, does improve somewhat in the sense that the estimated Durbin-Watson statistics moves into the range of indeterminacy when we compare (14-a) with (17-b). In any case, there does not appear to be sufficient evidence from our formulation to preclude the estimation of the demand for or supply of money as single, independent equations.

One possible reason as to why we were unsuccessful in removing simultaneity bias is that among the list of exogenous variables, the exogeneity of Y, W, and i_L may be questioned. On the other hand, assuming that the market for money adjusts fairly quickly compared to other markets such as the goods or labor market, the assumed exogeneity of Y and W may not be so bad. Another reason for the failure of removing simultaneity bias may lie in the fact that the money supply equation (12) is not really a true supply equation. As we shall point out in Appendix A, the equilibrium assumption, as is the case in the literature on this topic, is imbedded in the derivation of (12) via α, the currency-money ratio. Still another problem is that of the endogeneity of i_L via i_S and the term structure of interest rates. This is not an easy question either. Not only is there a lack of consensus on the theoretical formulation of the term structure equation, but also, any such (plausible) formulation may not easily be statistically distinguishable from the demand and supply equations of money.

APPENDIX: THE MONEY SUPPLY FORMULA[19]

In the appendix, we shall derive the money supply equation which was used for our empirical estimation. We begin our discussion with depicting the basic balance sheets of the central bank and commercial banks.

Central Bank		Commercial Banks	
Assets	Liabilities	Assets	Liabilities
S^c	C	R^b	D
	R	S^b	T

Figure 1. The Balance Sheets of the Central Bank and Commercial Banks

[19] The discussion here was originally by J. Z. Drabicki and A. Takayama and recorded in Drabicki ([1974], pp. 90–92), in which time deposits were also included. The gist of their analysis is published in Takayama-Drabicki (1976) in which time deposits are assumed away for the sake of simplicity. Comparisons of the formula here to the ones found in the literature are discussed in Takayama-Drabicki (1976) as mentioned earlier.

where S^c and S^b, respectively, represent the net holding of securities by the central bank, and the commercial banks; C, D, and T, respectively, represent the central bank's currency, and demand and time deposits at commercial banks, and R^b ($=R$ in equilibrium) denotes the net reserves of the commercial banks.[20]

From the balance sheet identity of the commercial banks, we obtain,

$$D+T\equiv R^b+S^b\,. \tag{A-1}$$

Also, by definition we have,

$$R^b\equiv(\gamma^D D+\gamma^T T)+F\,, \tag{A-2}$$

where γ^D and γ^T are the required reserve ratios of demand and time deposits, respectively, and where F denotes free reserves (excess reserves minus borrowed reserves). Letting $t\equiv T/D$ (the time and demand deposit ratio) and $\gamma\equiv\gamma^D+\gamma^T t$, we may rewrite (A-1) and (A-2), respectively, as,

$$(1+t)D\equiv R^b+S^b\,, \tag{A-1$'$}$$

$$R^b\equiv\gamma D+F\,. \tag{A-2$'$}$$

Substituting (A-2′) into (A-1′) yields,

$$(1+t-\gamma)D\equiv F+S^b\,. \tag{A-3}$$

Rewriting (A-1′) as $D\equiv(R^b+S^b)/(1+t)$ and substituting this into (A-2′), we obtain,

$$(1+t-\gamma)R^b\equiv(1+t)F+\gamma S^b\,. \tag{A-4}$$

Then dividing (A-3) by (A-4) and letting $\psi\equiv S^b/F$, we may obtain,

$$D\equiv\frac{1+\psi}{(1+t)+\gamma\psi}R^b\,. \tag{A-5}$$

Following the usual practice in the literature, assume that the public holds currency and demand deposits in a fixed or an exogenously determined proportion. Then letting $M=C+D$ (money), we have: $C=\alpha M$ and $D=(1-\alpha)M$, where α is exogenously given. Next, making use of the central bank's balance sheet

[20] To the extent that foreign countries hold U.S. assets as foreign exchange reserves, etc., the liabilities of the U.S. central bank (the Fed) should include such items. These items undoubtedly play an important role on the U.S. money supply for recent decades. It is assumed here that such liabilities of the Fed during our sample period (1929–1958) do not play a significant role. In fact, the choice of our sample period is partially motivated by such a consideration. Our estimates reported in the text appear to be consistent with such an assumption. Needless to say, if we wish to investigate the money supply behavior for more recent periods, we need to incorporate the foreign countries' demand for U.S. assets as foreign exchange reserves, etc. which in turn constitute liabilities of the U.S. Fed. We leave such analysis to future study. In this connection, we might also mention that if we wish to study the money supply behavior of non-U.S. countries, we need to take account of the fact that a part of S^c are foreign exchange reserves.

identity $S^c \equiv C+R$ and noting $R^b = R$ in equilibrium,[21] we have $R^b = S^c - C = S^c - \alpha M$. Substituting this and $D = (1-\alpha)M$ into (A-5), and rearranging terms, we obtain,

$$M = \frac{1+\psi}{\beta+\theta\psi} S^c , \tag{A-6}$$

where $\beta \equiv 1+(1-\alpha)t$ and $\theta \equiv \alpha+(1-\alpha)\gamma$. The quantity $C+R^b$ ($=S^c$) is often called the *augumented monetary base*.[22]

Let RR denote the required reserves, i.e., $RR \equiv \gamma^D D + \gamma^T T$. Then the balance sheet identity of the commercial banks may also be rewritten as, $RR+F+S^b \equiv T+D$. Let $Z \equiv T+D-RR$, which is the amount that the commercial banks can discretionarily allocate between F and S^b. Letting i_F and i, respectively, denote the central bank's discount rate and the rate of interest (or more precisely, the commercial bank's interest rate on loans and advances), we may hypothesize the following portfolio choice behavior of the commercial banks:

$$F = f(i, i_F)Z , \quad S^b = s^b(i, i_F)Z , \tag{A-7}$$

$$\partial f/\partial i < 0 , \quad \partial f/\partial i_F > 0 , \quad \partial s^b/\partial i > 0 , \quad \partial s^b/\partial i_F < 0 , \tag{A-8}$$

where not all of the relations in (A-8) are independent.[23]

Recalling $\psi \equiv S^b/F$, (A-7) implies:

$$\psi(i, i_F) \equiv s^b(i, i_F)/f(i, i_F) , \tag{A-9}$$

$$\partial\psi/\partial i > 0 \quad \text{and} \quad \partial\psi/\partial i_F < 0 . \tag{A-10}$$

Substituting (A-9) into (A-6), we finally obtain:

$$M = \phi(i, i_F, \alpha, t, \gamma)S^c , \qquad \text{where} \quad \phi \equiv (1+\psi)/(\beta+\theta\psi) , \tag{A-11}$$

where we may recall $\beta \equiv 1+(1-\alpha)t$ and $\theta \equiv \alpha+(1-\alpha)t$, and where we assume that α, t and γ are exogenously given. We call (A-11) the "money supply equation." From the definition of ϕ, β and θ, and from (A-10), it is easy to show:

$$\frac{\partial\phi}{\partial i} > 0 , \quad \frac{\partial\phi}{\partial i_F} < 0 , \quad \frac{\partial\phi}{\partial\alpha} < 0 , \quad \frac{\partial\phi}{\partial t} < 0 , \quad \frac{\partial\phi}{\partial\gamma} < 0 , \tag{A-12}$$

all of which conform with conventional wisdom (as discussed in the text). Also, doubling the unit of the currency denomination should theoretically double both M and S^c as they are measured in nominal units. Note that this homogeneity

[21] We are assuming that R is supplied indefinitely by the central bank at any moment of time at an exogenously given rate (i_F), where i_F is the central bank's discount rate.

[22] Since total bank reserves (TR) is equal to R^b plus borrowed reserves (BR), we have, $C+TR \equiv C+R^b+BR$. The quantity ($C+TR$) is called the *monetary base*, or *high powered money*. The *argumented* monetary base thus differs from the monetary base by the amount of borrowed reserves.

[23] Since $F+S^b \equiv Z$ from the balance sheet identity of the commercial banks, we have $f(i, i_F)Z + s^b(i, i_F)Z \equiv Z$, or $f(i, i_F) + s^b(i, i_F) \equiv 1$. Hence assuming $\partial f/\partial i_F > 0$ and $\partial s^b/\partial i > 0$ yields the rest of (A-8).

property is satisfied in our formula (A-11). Note also that (A-11) reduces to the formula reported in Takayama-Drabicki ([1976], p. 338) when $T \equiv 0$ (so that $t \equiv 0$). Incidentally, the assumption of exogeneously given α, t and γ follows much of the literature (except possibly for that of t). Relaxing this assumption in the empirical context is certainly interesting, and is left for future study.

In the above and also in the text, we called (A-11) the money supply equation. Strictly speaking, this is not correct. This is because in obtaining (A-11) we (following much of the literature on the "supply of money") assumed the monetary *equilibrium* relations, $C = \alpha M$ and $D = (1 - \alpha)M$, where C and D, respectively, represent the public's demands for currency and demand deposits. Relaxing this assumption is obviously desirable. However, such a task involves the simultaneous equation system which involves various assets and the public's demand functions of such assets. Since this will blur the focus of the present study as well as of the theoretical issue, such a study is beyond the scope of the present paper.

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