The Determinants of Real Cash Balances in the U.S. Total Manufacturing Sector

M. I. Nadiri

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I. INTRODUCTION

This paper has two primary purposes. The first is to develop a theory on the demand for cash balances by the manufacturing sector based on a model of rational entrepreneurial behavior. For this purpose firms are considered to minimize their costs subject to a production function which includes real cash balances as an input. The second objective of the paper is to estimate the demand function for real cash balances of the corporate sector using quarterly data on total manufacturing for the period 1948-I to 1964-IV. The empirical section of the paper may be of special interest inasmuch as very few systematic studies of the determinants of the business sector's cash holdings using quarterly data have been reported in the literature.¹ Utilizing such data may reveal the adjustment

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process and the dynamic properties of the money demand function better than studies based on yearly data.

The problem is stated in Section II. Section III pertains to the derivation of the demand function for real cash balances of the corporate sector. In Section IV the empirical results of the model for the sample period 1948-I to 1960-IV are presented. The adjustment properties of the model and its forecasting performance beyond the sample period are considered in Section V. In Section VI the results of a set of conceptual experiments are reported. These experiments are designed to test the intertemporal stability and comparative performance of the model against a set of "alternative" demand functions for money. The measurement of the variables of the model and a description of the data are presented in the statistical appendix to the paper.

The main findings are: (1) the demand for real cash balances is determined by output (wealth), the interest rate, the expected rate of change in the general price level, and factor prices. The cross-elasticity of real cash balances with respect to relative factor prices is generally smaller in magnitude than their elasticity with respect to interest rates; (2) there are evidences of speculative motives in holding real cash balances; (3) changes in the price level seem to affect desired cash holdings of the manufacturing sector significantly; (4) the elasticity of real cash balances with respect to scale variables suggests substantial economies of scale; and (5) the speed of adjustment of actual to desired real cash balances is much faster than that reported so far in the literature.

II. THE SETTING OF THE PROBLEM

The post-Keynesian revival of interest in the demand function for money has followed two distinct paths. One is an inventory-theoretic approach developed by Baumol, Tobin, and Miller and Orr. The other is a long-run asset preference theory proposed by Friedman, Brunner and Meltzer, Meltzer, Chow, and others. The essence of the two approaches is aptly stated by Friedman:


Businesses hold cash as a productive resource. The question is whether cash is a resource like securities, in which case it might be expected to fluctuate more over the cycle than current production, or like fixed capital, in which case it might be expected to fluctuate less and to be adapted to the longer term level of production at which a firm plans to operate.4

Advocates of both theories often imply that their theories apply to the behavior of business firms. However, only scattered evidence has been reported to substantiate this claim. A new approach is needed and the model specified in this paper is an effort to fulfill this need. The model is based on the neoclassical theory of the firm. Real cash balances are considered to be a function of the level of output, relative factor prices, and the opportunity cost of holding money. By specifying and accurately measuring the opportunity cost of money, factor prices, and scale variables, it is possible to trace the influences of capital gains, interest rates, factor prices, changes in general price levels, and the size of transactions on the desired real cash holdings of the corporate sector.

III. Specifications of the Model

Real cash balances serve as productive inputs. They are part of the working capital of the firm facilitating its productive process, often by indirect means, such as hedging against changes in the prices of capital and labor and the interest rate. Holding adequate cash balances may reduce the uncertainty of meeting current payments, thus avoiding unnecessary and unprofitable liquidation of other assets. Desired real cash balances of the firm are related to the expected level of its operation and movements in the opportunity cost money (v), the user cost of capital services (c), the price of labor services (w), and the general price level (p). Output serves as a scale variable while v, c, and w depict the own- and cross-elasticities of real cash balances to changes in various input prices.5

The opportunity cost of money has three components: an inter-


est cost, capital gains (losses) in the securities market, and a depre-
ciation cost. The first element is the interest income foregone by
holding cash rather than short term securities. The capital gains
component of \( v \) is generally due to an anticipated rise in the prices
of securities. The third element is a reduction in the purchasing
power of money due to an expected increase in the general price
level. We can write

\[
(1a) \quad v = [r + p'_{b}/p_{b} + p'/p],
\]

where \( v \) is the opportunity cost of money, \( r \) is the interest rate, \( p'_{b} \)
is the expected change in the price of securities, \( p_{b} \) is the price of
securities; \( p' \) is the expected change in the general price level, and
\( p \) is the level of general prices. Assuming that a change in the ex-
pected rate of interest \((- r')\) is a good proxy for expected capital
gains (losses), \( p'_{b}/p_{b} \), we can write

\[
(1b) \quad v = [r - r' + p'/p].
\]

Labor is a quasi-fixed factor of production and its “user” cost
consists of a variable component and fixed charges. The variable
component consists of the straight-time wage payments; the fixed
costs are investment in training, skills, conditions of work, etc., and
a “depreciation cost” due to separation of the firm’s labor force. The
appropriate measure of user cost of labor services is to define the
total wage bill as

\[
w_{1}N + h(r + g)L/H
\]

where \( w_{1} \) is the wage rate, \( N \) is the number of employees, \( h(r + g) \)
is the fixed cost of labor services, \( L \) is total man-hours, \( H \) is the
hours-man ratio, \( h \) is the hiring cost, and \( g \) is the separation cost of
labor. Holding \( H \) fixed, the marginal cost of labor services is

\[
(1b) \quad w = w_{1} + h(r + g)/H \text{ for } H < H_{0},
\]

\[
= w_{1}(1 + \sigma) + h(r + g)/H \text{ for } H > H_{0},
\]

where \( \sigma = dw/dH \cdot H/w \) and \( H_{0} \) is standard hours.\(^6\) If we neglect
the second relation and assume \( h = \beta w_{1} \), the marginal cost of labor
reduces to \( w_{1}(1+\beta (r+g)/H) \), where \( \beta \) is the “fixity coefficient”
suggested by Oi.\(^7\)

The user cost of capital services is a modification of Jorgenson’s

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6. See S. Rosen “Short-Run Employment Variation, on Class-I Railroads
in the United States, 1947–1963,” *Econometrica*, forthcoming, for further com-
ments on the user cost of labor services.

measure; the modification is to include depreciation due to use as an additional element of the user cost of capital. That is,

\[(1c) \quad c = q/(1 - \mu) [d + \delta_0 + \delta_1 s - q'/q],\]

where \( q \) is the price of capital goods, \( \mu \) is the rate of the corporate tax, \( d \) is the cost of capital, \( \delta_0 \) is the rate of depreciation due to passage of time, \( \delta_1 \) is the depreciation rate due to intensive use of capital, \( s \) is the rate of utilization, and \( q' \) is the change in the price of capital goods as a measure of capital gains (losses).

Assume that the firm minimizes its expected total costs defined as:

\[(2) \quad C = wL + cK + vm,\]

subject to a twice differentiable production function,

\[(3) \quad X^* = F(L, K, m),\]

where \( C \) is the total cost, \( K \) is capital stock services measured as \( k \) where \( k \) is the capital stock and \( s \) is its rate of utilization, \( m \) is the stock of real cash balances, and \( X^* \) is the expected level of output. Minimizing (2) subject to the production function (3) suggests that the demand function for real cash balances is

\[(4) \quad m^* = f(c/w, v, X^*),\]

where \( m^* \) is the desired level of real cash balances. If we allow the elements of \( v \) to appear separately in (4) we get the "unrestricted" version of our model,

\[(5) \quad m^* = f'(c/w, r, r', p'/p, X^*).\]

The independent variables of (4) and (5) are in terms of expected values and the functions are assumed to be nonhomogenous in factor prices, reflecting the notion that there are economies of scale in purchasing inputs. To simplify the analysis we assume that (4) and (5) are multiplicative, i.e.,

\[(6) \quad m^* = A_0 X^{*1/\rho} v^{\alpha} (c/w)^{\beta}\]

and

\[(7) \quad m^* = A_1 X^{*1/\rho} r^{\beta} (p'/p)^{\omega} (c/w)^{\psi},\]

where \( A_0 \) and \( A_1 \) are constants; \( \rho, \alpha, \beta, \lambda, \pi, \omega, \) and \( \psi \) are elasticities of \( m^* \) with respect to the explanatory variables of the model. Of particular interest are the magnitudes of \( 1/\rho, \alpha, \beta, \) and \( \psi \). The economies of scale in holding real cash balances and the own- and cross-

elasticities of real cash balances can be measured from the values of these parameters.\textsuperscript{9} We assume the following reasonable a priori hypotheses:

\begin{equation}
\frac{\partial m^*}{\partial x^*} > 0, \frac{\partial m^*}{\partial r} < 0, \frac{\partial m^*}{\partial (p'/p)} < 0, \frac{\partial m^*}{\partial r'} > 0, \frac{\partial m^*}{\partial v} < 0, \text{ and } \frac{\partial m^*}{\partial (c/w)} > 0.
\end{equation}

The partial derivative of $m^*$ with respect to the output of the firm, $X^*$, is certainly positive; the reasons why real cash balances decrease with a rise in the interest rate, the general price level, and capital gains ($-r'$) were stated earlier and need not be repeated. The relation between $m^*$ and $v$, the opportunity cost of holding real cash balances is also apparent. A positive sign for the partial correlation of $m^*$ and $c/w$ suggests that real cash balances can be substituted for both capital and labor and if $|\frac{\partial m^*}{\partial (c/w)}| < |\frac{\partial m^*}{\partial r}|$, then real cash balances will be better substitutes for financial securities than for capital and labor.

Generally there is a time lag between actual and desired real cash balances of the firm. The lag could be due to uncertainty about the demand conditions, incomplete information about financial markets, etc. It may also reflect the disequilibrium in other assets of the firm. That is, adequate cash balances are needed to facilitate and lower the adjustment costs of other assets.\textsuperscript{1} We postulate a simple Koyck distributed lag mechanism to depict the adjustment process of actual to desired real cash balances, i.e.,

\begin{equation}
\frac{m_t}{m_{t-1}} = \left(\frac{m_t^*}{m_{t-1}^*}\right)\gamma,
\end{equation}

where $\gamma$ is the adjustment coefficient. Combining equations (6) or

\textsuperscript{9} The model can be specified in an alternative way, though the estimating equations may remain the same. Assume that there are four factors of production $m$, $B$, $L$, and $K$; $B$ is the net stock of bonds held by the firm, $m$, $B$, and $K$ are part of the asset structure of the firm, and each is subject to depreciation. Assume that the cost of capital to the firm is $d$. The firm produces output and financial services by combining its physical inputs $K$ and $L$ and by combining its financial assets. The problem is to minimize

\begin{equation}
C = wL + cK + vm + bB
\end{equation}

subject to

\begin{equation}
X^* = f_1(L, K, (B, m)).
\end{equation}

Assuming that the production function has desirable properties we can deduce the implicit input prices as

\begin{align*}
v_m &= \left[1/(1+\mu)\right] (d+p'/p) \\
v_b &= \left[1/(1+\mu)\right] (d-r+p'/p) \\
v_K &= \left[1/(1+\mu)\right] (d-\delta) + s - q' - q/p
\end{align*}

and

\begin{equation}
v_L = w/p \text{ (see eq. (1b))}
\end{equation}

Thus, when $d$ increases, labor services are substituted for $K$, $B$, and $m$, while the substitutions between different assets depend on $r$, capital gains, and the depreciation rates $\delta$ and $s$.

with (9) and taking logs we get the following estimating equations:

(a) restricted model,

\[
lnm_t = a_0 + a_1lnz_t + a_2ln(c/w)_t + a_3lnX_t^* + a_4lnm_{t-1} + \xi_{it};
\]

(b) unrestricted model,

\[
lnm_t = b_0 + b_1lnr_t + b_2dlnr_t + b_3dlnp_t + b_4ln(c/w)_t + b_5lnX_t^* + b_6lnm_{t-1} + \xi_{it};
\]

where \(a_4 = (1 - \gamma_1)\) and \(b_6 = (1 - \gamma_2)\); and \(\gamma_1\) and \(\gamma_2\) are the adjustment coefficients in the two equations. The a priori hypothesis (8) suggests that

\[a_1 < 0, a_2 > 0, \text{ and } a_3 > 0 \quad \text{in (9a)}\]

and

\[b_1 < 0, b_2 > 0, b_3 < 0, b_4 > 0, \text{ and } b_5 > 0 \quad \text{in (9b)}\].

Variable \(X^*\) depicts the scale of operation of the firm and can be measured by total assets, total output, or the level of sales of the firm. The model suggests using flow variables such as output or sales as the scale variable. Setting the problem of measuring \(X^*\) aside for the moment, we assume that the firm maintains a desired relation between its real cash balances and its expected level of output, \(X^*\). It forecasts expected output by a simple mechanism such as

\[
X^*_{t-1} = (X_t/X_{t-1})c_0(X_{t-1})^{(c_0-c_1)},
\]

where \(c_0\) and \(c_1\) are discount rates. From equation (9c) \(X^*_{t-1}\) can be interpreted as a trend extrapolation \(X_{t-1}\), with allowance for deviations from trend, \(X_t/X_{t-1}\). Substituting for \(X^*_{t-1}\) in equations (9a) and (9b) from equation (9c) and rearranging, we get the final forms of the estimating equations:

(a) restricted model,

\[
lnm_t = a_0 + a_1lnz_t + a_2ln(c/w)_t + a_3lnX_t + a_4lnm_{t-1} + \xi_{it};
\]

(b) unrestricted model,

\[
lnm_t = b_0 + b_1lnr_t + b_2dlnr_t + b_3dlnp_t + b_4ln(c/w)_t + b_5lnX_t + b_6lnm_{t-1} + \xi_{it}.
\]

where \(\xi_{it}\) and \(\xi_{2t}\) are random errors. \(c_0\) and \(c_1\) can be interpreted as the elasticities of real cash balances with respect to "permanent" and "transitory" output. They can easily be calculated from the

2. This interpretation critically depends on the assumption about the residuals of equations (10a) and (10b). Variables \(lnm_{t-1}\) and \(\xi_{it}\) or \(\xi_{2t}\) will generally be correlated in these equations if \(\xi_{it}\) or \(\xi_{2t}\) in equations (9a) and
regression coefficients of either equation. For example, the values of these parameters in equation (10b) are

\[ c_0 = (b_5 + b_6)/(1 - b_7) \quad \text{and} \quad c_1 = b_6/b_7. \]

In the long run, \( c_1 \) will tend to be zero and \( c_0 \) may take values greater, equal, or smaller than unity. The magnitude of \( c_0 \) depends largely on the methods of pooling small transactions together, such as using calculating machines, computers, etc., which allow for economies of scale in managing cash balances. In such a case, the income elasticity of real cash balances will be less than one.

IV. The Empirical Results

Both versions of the model are fitted to the quarterly time series data, described in the Appendix, for the total manufacturing sector. The sample period chosen is 1948-I to 1960-IV; the dynamic stability of the model is tested beyond the sample period of 1961-I to 1964-IV. The main empirical results are reported in Tables I and II; Table I pertains to the results of equations (10a) and (10b) and Table II displays the results for various forms of the unrestricted model. The long-run elasticities of real cash balances with respect to their determinants, and the average and variance of the adjustment lag of both versions of the equations, are presented in Table III. In Tables IV and V the results of a set of conceptual experiments are reported. These experiments consisted of (a) comparing the results of our model with "alternative" models of the demand function for money, and (b) examining the stability of a stepwise procedure to discern the contribution of each variable of the model.

The overall results of the model shown in Tables I and II are encouraging. The signs of all the coefficients of the model confirm the hypotheses suggested in (8). The coefficients are statistically significant and the goodness of fit of the model is satisfactory; the values of Durbin-Watson test statistics are around 1.85 for most of the equations.\(^3\) Note that the estimates of equations (10a) and (10b), shown in Table I, are generally similar. The fit and the co-

\( (9b) \) are serially correlated. Then the least squares estimates of equations (10a) and (10b) will be biased. For further discussion see P. Taubman, "Permanent and Transitory Income Effects," Review of Economics and Statistics, XLVII (Feb. 1965), 38-43.

efficient of \((c/w)_{t-2}\) for the two equations are the same; the restricted model shows a slightly lower income elasticity and has a higher coefficient of adjustment. The remaining discussion will be

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<th>Variables</th>
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* The figures in parentheses are the standard errors of the coefficients.

centered, however, around the unrestricted equation (10b), which provides direct evidence on the role of the interest rate, capital gains, and changes in the price level in the demand function for real cash balances.

### A. The Price Elasticities

The price variables relevant for decision-making are the expected future prices, which are generally not known; they have to be approximated from past data according to some expectation hypotheses. The expectation hypotheses used in this model are extremely simple; we use the current values of \(r, r'\) and \(p'\) to approximate their expected values. These hypotheses are theoretically very simple but the surprising fact is their empirical significance, as we shall observe later. Why these simple hypotheses work in
the face of the contrary evidence suggested by other writers is not easily answered and no attempt is made here to find an explanation.

The role of the interest rate as a determinant of the demand for money has been widely discussed and is a controversial issue in the literature. The controversy seems to center on (a) the magnitude of the interest elasticity of cash balances, and (b) whether the short or long term interest rate is the appropriate variable in the demand function for money. Friedman 4 considers the interest elasticity of money to be very low, while Brunner and Meltzer 5 think cash balances are approximately unitarily elastic. Laidler 6 favors the short term interest rate in his discussion of the demand function of money on the grounds that money is a close substitute for very short term securities and that the short term interest rate gives better empirical results. However, other studies indicate that the long term interest rate empirically performs better.

Whether the short or the long term interest rate is the appropriate variable in the demand for corporate real cash balances is difficult to decide on a priori grounds. Empirically, the long term rate performs somewhat better than the short term interest rate in various estimations of equations (10a) and (10b). The elasticity of real cash balances is generally higher with respect to the long term rate than the short term rate of interest (equation (10b), Table I, and equation (5), Table II). The capital gains term, \( dlnr_t \), when measured by the change in the short term rate of interest, is statistically insignificant. The slightly better performance of the long term rate can be rationalized in two ways: (a) the long term interest rate represents the systematic part of variations of the short term interest rate and therefore is a good proxy for the "theoretical" interest rate; (b) in the context of our cost minimization model, switching between cash and short term government securities does not mean that the short term rate is the most lucrative opportunity income foregone by holding cash. Holding short term government securities may involve some further opportunity costs as well. However, the question of the relevance of short or long term interest rates in the demand function for real cash balances cannot be resolved unequivocally from our results.

The interest rate variable, \( lnr_t \), has a negative coefficient and is

statistically significant at the 5 per cent level of confidence. The short term interest elasticity of real cash balances is about —.10 in the unrestricted version of the model. This is a pure interest rate effect and does not include the influences of capital gains (losses) and depreciation due to an increase in the general price level. The

<table>
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* The figures in parentheses are standard of the coefficients.
coefficient of \( v_t \) in the restricted form of the model is negative, statistically significant, and about .04. The comparable estimate of the opportunity cost of real cash balances derived from equation (10b) is about \(-.034\). These two estimates of the own elasticity of real cash balances are not substantially different. The long-run interest elasticities of real cash balances with respect to \( r \) and \( v \) are very close, approximately \(-.14 \) and \(-.17 \), respectively. These results are in contrast to the Friedman and Brunner and Meltzer hypothesis discussed earlier.\(^7\) Note, also, that the "pure" interest elasticity of real cash balances is greater than their cross-elasticity with respect to \( c/u \), supporting Tobin's contention that substitution between liquid assets is greater than between money and physical inputs.\(^9\) However, if we allow for effects of capital gains (\( dlnr_t \)) and price changes (\( dlnp_t \)) and compare the own- and cross-elasticities of real cash balances, that conclusion is reversed.

The expected capital gains (losses) variable, \( dlnr_t \), in equation (10b), has the a priori positive and statistically significant coefficient. It suggests that the anticipation of a rise in interest rates may lead firms to shift from securities to cash. As a borrower, the firm may attempt to borrow now in anticipation of higher future costs.\(^1\) The short-run elasticity of real cash balances with respect to \( dlnr_t \) is positive and approximately equal to their interest elasticity.\(^2\) The empirical results of the model are sensitive to the presence of this variable in the regression equation; the speed of adjustment, the fit, and the coefficients of the output variables are sensitive to the presence of \( dlnr_t \) in the regression equation.

Expectations about changes in the general price level influence real cash balances through changes in the purchasing power of

\(^{7}\) The opportunity cost of \( m \) from equation (10b) is calculated by \( [b_1 - b_2 - b_3 \cdot p^*] \) where \( p^* \) is the mean value of \( (p_t - p_{t-1})/p_{t-1} \) for the sample period. Multiplication of \( b_3 \) by \( p^* \) is necessary since the price variable is measured in index terms. The value of \( p^* \) for the period 1948-I to 1960-IV is .023.


\(^{9}\) Tobin, "The Interest-Elasticity of Transactions Demand for Cash," op. cit.
money. There have been several studies attempting to detect empirically the role of price changes on real cash balances. However, most of them are confined to hyper-inflationary periods and little is known about the effect of price changes on money holdings during periods of slowly rising prices. The main difficulty has been the absence of an adequate price expectation hypothesis. Our simple price expectation hypothesis noted earlier performs very well; it has a negative and statistically significant coefficient at the 5 per cent level of confidence. However, the statistical significance of the coefficient of this variable is affected by the choice of the scale variable (equations (1) through (5) Table II). When $dlnp_{t-1}$ is used instead of or in conjunction with $dlnp_t$ in equation (10b), the empirical results do not change much. The short- and long-run price elasticities of real cash balances in the total manufacturing sector, calculated from estimates of Table I, are about $-0.0309$ and $-0.094$, respectively, during the period 1948 to 1960.

The performance of the expected relative factor price variable is interesting. This variable is approximated by actual factor prices lagged two quarters, i.e., $(c/w)_{t-2}$ is a proxy of future relative factor prices. The choice of a two-period lag for this variable is arbitrary; the results do not change when $(c/w)_t$ or $(c/w)_{t-1}$ is used in the regressions. The coefficients of $(c/w)_{t-2}$ is positive, statistically significant, and takes values of 0.055 to 0.065. It suggests that real cash balances are substitutes for capital or labor in the asset structure of the firm. When the user cost of capital $(c/p)_{t-2}$, and the user cost of labor services, $(w/p)_{t-2}$, were used separately, both variables had positive and statistically significant coefficients (equation (5), Table II). These findings support the hypothesis put forward by Tobin and Sidrauskis that diversion of funds to cash balances reduces investable funds for new investment and thus may affect the capital-intensity of the firm.

B. Income Elasticity of Real Cash Balances

Two issues which have received considerable attention in the literature are whether income or wealth is the proper constraint on real cash balances of the economic unit and the proper measurement

4. See fn. 7, p. 183. The long-run price elasticity of $m$ is calculated by $[\beta_1 + \beta_2 + \beta_3 \cdot p^*/(1 - \beta_2)]$ in equation (10b).
of these constraints. In the context of our model the theoretically relevant variable is a measure of output. However, to ascertain, at least empirically, the "relevant" scale variable, several proxies for wealth and output are used for the scale parameter in establishing equations (10a) and (10b). Two measures of deflated total assets, excluding real cash balances, are used as proxies for the wealth variable. The first measure is total assets of the industry deflated by the GNP price deflator and the second measure is a synthetic measure of total assets, \( T^* \), allowing for the price variations of specific assets. Three measures of output are used in the preliminary stages of the investigation. They are deflated sales \( (X_t) \), deflated actual output \( (X_{ot}) \), and deflated capacity output \( (X_c) \). \( X_c \) is derived from \( X_c = X_{ot}/s \), where \( s \) is the rate of capacity utilization.

### TABLE III

**The Long-Run Income and Price Elasticities of Real Cash Balances in the Total Manufacturing Sector, 1948-I to 1960-IV**

<table>
<thead>
<tr>
<th>Equations</th>
<th>Estimated Parameters *</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( 1/\rho' )</td>
</tr>
<tr>
<td>6</td>
<td>.3852</td>
</tr>
<tr>
<td>7</td>
<td>.4460</td>
</tr>
</tbody>
</table>

*The long-run income elasticity of real cash balances, \( 1/\rho' \), is measured by \( c_o = (a_o + a_c)/(1 - a_o) \) from equation (10a) and by \( c_o = (b_o + b_c)/(1 - b_o) \) from equation (10b). The parameters of the price variables are measured by dividing their corresponding coefficients in Table I by \( (1 - a_o) \) or \( (1 - b_o) \). \( E \theta \) and \( V \theta \) are the average and variance of the adjustment lag and are measured as \( E \theta = \gamma'/(1 - \gamma') \) and \( V \theta = \gamma'/(1 - \gamma')^2 \), where \( \gamma' \) is the coefficient of the lagged dependent variable in equations (10a) or (10b).

As can be seen from Table II, the coefficients of the scale variables \( T \) and \( T^* \) are not statistically different from the sum of the coefficients of \( X_t \) and \( X_{t-1} \) in Table I. They imply similar values for \( c_o \). However, the coefficients of \( dlnr_t \), \( dlnp_t \), and to a lesser extent \( lnm_{t-1} \) are sensitive to the choice of the scale variable. Using \( X_c \) as a measure of the scale variable reduces the price elasticity of real cash balances and affects the adjustment coefficient of the model. The long-run income elasticity of real cash balances \( c_0 \) \([= (b_5 + b_6)/(1 - b_7)\) where \( b_5, b_6, \) and \( b_7 \) are, respectively, the coefficients of current and lagged \( X_t \) and \( lnm_{t-1} \) in equation (10b)] is about .44. The transitory income elasticity of real cash balances \( c_1 (= b_6/b_7) \) is approximately .29 and the short-run income elasticity of real cash balances, \( (b_5 + b_6) \), as distinct from \( c_1 \), is about .14.
The important point to note is that no matter which measure of the scale factor is used the evidence provided implies economies of scale with respect to cash holding of about 2.5. Despite the aggregation problems, the income elasticities of real cash balances are consistently less than unity. This finding supports the theoretical propositions of Baumol, Miller and Orr, and Tobin and contradicts Friedman's high income elasticity and Brunner and Meltzer's unitary income elasticity hypotheses of real cash balances with respect to the scale variables of income or wealth. The question of why our results are so at variance with the findings of other writers and with evidence from the cross-section data is left open at present. The nature of the data and the specification of our model may be responsible for the difference in the results. However, the question needs further exploration.

V. THE ADJUSTMENT PROPERTIES AND FORECASTING PERFORMANCE OF THE MODEL

A. The Adjustment Process

The coefficient of $\ln m_{t-1}$ is about .75 in equation (10a) and approximately .68 in equation (10b). The speeds of adjustment implied by these values are much faster than those reported by de Leeuw. The adjustment paths implied by the equations take the forms:

\begin{table}
<table>
<thead>
<tr>
<th>Equations</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>\ldots</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>(10a)</td>
<td>.2438</td>
<td>.1844</td>
<td>.1394</td>
<td>.1054</td>
<td>.0798</td>
<td>.0603</td>
<td>.0456</td>
<td>.0344</td>
<td>\ldots</td>
<td>.0035</td>
</tr>
<tr>
<td>(10b)</td>
<td>.3276</td>
<td>.2203</td>
<td>.1481</td>
<td>.0996</td>
<td>.0669</td>
<td>.0450</td>
<td>.0303</td>
<td>.0204</td>
<td>\ldots</td>
<td>.0000</td>
</tr>
</tbody>
</table>
\end{table}

It seems that about 70 to 80 per cent of the adjustment, of actual to desired real cash balances, is completed within one year. The

3. It is not obvious from our results whether the economies of scale are due to the expansion of the scale of the existing firms or the entry of new firms in the manufacturing sector. To ascertain the "true" economies of scale we should not out the effect of entry. However, our data do not allow such a distinction and thus our interpretation of economies of scale with respect to real cash balances is tentative.
mean adjustment lag for real cash balances is about 2 to 3 quarters and the variance of this lag is about 6 to 10 quarters (see Table III). These results are in contrast to the average adjustment lag of 2½ years with a variance of 22 years reported by de Leeuw. It is difficult to accept de Leeuw’s long adjustment hypothesis. It is improbable that a highly liquid asset like real cash balances should adjust more slowly to its desired level than a relatively fixed asset like plant and equipment. Our results, which are close to the recent findings reported by Feige, seem more consistent with the a priori notion about adjustment of liquid assets.

When \( \ln m_{t-1} \) was omitted from the regression equation, the goodness of fit of the model declined and the serial correlation of the model increased (equation 6, Table II). However, the independent variables of the model still explain about 80 per cent of the variance of real cash balances and the coefficients of these variables retain their expected signs, are statistically significant at the 5 per cent level of confidence, and take, approximately, their long-run values.

B. The Forecasting Performance

The predictive performance of the model is tested by using regression equation (10b) to forecast the level and turning points of real cash balances of the total manufacturing sector for the period 1961-I to 1964-IV. The forecast errors are:

<table>
<thead>
<tr>
<th></th>
<th>1961</th>
<th></th>
<th>1962</th>
<th></th>
<th>1963</th>
<th></th>
</tr>
</thead>
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<tr>
<td></td>
<td>I</td>
<td>II</td>
<td>III</td>
<td>IV</td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td></td>
<td>.0185</td>
<td>.032</td>
<td>.043</td>
<td>-.062</td>
<td>.058</td>
<td>.015</td>
</tr>
</tbody>
</table>

5. "A Model of Financial Behavior," op. cit. The adjustment coefficient which gives the best result in de Leeuw’s model has a value of \((k = .1)\) where \((1 - k)\) is the coefficient of the lagged dependent variable. This implies a very long lag with a 43 per cent completion of the desired money balance after two years time.

H. Johnson, "Comments on the de Leeuw Findings on Demand for Money," in G. Horwich (ed.), Monetary Process and Policy (Homewood, Ill.: Irwin, 1967), 368-70, surprisingly accepts the long lag hypothesis and suggests a rationale for de Leeuw’s findings. He suggests that (i) the cost of acquiring and acting on information about future economic conditions, (ii) a long lag between desired money balances and the variables determining desired balances, and (iii) the differential adjustment lag of the independent variables, e.g., interest rate and output, lead to the emergence of a long lag between the actual and desired cash balances. This may be the correct rationale but what is interesting is that Johnson’s own finding suggests an average lag of two quarters between actual and desired cash balances, which is quite different from de Leeuw’s approximately 2½ year average lag. It is not clear why Professor Johnson accepted de Leeuw’s long lag hypothesis to begin with.

Part of the difference between our findings and those of de Leeuw could be due to the nature of the data used in the studies. His study uses data for cash balances of the whole private sector. Nevertheless, his results of the speed of adjustment seem quite unreasonable.

The sign and the size of the errors fluctuate greatly and the model seems to overstate in 1961 and 1962 and underestimate in 1963 and 1964 the level of real cash balances. However, the mean, absolute mean, and mean square of the forecast errors are not very large. The model does very well in calling the turning points. The turning point test is defined as $P_t - A_{t-1} = \text{sign} \left( A_t - A_{t-1} \right)$ where $P_t$ and $A_t$ are the predicted and actual values of real cash balances. Out of four actual turning points the model predicted accurately three and erroneously called a turning point for the period 1964-III and 1964-IV.

VI. Conceptual Experiments

A. Intertemporal Stability

To examine the intertemporal stability of the model, a test for structural change was made by fitting the model to the entire period 1948-I to 1964-IV and the subperiods 1948-I to 1960-IV and 1961-I to 1964-IV. The appropriate test is

$$F = \frac{(S_1 - S_2)/k}{S_2/(n + z - 2k)},$$

where $S_1$ and $S_2$ are respectively, the sum square residuals of the regression for the whole period and for the combined subperiods, $k$ is the number of parameters, $n$ is the number of observations for the sample period (1948-I to 1960-IV), and $z$ is the number of observations outside the sample (1961-I to 1964-IV). This test is most powerful among invariant tests with the same level of Type I error. The calculated and critical values of this test for equation (10b) are 4.252 and 2.71. They suggest rejecting the null hypothesis of no structural change during the period 1948-I to 1964-IV.

B. Comparison with “Alternative” and Autoregressive Models

A set of alternative demand functions suggested by Brunner and Meltzer,8 de Leeuw,9 and Teigen 1 were chosen as a standard

<table>
<thead>
<tr>
<th>Equations</th>
<th></th>
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<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Brunner-Meltzer (A - 1)</td>
<td>log ( (M/p) _t = -1.48 - 0.949 \log E _t + 1.11 \log (W/p) _t )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(.0436)</td>
<td>(.0261)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>de Leeuw (A - 2)</td>
<td>( d_t = 96.4 - 11.989r_t + 0.002 (W/p) _t + 0.024 (Y - Y) _t + 0.907d_{t-1} )</td>
<td></td>
<td></td>
<td></td>
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<tr>
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<td>(1.7561)</td>
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<td>(.0070)</td>
<td>(3.488)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teigen (A - 3)</td>
<td>log ( (M/p) _t = .5512 - .0200 \log r^* _t + .1481 \log Y _t + .7182 \log (M/p) _{t-1} )</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>(.0072)</td>
<td>(.0355)</td>
<td>(.0732)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### PANEL A

**R²** = .992  
**D/W** = not given

### PANEL B: PERIOD OF FIT: 1948-I to 1960-IV

#### B-1

\[ lnm_1 = -2.2337 - 0.6424 lnr_1 + 2.877 \ln T, \]

#### B-2

\[ lnm_1 = -0.3442 - 0.0244 lnr_1 + 0.0753 \ln T_1 - 0.0504 \ln (X/X) \_1 + 0.8541 lnm_{1-1} \]

#### B-3

\[ lnm_1 = -0.28409 - 0.0229 lnr^*_1 + 0.0076 lnX_1 + .8871 lnm_{1-1} \]

#### B-4

\[ lnm_1 = .2123 + .8855 lnm_{1-1} + .0109 lnm_{1-2} - .0500 lnm_{1-3} + .0796 lnm_{1-4} \]

**R²** = .6485  
**D/W** = .812

**R²** = .846  
**D/W** = 1.935

**R²** = .866  
**D/W** = 2.625

**R²** = .8515  
**D/W** = 1.740

---

*The figures in parentheses are the standard errors of the coefficients.

a. The variables of these equations are defined as:

- \( M \) = Stock of money exclusive of time deposits;
- \( p \) = GNP price deflator;
- \( W \) = wealth;
- \( Y \) = real income;
- \( Y_t \) = mean deflated sales;
- \( E \) = long term quarterly interest rate;
- \( r^* \) = short term quarterly interest rate;
- \( X \) = mean deflated output.

b. Brunner and Meltzer use yearly time series data for the period 1900 to 1953.
c. de Leeuw fits his model to quarterly data for the period 1948-I to 1964-IV period data.
d. Teigen has fitted his model to seasonally unadjusted quarterly time series data for the period 1948-I to 1963-IV. The values of the coefficients of the seasonal dummies reported by Teigen, *op. cit.*, are not produced here.
of comparison. The functional form of their equations was fitted to our sample data. In Panel A of Table IV the estimates reported by these writers are presented while in Panel B of this table our own results for these equations are given. The estimates in Panels A and B vary significantly. They suggest: (a) the interest and income (wealth) elasticities of real cash balances of the manufacturing sector vary significantly from those of the aggregate economy; (b) certain explanatory variables of equations (A-1), (A-2), and (A-3) would be irrelevant in explaining the behavior of real cash balances in the corporate sector; and (c) on statistical ground our model seems to perform better than these equations, in estimating quarterly real cash balances of the manufacturing sector. These observations imply that aggregated demand functions for real cash balances are subject to a considerable aggregation bias.

Another test of the model is to compare its performance with those of an autoregressive model of the form:

\[
\ln m_t = a_0 + a_1 \ln m_{t-1} + a_2 \ln m_{t-2} + a_3 \ln m_{t-3} + a_4 \ln m_{t-4}.
\]

This comparison is a stringent test of a quarterly model and includes the familiar naive models as special cases. As can be seen from equation (B-4) of Table IV the statistical fit of our model is slightly better than that of (11), but our model performs much better than the usual naive models.

C. Decomposition of the Model

A stringent test of the model is to decompose equation (10b) into its various components by starting from a regression of \( m_t \) on the level of output and then adding other variables and re-estimating the equation. The variables are chosen not on the basis of results of a stepwise regression program but on the frequency of their use in the liquidity functions reported in the literature.

The results are reported in Table V. Variable \( \ln m_{t-1} \) is included in each equation on the assumption that the actual cash balance always adjusts to its desired level, with a time lag. The output variable, \( \ln X_t \), has a negative coefficient when it enters the regression equation alone; when the interest rate is included the coefficients of both variables have the right signs but they are not statistically significant. Introducing \( \ln X_{t-1} \) improves the performance of other explanatory variables but the crucial breakthrough comes when \( dln p \) is included in the regression equation; the coefficients of all the variables introduced thus far become significant
<table>
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<tr>
<th>Equations</th>
<th>Intercept</th>
<th>Coefficients</th>
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<th>$S_y$</th>
<th>D/W</th>
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</thead>
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<td>$lnX_{t-1}$</td>
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<td>-.2506</td>
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<td>(.1064)</td>
<td>(.6065)</td>
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<td>(.0493)</td>
<td>(.1236)</td>
<td>(.1067)</td>
<td>(.5607)</td>
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</tbody>
</table>

* The figures in parentheses are the standard errors of the coefficients.
at the 5 per cent probability levels and the speed of adjustment of the model is increased. Inclusion of $dlnr_t$ improves the performance of the equation still further. When the relative prices are introduced in the equation, it has a significant coefficient and adds substantially to the explanatory power of the model. With the introduction of every variable the goodness of fit of the equation improves and the speed and adjustment of actual to desired cash balances increases. This experiment suggests that three unique variables of our model, $dlnr_t$, $dlnP_t$, and $ln(c/w)_{t-2}$, are of importance in explaining the real cash holdings of the manufacturing sector; their omission would substantially bias the results.

**VII. Conclusions**

The primary purpose of this study was to develop a theory of demand for cash balances of the business sector and to estimate it, using the quarterly data for the U.S. total manufacturing sector in the postwar period. The following tentative conclusions seem to follow from this analysis:

1. It seems that the level of the long term interest rate and the change in the interest rate are significant determinants of real cash holdings of the manufacturing sector. The former variable depicts the influence of average return on financial assets and the latter serves as an exceptional variable representing expected capital gains. However, the question of whether the short or long term interest rate is a better proxy of the "relevant" interest rate in the demand function requires further investigation for real cash balances.

2. Our results indicate substantial economies of scale with respect to holding real cash balances. This result does not depend on the choice of the measure of the scale variable of the model.

3. It seems that real cash balances are sensitive to movements of factor prices. The cross-elasticity of real cash balances seems to be lower than their elasticity with respect to the opportunity cost of money.

4. Real cash balances of the manufacturing sector are sensitive to changes in the general price level. Their price elasticity seems to be about .029 in the short run and about .09 in the long run.

5. The adjustment of actual real cash balances to their de-
sired level seems to be very rapid and in contrast to some of the findings reported in the literature.

(6) The model seems to pass the various tests of intertemporal stability and adequately forecasts the level and turning point of real cash balances beyond the sample period.

**Statistical Appendix**

**The Nature of the Data and Specification of the Variables**

The liquidity preference functions specified by equations (10a) and (10b) were fitted to quarterly data for the total manufacturing sector for the period 1948-I to 1964-IV. The main sources of data were the various issues of the FTC-SEC *Quarterly Financial Report* and the *Economic Report of the President*. The *Quarterly Financial Report* data were adjusted for sample changes. The data are not seasonally adjusted, but dummy variables are introduced in the regression equations to account for the effects of seasonal variation. The variables used in the regression equations are measured as follows:

\[ m_t = \text{the quarterly cash holdings of each industry deflated by the quarterly GNP deflator, published in the August 1965 issue of the Survey of Current Business (SCB)}; \]

\[ T_t = \text{quarterly total assets deflated by GNP deflator}; \]

\[ T_t^* = \text{quarterly adjusted wealth variable}; \]


5. Assume that there are \( N \) assets on the balance sheet of the firm. They are labeled as follows:

\[ G_t = \text{assets which are liquid in character but subject to price fluctuations such as inventories; suppose there are } n \text{ such assets on the firm's balance sheet}; \]

\[ H_t = \text{assets which are of a long term nature, e.g., plant and equipment; these assets are subject to price changes, depreciation, etc.; let the number of this type of assets be } m; \]

\[ I_t = \text{assets which are highly liquid and could easily be exchanged for cash, e.g., short term securities and receivables; the value of these assets is relatively fixed in nominal terms; thus, there is no need to adjust them for their "own" price changes; assume there are } l \text{ assets of this kind.} \]

Then, we may write:

\[ T^* = \left[ \sum_{i=1}^{n} (1 + p_t^{i''}/p_t^*) G_i + \sum_{i=1}^{m} (1 + p_t^{i''}/p_t^*) H_i + \sum_{i=1}^{l} i \right] / P, \]

where \( p_t^{i''} \) is the change in the wholesale price index, \( p_t^* \) is the wholesale
THE DETERMINANTS OF REAL CASH BALANCES 195

\( X_{ot} = \) quarterly deflated output defined as the sum of sales plus changes in inventories;

\( X_{ot}^{s} = \) the quarterly deflated capacity output defined as \( X_{ot}/s^{t} \)

where \( s^{t} \) is the rate of utilization;

\( X_{t} = \) quarterly sales deflated by the quarterly GNP price deflator;

\( r_{s} = \) the quarterly short term rate of interest on government bonds from various issues of the Federal Reserve Bulletin;\(^6\)

\( r^{s} = \) the quarterly short term rate of interest on government bonds from various issues of the Federal Reserve Bulletin;

\( v = \) the opportunity cost of real cash balance \( (v = r - r^{s} + p^{d}/p) \);

\( p = \) the GNP deflator from the SCB; \( p^{d} = dp/dt \).

\( (c/p)_{t} = \) the user cost or rental of capital, \( c, \) defined as \( c = q/(1 - \mu) [1 - \mu v^{d}] d + (1 - \mu r) d + s^{0} s \]. The data for constructing \( c \) are chiefly from the SCB and Statistics of Income.\(^7\) The income tax rate, \( \mu, \) is the ratio of corporate tax payments to gross corporate profits. The proportion of current replacement cost allowable for tax purposes, \( v^{d}, \) is the ratio of tax depreciation to replacement in constant prices. A better measure of \( v^{d} \) has been recently constructed by Hall and Jorgenson,\(^8\) which takes into account changes in depreciation rules. We unfortunately had no access to these data and consequently our measure of \( v^{d} \) is somewhat biased. The cost of capital, \( d, \) is computed by using the earnings-price ratio and the rate of interest on government bonds. The proportion of the total cost of capital allowable for tax purposes, \( r, \) is the ratio of net monetary interest to total cost of capital. The rate of utilization, \( s, \) is described below. \( s^{0} \) is the rate of depreciation due to use and set to a value of .02 based on findings by the author.\(^9\)

\( (w/p)_{t} = \) the BLS quarterly user cost of labor services deflated by the index of GNP price deflator; \( w = w_{1}(1 + \beta(r + g)/H); \beta \) is the fixity factor set to .075 (this value is suggested by Oi \(^1\)); \( g \) is the quit rate as a proxy of departure of the labor force.

Price index, \( p^{w} \) is the change in the index of the capital stock deflator, \( p^{w}, \) is the index of the price of capital and is the GNP price deflator (1958 = 100). This method of adjustment has the advantage of explicitness taking into account the relative price changes of the specific assets which have different characteristics.

6. Federal Reserve Board of Governors, Washington, D.C.
$s_t = \text{a four-quarter moving average of capacity utilization index constructed by dividing the Federal Reserve Industrial Production series by the McGraw-Hill quarterly capacity index based on the question, "How much did capacity increase?" The McGraw-Hill capacity index was interpolated using quarterly investment series as weights. This capacity index is quite similar to the FRB capacity utilization rate.}$

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