



# Differential cash constraints, financial leverage and the demand for money: Evidence from a complete panel of Taiwanese firms

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## Abstract

This paper studies firms' demand for money by developing a differential-cash-constraint framework with firms' entire wage bills requiring cash in advance and a fraction of investment purchases being financed by credits. In addition to conventional scale and opportunity-cost factors, firms' financial status and profitability are crucial determinants for their money demand behavior. Employing a new data set consisting of a panel of Taiwanese firms over 1990–97, our econometric analysis lends empirical support to our theory. The estimates suggest that economies of scale in firms' cash management are present and that lower financial leverage or higher profitability raises money demand significantly.

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## 1. Introduction

Theoretical and empirical studies on money demand have been at the center of the stage of monetary economics. Such issues are not only important for understanding the relationships between money, inflation and growth, but also crucial for conducting monetary policy and evaluating its welfare implications. While there is a large body of research on household demand for money, the literature examining money demand by firms is rather thin. Our paper contributes to the latter literature both theoretically and empirically. Specifically, we develop a generalized differential cash constraint model by taking an explicit account of firms' financial status. We then perform a systematic empirical test of the validity of our theory using a newly available panel data set of reliable quality.

Four decades ago, Miller and Orr (1966) extend the Alais–Baumol–Tobin inventory model to study firms' demand for money under uncertainty, suggesting the presence of economies of scale as money serves as a medium of exchange for firm transactions. Although the property of scale economies is empirically supported by Selden (1961) and Frazer (1964), Meltzer (1963) uses cross-section data and finds that the sales elasticity of money demand by firms is very close to unity, thereby implying the absence of economies of scale.<sup>1</sup> Since then, Whalen (1965), Vogel and Maddala (1967), and Falls and Natke (1988) have revisited this issue. By considering the portfolio choice aspect, their cross-sectional analyses reconfirm Selden's finding. Whalen and Vogel and Maddala suggest a tendency for cash economization when they incorporate assets as well as transactions into the demand function, obtaining estimates of the sales elasticities ranging from 0.86 to 1.08 (with only four industries below unity). Falls and Natke find that the sales elasticity of liquid assets of Brazilian manufacturing firms is about 0.9 after controlling for foreign ownership, industry structure, and macroeconomic variables. Thus, a general conclusion drawn from this later literature is that the economies of scale in cash management are essentially negligible. More recently, Mulligan (1997) re-estimates firm's money demand based on the value of time approach developed by Karni (1973) and Bomberger (1993), by constructing a pseudo panel data set from COMPUSTAT, which is clearly superior to the conventionally used cross-sectional data. In particular, Mulligan uses the wage rate to measure the cash manager's value of time and finds that an increase in the value of time results in higher money demand. His estimates of sales elasticities around 0.83 suggest moderate economies of scale of money in facilitating firm transactions. Bover and Watson (2005) correct measurement errors, accounting for firm unobserved effects that are correlated with sales. They find economies of scale in cash management in the US, but not in the UK or Spain.

Our paper contributes to the literature in two important aspects. First, we construct an intertemporal model of money demand by firms, in contrast to the conventional inventory or value of time approach.<sup>2</sup> The central feature of the theory developed here is the consid-

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<sup>1</sup> The cross-section studies by Selden (1961), Frazer (1964), and De Alessi (1966) are based upon the asset approach in which the wealth of the firm is viewed as a constraint on its money holdings. Selden relates the velocity of money to the assets of the firms, Frazer (1964) examines the percentage of cash to liquid assets as a fraction of the total assets of firms, and De Alessi examines the relationship between the cash holdings of British firms and the value of their common stock. While Selden and Frazer suggest the presence of sale economies in the holding of money, De Alessi finds little evidence of economies of scale in cash holdings.

<sup>2</sup> For a survey of dynamic models of money from an integrated household-firm unit, the reader is referred to Dornbusch and Frenkel (1973) and Wang and Yip (1992).

eration of differential cash constraints in which firms' entire wage bills require cash in advance whereas a nontrivial fraction of investment purchases can be financed by credits. This framework is not only simplistic to permit analytic solution for the money demand function, but also realistic to capture different cash requirements for different types of firms' purchases. An infinitely lived firm owner optimizes over labor, capital investment, asset holdings and real cash balances. In steady-state equilibrium, a firm's demand for money depends crucially on its wage bills and investment purchases, as well as on the nominal interest rate and an array of profitability and financial variables that may influence labor employment and the endogenous differential cash constraint factor.

Second, we perform empirical analyses based on a new data set that contains 345 Taiwanese companies of various sizes and industrial categories over the period of 1990–97. Although the data at the firm level are much smaller in sample size than the COMPUSTAT data, we are able to construct a complete panel from the original source particularly suitable for the purpose of our study. Our empirical work based on the generalized differential cash constraint theory can be thought of as a complement to the conventional inventory and the value of time models. While a firm's demand for money is increasing in wage bills and investment purchases, the coefficient estimates for wage bills far exceed those for investment purchases, justifying our differential cash constraint hypothesis. Moreover, the results lend support to the presence of economies of scale for firms' transactions use of money and indicate that lower financial leverage or higher firm profitability tends to induce greater money demand. The overall scale elasticity is in the range of 0.58–0.68, implying significant scale economies in firms' cash management. The interest rate elasticity is higher than the conventional estimates, falling between 0.70 and 0.98 (in absolute value). While the financial leverage is a consistently powerful explanatory variable for both the fixed-effects model and the instrumental variable method, turnover rates and term and risk premia have statistically significant effects in some specifications. These findings are robust to an alternative two-step estimation and to deletion of extreme sales values.

The remainder of the paper is organized as follows. Section 2 develops an intertemporal model of a representative firm owner facing a differential cash constraint that enables us to characterize the property of money demand in steady-state equilibrium. While Section 3 describes the data and the empirical methodology, Section 4 presents the panel data estimation using the fixed-effects model as well as the instrumental variable method. Finally, we conclude the paper and acknowledge the limitations of our study in Section 5.

## 2. The model

In this section, we provide an illustrative model to guide our empirical work on firms' demand for money. The main purpose is to emphasize firms' cash requirements may depend on the nature of the payments (wage vs. investment bills) and the underlying financial environment. To simplify the analysis, the model is stylized: it focuses on firms' behavior by assuming a well-functioned financial market with passive banking in a partial equilibrium framework.

Time is continuous. Consider a representative firm with an owner, utilizing labor ( $L$ ) and physical capital ( $K$ ) to produce a good  $Y$ . The production function of the firm is assumed strictly increasing and strictly concave in each of the inputs,  $K$  and  $L$ , satisfying the constant-returns-to-scale property and the Inada conditions. It can thus be specified as:  $Y = Y(K, L) = Ly(k)$ , where the output per unit labor functions,  $y$ , is strictly increasing

and strictly concave in the capital-labor ratio,  $k$ . Moreover, the firm owner is a residual claimer who consumes an amount of that good  $Q$  to receive utility of  $V(Q)$  at a particular point in time.<sup>3</sup> The instantaneous utility of the firm owner is strictly increasing and strictly concave in  $Q$ , satisfying the Inada conditions. Time index  $t$  is omitted whenever it does not cause any confusion.

There are three investment alternatives: the interest-bearing asset ( $A$ ), the capital good (PK) and non-interest-bearing real money balances ( $M$ ), where  $P$  is the relative price of the capital goods in unit of the output product. Thus, the three evolution equations are:

$$\dot{A} = [Y(K, L) - WL - PI] + RA - Q - Z \quad (1)$$

$$\dot{K} = I - \delta K \quad (2)$$

$$\dot{M} = Z - \pi M \quad (3)$$

where  $I$  and  $Z$  are, respectively, the flow investment in machine/equipment and real money balances,  $Q$  is the consumption by the owner of firm,  $W$  and  $R$  are, respectively, the real wage rate and real interest rate,  $\delta$  is the rate of depreciation of physical capital,  $\pi$  is the inflation rate. While (2) and (3) are obvious, (1) implies that the asset incremental is governed by the flow profit (in squared bracket) plus interest earnings net of firm owner consumption and incremental money holdings.

We follow in the spirit of the household demand for money model developed by Wang and Yip (1992), generalizing the Stockman (1981) cash-in-advance constraint to:

$$WL + \phi PI \leq M \quad (4)$$

where  $\phi \in [0, 1]$ . Importantly, when  $\phi = 0$ , only wage bills require cash payments; when  $\phi = 1$ , all investment good purchases require cash in advance.<sup>4</sup> The cash-in-advance setup highlights the transactions use of money by firms. In general, one may anticipate that only a fraction of investment good purchases is subject to the cash-in-advance constraint, as observed in reality. Thus,  $1 - \phi$  measures the fraction of credit goods, which is positively related to the leverage ratio (debt/equity) facing the firm. That is, the higher the financial leverage ratio is, the more accessible a firm will be able to undertake external financing and the more effective a firm will be able to manage cash flows, thus leading to less cash demand for facilitating transactions.<sup>5</sup> Because money has no intrinsic value and the firm owner utility function obeys nonsatiation, optimization implies this above cash-in-advance constraint must hold at equality in equilibrium.

<sup>3</sup> The residual claimer setup follows Diamond and Yellin (1990). Under a constant-returns-to-scale production technology, the structure yields comparative-static results consistent with those under the profit maximization framework.

<sup>4</sup> In the household demand for money literature, Stockman (1981) assumes both consumption and investment purchases requires cash in advance ( $\phi = 1$ ) whereas Wang and Yip (1992) allows a fraction of investment spending to be financed by credits ( $0 < \phi < 1$ ). As pointed out by Wang and Yip (1992) and Laing et al. (2005), the cash-in-advance setup, under plausible conditions, yields comparative-static predictions generally consistent with the money-in-the-production-function, the money-in-the-utility-function, the transactions-cost, and the search-theoretic approaches.

<sup>5</sup> Theoretically, high leverage ratios in previous years may cause firms credit constrained in the short run. Such firms may therefore hold greater cash balances to self-finance current operations or in anticipation of paying-off their high debt load. Empirically, however, we find that lagged leverage ratios are statistically insignificant, indicating that this alternative effect is not strong to overcome the credit-market accessibility effect.

The problem of this representative firm owner is therefore specified as:

$$\begin{aligned} \max_{Q,I,Z,L} \Omega &= \int_0^\infty V(Q) e^{-\int_0^t \gamma(\tau) d\tau} dt \\ \text{s.t. (1)–(4); } i &\geq 0 \quad (i = Q, I, Z, L); \quad A(0) = A_0 > 0, \\ &K(0) = K_0 > 0 \quad \text{and} \quad M(0) = M_0 > 0 \end{aligned}$$

where  $\gamma \in (0, \infty)$  is the subjective rate of discount of the firm.

Since our primary concern is with money demand by firms, we will regard the relative price and real wage rate as exogenously given. The only price variables to be determined in the model are therefore the inflation rate and the real interest rate. To close the model, we need to specify the money supply process, money market equilibrium and the asset portfolio possibility frontier pinned down by the loanable funds market. Money supply injected in the firm sector is assumed to grow at a constant rate  $\mu > 0$  and thus money market equilibrium implies:

$$\frac{\dot{M}}{M} = \mu - \pi \tag{5}$$

The asset portfolio possibility frontier is simply given by a linear transformation schedule:

$$A = \Psi PK \tag{6}$$

where  $\Psi > 0$  measures the ability to accumulate interest-bearing financial assets, depending positively on the profitability of the operation of the firm.

Denote  $\lambda$ ,  $\alpha$  and  $\beta$  as the co-state variables associated with the state variables  $A$ ,  $K$  and  $M$ , respectively, and  $\eta$  is the Lagrangian multiplier associated with the cash-in-advance constraint. Manipulating the associated necessary conditions and Euler equations for the optimization problem facing the representative firm owner (see the [Appendix](#)), we can obtain the following intertemporal pricing relationships:

$$\frac{\dot{\alpha}}{\alpha} = (\gamma + \delta) - \frac{V_Q}{p[1 + \phi(Y_L/W - 1)V_Q]} \tag{7a}$$

$$\frac{\dot{\beta}}{\beta} = (\gamma + \phi) - \left(\frac{Y_L}{W} - 1\right) \tag{7b}$$

Therefore, the rates of change of both the shadow cost of capital ( $\alpha$ ) and the shadow cost of money ( $\beta$ ) are increasing in the severity of cash requirement ( $\phi$ ). This provides a channel through which money complements capital, which is a consequence of the cash-in-advance setup. While the rate of change of the shadow cost of money is decreasing in the relative labor productivity, the rate of change of the shadow cost of capital is increasing in the relative labor productivity and decreasing in the firm's marginal valuation of output.

In the steady state, all variables are constant. Thus, we can obtain a set of relationships governing steady-state quantities and prices (see the [Appendix](#)). Particularly, we can pin down the real interest rate and the inflation rate, respectively, by the subjective discount rate and the money growth rate:

$$R = \gamma \tag{8a}$$

$$\pi = \mu \tag{8b}$$

Moreover, we can derive:

$$Y_L = (1 + R + \mu)W \tag{9}$$

which equates the marginal value of labor with its marginal cost. Since wage payments require cash in advance, the real wage rate is augmented by the intertemporal cost of money holdings (i.e., the nominal interest rate,  $R + \mu$ ) to measure the marginal cost of labor. Furthermore, we can use the following condition:

$$[1 - \phi P(R + \delta)(R + \mu)]V_Q = P(R + \delta) \tag{10}$$

to determine the firm owner consumption demand:  $Q^d = Q^d(R, P, \mu)$  where  $\partial Q^d/\partial i < 0$  for  $i = R, P, \mu$ .<sup>6</sup> While the negative effects of the real interest rate and the relative price of capital on the firm owner's residual claim is straightforward, the downward force of money growth deserves further elaboration. An increase in the rate of money growth raises the intertemporal cost of money holdings. Due to cash requirements, both augmented wage and investment costs become higher. As a result, the firm's profitability is lower, thereby reducing its owner's consumption demand.

By the constant-returns property, the marginal product of labor ( $Y_L$ ) depends on the capital-labor ratio ( $k$ ) alone. This, together with (9), implies the equilibrium capital-labor ratio,  $k^*$ , is a monotone increasing function of  $(1 + R + \mu)W$ . Applying (2) in the steady state, we have:

$$I = \delta Lk^*[(1 + R + \mu)W] \tag{11}$$

That is, an increase in the money growth rate creates a positive “asset substitution” effect in that the representative firm lowers money holdings and increases capital investment. However, there is also a negative productivity effect: the increased marginal cost of labor (as a result of the cash requirement for wage payments) reduces employment, thus leading to lower investment (as the two production factors are Pareto complements, i.e.,  $Y_{LK} > 0$ ).

By tedious but straightforward manipulations of the steady-state version of (1)–(3), and (4) (with equality), (6), (8b) and (11), one obtains:

$$Y\left(\frac{I}{\delta}, L\right) - (1 + \mu)WL = \frac{1}{\delta} [((1 + \phi\mu)\delta + \Psi R)PI + Q] \tag{12}$$

Define  $\Gamma(R, P, \mu, k, W, \Psi) = \{y(k[\cdot]) - (1 + \mu)W - [(1 + \phi\mu)\delta + \Psi R]Pk[\cdot]\}$  where  $\Gamma > 0$ ,  $\partial\Gamma/\partial k > 0$  [using the envelope property of the production function with the steady-state version of (1)] and  $\partial\Gamma/\partial i < 0$  for  $i = R, P, \mu, \Psi$ . Then, (10)–(12) together with the production function lead to:

$$\Gamma(R, P, \mu, k, W, \Psi)L = Q^d(R, P, \mu) \tag{13}$$

An important implication of (13) is that the effect of a higher  $\Psi$  is to increase steady-state labor employment ( $L^*$ ). As for the effects of  $R$  and  $\mu$ , there are three channels: (i) a negative direct effect via  $Q^d$ , (ii) a negative capital accumulation effect via  $k$ , and (iii) a positive factor substitution effect via  $\Gamma$ . Throughout the remainder of the paper, we assume that the elasticity of factor substitution is not too high so that a higher rate of real interest or money growth results in a lower level of employment.<sup>7</sup> This may be referred to as an “intertemporal employment normality” condition (or, shortly, Condition N), which is

<sup>6</sup> It is useful to note that  $|\partial Q^d/\partial \mu| = [V_Q^2/(-V_{QQ})]\phi < [V_Q^2/(-V_{QQ})]\{\phi + 1/[P(R + \delta)^2]\} = |\partial Q^d/\partial R|$ .

<sup>7</sup> Precisely, by noting that  $|\partial Q^d/\partial \mu| < |\partial Q^d/\partial R|$ , it is sufficient to assume the following inequality holds in the steady state:  $|\partial Q^d/\partial \mu| + WL\{y_k - P[(1 + \phi\mu)\delta + \Psi R]/(-ky_{kk})\} > L \max\{W + \phi\delta Pk, \Psi Pk\}$ .

consistent with findings in conventional optimal monetary growth models summarized by Wang and Yip (1992).

We are now ready to use (4) (with equality) to pin down the money demand function:<sup>8</sup>

$$M^d(W, k, \phi, \Psi, R, \mu) = (W + \phi P \delta k) L^*(\cdot, k, \Psi, R, \mu) \quad (14)$$

Under the intertemporal employment normality condition, straightforward differentiation of (14) yields:  $\partial M^d / \partial W > 0$ ;  $\partial M^d / \partial k > 0$ ;  $\partial M^d / \partial \phi > 0$ ;  $\partial M^d / \partial \Psi > 0$ ;  $\partial M^d / \partial R < 0$ ; and,  $\partial M^d / \partial \mu < 0$ . Intuitively, an increase in the wage rate, via the cash-in-advance constraint, increases firm demand for money. An increase in investment enlarges the capital-labor ratio and, via the fractional cash-in-advance constraint and labor employment, raises money demand. An increase in the severity of the cash requirement for investment good purchases (higher  $\phi$ ) enhances the role of money in facilitating firm transactions and thus induces higher money demand. Increased profitability that raises firm ability to hold interest-bearing financial assets (higher  $\Psi$ ) induces a greater demand for money. Finally, an increase in either the real interest rate or the money growth rate creates an adverse effect on steady-state employment, thereby reducing firm's money demand.

Eq. (14) provides a theoretical foundation for the econometric model of money demand by firms to be constructed in the next section. In practice, the capital stock data are not available, and hence, we must proxy the capital-labor ratio by the firm's capital investment.<sup>9</sup> Such a transformation can be obtained by manipulating (12)–(14), throughout replacing  $k$  with  $I/(\delta L^*)$ .<sup>10</sup> Indeed, as we will see below, the econometric models are based on a log-linear approximation of the transformed money demand Eq. (14), with added empirical explanatory variables and/or industry dummies.

### 3. Data and empirical methodology

#### 3.1. The data

The firm-level data in this study are drawn from the *Taiwan Economic Journal Data Bank* which is collected by the Taiwan Economic Journal Company. The original data set consists of 376 companies. Selected items from corporate end-of-year balance sheets and income statements are reported for the manufacturing and nonmanufacturing sectors. The firms in our study are in 14 industries as classified by Standard Industrial Classification (SIC). These sectors include food processing, textile, plastic products, rubber products, electrical machinery and electronic products, cement, industrial chemicals and chemical products, pulp and paper products, non-metallic products, primary metal industry, motor vehicles, transportation equipment, construction, and service sector. Thus, these firms represent well the entire Taiwanese economy with regards to their scopes of

<sup>8</sup> Let  $Y(K, L) = y_0 K^\epsilon L^{1-\epsilon}$  and  $V(Q) = \ln(Q)$ . Then, (14) becomes:  $M^d = \frac{1-\phi(R+\mu)P(R+\delta)}{P(R+\delta)} \left\{ \frac{1}{1-\epsilon} [R + \zeta(1 + \mu)]W - [(1 - \phi\mu)\delta + \Psi R] P k^* \right\} (W + \phi \delta P k^*)$  where  $k^* = \left[ \frac{(1+R+\mu)W}{(1-\epsilon)y_0} \right]^{\frac{1}{\epsilon}}$ .

<sup>9</sup> In practice, firms use different methods assessing the values of machines, equipment and depreciation, thus making the capital stock data less compatible in cross-sections. Moreover, the increment of capital stock ties better with current needs for cash.

<sup>10</sup> From (12) and (13),  $I = \delta k L^*(\cdot, k, \Psi, R, \mu)$  can be shown as a monotone increasing function in  $k$  under Condition N. It can thus be inverted to derive the monotone relationship  $k = I/(\delta L^*)$ .

production. Because all the firms are listed on the Taiwan Stock Exchange since 1990, it is expected that they are larger and likely better-performing than smaller enterprises, implying perhaps more effective cash management. That is, an average Taiwanese firm may be anticipated to have smaller scale economies in the transactions use of money than those of our sample firms.

Based on the availability of consistent series, we construct from the original data a balanced panel data set containing 345 Taiwanese firms from 1990 to 1997. It includes 28 firms in food processing, 49 firms in textile, 17 firms in plastic products, 8 firms in rubber products, 90 firms in electrical machinery and electronic products, 8 firms in cement, 18 firms in industrial chemicals and chemical products, 8 firms in pulp and paper products, 7 firms in non-metallic products, 23 firms in primary metal, 5 firm in motor vehicles, 14 firms in transportation equipment, 28 firms in construction, and 42 firms in service sector.<sup>11</sup> In constructing a balanced panel, we ignore data on firms which are listed only a subset of the years 1990–97, which raises the issue of sample selection that need be addressed below. Table 1 reports basic statistics for the variables used in the regression analysis. The variables are summarized into three groups: (i) firm-level variables, (ii) industry-level variables, and (iii) macro-level variables.

The real cash balances variable ( $M$ ) is measured by “cash and cash equivalent” on each firm’s balance sheet. It is defined as cash and any instruments normally accepted by banks for deposit and immediate credit to a customer’s account, including bank drafts, banker’s acceptances, checks, demand certificates of deposit, demand deposits, letters of credit, and money orders. There is an array of other firm-level variables used for econometric estimation. The conventional scale variable ( $S$ ) is measured by “gross sales”, the wage variable ( $W$ ) by “wage bills”, the capital investment variable ( $INV$ ) by “investment bills” (including both new and replacement investments) and the profit variable by “pre-tax gross profits” all from each firm’s income statement. We measure firm’s profitability (denoted  $\Pi_F$ ) by the ratio of profit to sales. Three firm-level financial variables available in the data set are the turnover days for funds-payable ( $F_P$ ) and for funds-receivable ( $F_R$ ), as well as the leverage ratio variable ( $\theta$ ), which is measured by the ratio of short-term borrowing to total current assets in percentage.

At the industry level, the value of time variable ( $VT$ ) is measured by “annual wage and salary income per employee,” which is obtained from the *Monthly Bulletin of Earnings and Productivity Statistics in Taiwan*.<sup>12</sup> Another industry-level variable is exportability, measured by the “export to production share” for each industry classification. This is computed from the data on export values and production values by two-digit industry in the *Monthly Statistics of Exports and Imports in Taiwan* and the *Monthly Statistics of Industrial Production in Taiwan*, respectively.

At the macro level, the nominal interest rate ( $RN$ ) is measured by the 3-month time deposit rate. While the risk premium ( $R_{RP}$ ) by the difference between the annual average of unsecured loans rates and 91-day Treasury Bills rates in primary markets, the term premium ( $R_{TP}$ ) by the difference between the 3-year time deposit rate and the 3-month time deposit rate. All the interest rates are posted by the Bank of Taiwan.

<sup>11</sup> We have deleted 31 sample firms from our empirical analyses due to incomplete data on cash and sales.

<sup>12</sup> The measure of the value of time follows directly from Mulligan (1997), which is only a proxy due to data limitation. It is also noted that this industrial-level wage measure and the firm-level wage payment variable are not highly correlated: the correlation coefficient is only about 0.33.

Table 1  
Definition of variables and summary statistics

Variables	Definition	Mean	Standard deviation	Minimum	Maximum	<i>N</i>
<i>A. Firm-level variables</i>						
$\ln M$	Log (Cash and cash equivalent) (NT\$)	11.954	1.508	4.697	16.671	2760 (345 × 8)
$\ln S$	Log (Gross sales) (NT\$)	14.779	1.123	3.867	18.198	2760 (345 × 8)
$\ln W$	Log (Wage bill) (NT\$)	12.502	0.967	6.886	15.530	1008 (126 × 8)
$\ln INV$	Log (Investment bill) (NT\$)	11.529	3.914	0.000	17.210	1008 (126 × 8)
$\Pi_F$	Profit/sales (%)	6.415	8.517	-59.165	41.196	1008 (126 × 8)
$\theta$	Short-term borrowing/total current assets (%)	27.589	49.372	0.000	703.687	1008 (126 × 8)
$F_P$	Turnover days for funds-payable (days)	35.997	24.249	0.000	305.000	992 (124 × 8)
$F_R$	Turnover days for funds-receivable (days)	63.057	34.529	2.000	282.000	992 (124 × 8)
<i>B. Industry-level variables</i>						
$\ln VT$	Log (Annual wage and salary income per employee by industry) (NT\$)	12.801	0.182	12.357	13.144	112 (14 × 8)
$EX$	Export share by industry (%)	35.848	31.167	0.000	93.300	112 (14 × 8)
<i>C. Macro-level variables</i>						
$RN$	Three-month time deposits rate (%)	6.359	0.741	5.250	7.750	8
$R_{TP}$	Three-year time deposits rate-three month deposits rate (%)	1.272	0.371	0.825	2.000	8
$R_{RP}$	Annual average of unsecured loan rates-91 day treasury bills in primary market (%)	17.871	0.651	16.770	18.780	8

Notes: *N* is the number of observations. While 115 observations have zero short-term borrowing, 6 show zero funds-payable turnover days. Industry-level wages do not include bonus or overtime payments. The Wholesale price index is used to convert all current dollars to 1990 values. The exchange rate in 1990 was US\$1 = NT\$27.11.

To correct for inflation, all monetary measures are expressed in 1990 New Taiwan dollars (NT\$).<sup>13</sup> Notably, for comparison purposes, our measures of gross sales, the value of time, and the nominal interest rate are consistent with those used by Mulligan (1997).

### 3.2. Econometric methodology

For comparison purposes, we begin by estimating conventional quantity theory, inventory and value-of-time models. Denote the firm index by  $i$ , the industry index by  $j$  and the time index by  $t$ . The money demand regression setups based on these conventional approaches are given by:

$$\begin{aligned}\ln M_{it} &= a_0 + a_1 \ln S_{it} + \varepsilon_{it} \\ \ln M_{it} &= a_0 + a_1 \ln S_{it} + a_2 RN_t + \varepsilon_{it} \\ \ln M_{it} &= a_0 + a_1 \ln S_{it} + a_2 RN_t + a_3 \ln VT_{jt} + \varepsilon_{it}\end{aligned}\quad (15)$$

where  $M_{it}$  = real cash balances (of firm  $i$ );  $S_{it}$  = gross sales (of firm  $i$ );  $RN_t$  = the nominal interest rate; and,  $VT_{jt}$  = annual wages per employee (of industry  $j$ ). Following the conventional wisdom, the sales and the value of time variables are transformed logarithmically, and thus the associated coefficients can be interpreted as elasticities. Any ratios or percentage measures are in levels.

In addition to the scale variable ( $S$ ), the explanatory variables,  $RN$  and  $\ln VT$ , are sequentially introduced to see how they affect the opportunity cost of holding money. As in the Alais–Baumol–Tobin inventory model, a higher nominal interest rate increases the opportunity cost of money hoarding and is thus expected to lower the demand for money. Following the arguments in the value of time framework adopted by Mulligan (1997), a higher value of time (of the cash manager) suggests increased time costs for transactions, therefore increasing money holdings. Finally, an additional explanatory variable  $EX_{jt}$  (the exports to output share of industry  $j$ ) is included because it is emphasized by Tsiang (1977) that in a highly trade-dependent, small open economy such as Taiwan, greater exportability requires more money demand.

Turning now to our main task in estimating our generalized differential cash constraint theory, we specify the econometric model based on its theoretic counterpart, Eq. (14), as:

$$\ln M_{it} = b_0 + b_1 \ln W_{it} + b_2 \ln INV_{it} + b_3 \Pi_{Fit} + b_4 RN_t + b_5 \theta_{it} + b_6 X_{mt} + v_{it} \quad (16)$$

where  $W_{it}$  = wage bills (of firm  $i$ );  $INV_{it}$  = investment bills (of firm  $i$ );  $RN_t$  = the nominal interest rate;  $\Pi_{Fit}$  = the profit to sales ratio (of firm  $i$ );  $\theta_{it}$  = the leverage or debt-to-equity ratio (of firm  $i$ ); and,  $X_{mt}$  = other added explanatory variables (of firm  $i$  or industry  $j$  with  $m = i$  or  $j$ ).

Importantly, an increase in financial leverage  $\theta$  is expected to lead to a higher fraction of credit purchases (i.e., lower  $\phi$  in the theoretical model), whereas greater profitability (higher  $\Pi_F$ ) corresponds to a positive autonomous change in  $\psi$ . Therefore, the comparative statistics derived from the equation system (12)–(14) imply:  $b_1 > 0$ ,  $b_2 > 0$ ,  $b_3 > 0$ ,  $b_4 < 0$ , and  $b_5 < 0$ . Despite that the ratio of the coefficients  $b_2/b_1$  does not provide a direct empirical measure for the factor of differential cash constraints,  $\phi$ , a small value of this

<sup>13</sup> The Wholesale Price Index is used to convert all current dollars to 1990 values. The exchange rate in 1990 was US\$1 = NT\$27.11.

ratio would suggest the likelihood for investment purchases to require proportionally less cash-in-advance than wage payments (i.e.,  $\phi < 1$ ). Notice that our benchmark specification of the interest rate uses the semi-log form, yet we report the estimates in complete log-form in the [Appendix](#) to check the robustness of our findings. In addition to the interest rate variable, we take term premium ( $R_{TP}$ ) and risk premium ( $R_{RP}$ ) as alternatives to  $RN$  in our analysis. While a higher term premium suggests greater time preferences and opportunity costs of cash hoarding, an increase in the risk premium favors money holdings as cash is certainly a safer portfolio outlet. Hence,  $R_{TP}$  has a negative impact on money demand, but the effect of  $R_{RP}$  is positive. Moreover, we also include the turnover days for funds-payable ( $F_P$ ) and for funds-receivable ( $F_R$ ) as two additional indicators for firm's financial status. Obviously, an increase in  $F_P$  loosens the cash flow whereas an increase in  $F_R$  tightens it. While the effect of a higher  $F_R$  is expected to reduce firm's demand for money, that of a greater  $F_P$  need not be associated with an increased demand for money because it may be a *consequence* of poor cash management which results in longer funds-payable turnovers and lower real money holdings.

As an alternative to the log-linearized regression specification (16), one may adopt a two-step procedure. In the first step, one may impute directly a firm's expenditures that require cash payments ( $E_{it}$ ):

$$E_{it} = W_{it} + \phi_i INV_{it} \quad (17)$$

Since  $E_{it}$  is unobservable, one cannot use (17) to estimate  $\phi_i$ . Instead, one would need to impute  $\phi_i$  by utilizing the data on financial leverage ( $\theta_i$ ). More precisely, we order all firms by  $\theta_i$ , assign that with lowest value of  $\theta$  with  $\phi = .8$  and that with highest value of  $\theta$  with  $\phi = .2$  (the plausible upper and lower bounds for  $\phi$ ), and interpolate all other values of  $\phi_i$  linearly according to  $\theta_i$ . This enables us to obtain an imputed firm-level measure  $E_{it}$ , using the identity (17). In the second step, we estimate the following econometric model:

$$\ln M_{it} = d_0 + d_1 \ln E_{it} + d_2 \Pi_{Fit} + d_3 RN_t + d_4 X_{mt} + v_{it} \quad (18)$$

where the comparative-statistic results derived from the equation system (12)–(14) imply:  $d_1 > 0$ ,  $d_2 > 0$  and  $d_3 < 0$ .

Following the conventional wisdom, we adopt the fixed-effects model as the benchmark.<sup>14</sup> This is because that inter-firm variation in cash holdings is expected to depend on the nature of its industrial environment (e.g., the market structure, the manufacturing process, the nature of rivalry, the inventory policy, and the degree of riskiness). The estimation using fixed-effects models accounts for such a possibility, capturing diverse industrial influences on firm behavior.

## 4. Empirical evidence

### 4.1. Conventional models

Columns 1–3 in [Table 2](#) present the results of estimation based on the conventional quantity theory, the conventional inventory approach, and Mulligan's value of time

<sup>14</sup> The empirical findings remain largely unchanged with random-effects estimators. Indeed, the only difference is: some financial variables (particularly,  $F_R$ ) that are insignificant under the fixed-effects specification now become significant because the estimation efficiency is improved. The estimation results are available upon request.

model, respectively, as given by (15). Extensions of the inventory and the value of time frameworks with an added exportability variable are reported in columns 4 and 5, respectively.

Column 1 shows that the elasticity of the demand for money with respect to sales is about 0.63, which is reduced in magnitude (to 0.56) when the interest rate is included in the second column. Consistent with models of money demand, the sign of interest rate is negative. Based on the semi-elasticity estimates, we can compute the interest rate elasticity as 0.92, which is much higher than that implied by the Alais–Baumol–Tobin square-root formula (0.5). In column 3, we use an index of wages and salaries per worker as a proxy for transactions-time costs associated with cash management. If labor is a substitute for money as suggested by the value of time approach, one may expect that the value of time measure ( $VT$ ) should increase the demand for money. Our finding is consistent with this prediction, displacing an estimated wage elasticity of 1.16.<sup>15</sup> Moreover, the sales elasticity is about 0.53 (column 3), much lower than the comparable figure reported by Mulligan (1997), which is about 0.83. Thus, we have identified stronger scale economies of cash management. Additionally, the coefficient of export share is positive but statistically insignificant in both columns 4 and 5.

#### 4.2. Differential cash constraint model

Concerning our differential cash constraint model, we report the results obtained from estimating regression (16) in Table 3 and those from estimating (18) in Table 4.<sup>16</sup> In all cases, the coefficients on wage bills, investment purchases and profit rates are positive and statistically significant at the 1% (for most cases) or at least the 5% level. These findings are consistent with the predictions of our theoretical model.

Based on the model specified as in (16), a measure of the overall scale elasticity ( $\xi = \xi_W + \xi_{INV}$ , which corresponds to the estimates of  $b_1 + b_2$ ) is in the range of 0.60–0.68, based on regressions in columns 6–8, and 0.58 based on regressions in columns 9 and 10. The result implies significant scale economies associated with the use of money by firms. Moreover, the coefficient estimates for wage bills (ranging from 0.54 to 0.56 in the benchmark regressions in columns 6 and 9) far exceed those for investment purchases (ranging from 0.03 to 0.04). Although the coefficient estimates for investment bills may be downward biased due to the nature of its lumpy adjustments, such significantly low values (with a ratio of approximately 1:16 compared to the wage bill coefficient estimates) together with extremely tight standard error bands (with 95% confident interval lower and upper bands given by 0.015 and 0.055) lead us to conclude that the differential cash constraint hypothesis earns fairly strong empirical support.

The interest rate elasticity is 0.70 (computed from the semi-elasticity figure in column 6), lower than the estimates in Table 2. We also take term and risk premia as alternatives to interest rate. The influence of term premium on the cash holdings is, as anticipated, significantly negative (column 7). Conversely, the coefficient estimate of risk premium is sig-

<sup>15</sup> Based on the money-in-the-production empirical framework developed by Nadiri (1969), Dennis and Smith (1978) find that real cash balances is a substitute for labor and capital inputs in 11 US manufacturing industries. However, using India's manufacturing industry data, Laumas and Williams (1983) conclude that cash balances and labor are predominantly substitutes, yet cash balances and capital are by and large complementary.

<sup>16</sup> The sample is reduced to 126 firms after deleting the missing information on key variables.

Table 2  
Conventional inventory and value-of-time model (dependent variable:  $\ln M$ )

Independent variables	(1)	(2)	(3)	(4)	(5)
$\ln S$	0.627 (5.96) <sup>***</sup>	0.558 (5.45) <sup>***</sup>	0.526 (5.28) <sup>***</sup>	0.559 (5.46) <sup>***</sup>	0.526 (5.29) <sup>***</sup>
$RN$		-0.126 (-4.26) <sup>***</sup>	0.021 (0.47)	-0.121 (-3.66) <sup>***</sup>	0.023 (0.48)
$\ln VT$			1.157 (3.20) <sup>***</sup>		1.155 (3.20) <sup>***</sup>
$EX$				0.001 (0.26)	0.0003 (0.11)
$R^2$	0.69	0.69	0.70	0.69	0.70

Notes: All regressions contain a balanced panel of 345 firms and are estimated using a fixed-effects model. The asymptotic covariance matrix is calculated by using White correction.  $\ln S$ ,  $RN$ ,  $\ln VT$  and  $EX$  measure gross sales, national nominal interest rates, industrial wages and industrial export shares, respectively. Student  $t$ -statistics are in parentheses where <sup>\*\*\*</sup>, <sup>\*\*</sup>, and <sup>\*</sup> represent statistical significance at the 1%, 5%, and 10% level, respectively. See also Table 1 for detailed data description.

nificantly positive (column 8), indicating that an increase in the degree of riskiness concerning a firm's portfolio choice raises the demand for the safe asset, money. The positive effect of exportability on money holdings by firms is statistically insignificant, contrasting with the evidence found in a macroeconomic study by Tsiang (1977).<sup>17</sup> With respect to measures of firms' financial status, we find that the leverage ratio has a statistically significant and nonnegligible negative impact on firms' money demand, regardless of econometric model specifications (the estimated elasticity is about  $-0.08$ ). The negative and significant coefficient estimates of turnover days for funds-payable ( $F_P$ ) indicate that longer funds-payable turnovers are likely associated with poor cash management and lower cash holdings. The coefficient of turnover days for funds-receivable ( $F_R$ ) is, as expected, positive but statistically insignificant.

We next turn to the model specified as in (18) where in the first step we estimate cash required expenditures according to firm-specific financial leverage measures. A robust finding is the scale economies in cash management (based on the coefficient estimates on  $\ln E$ ). Compared with the same specification in Table 3, the interest rate and the turnover days for funds-payable continue to have significantly negative effects on money demand, whereas the positive profitability and exportability effects become more significant.

Because these larger firms included in our sample are more likely to have longer-term investment plan, it is reasonable to regard investment purchases as exogenous to cash management. However, wage bills may be endogenous to the money demand decision. Thus, instrumental variable (IV) procedures are used to account for possible endogeneity of  $W_{it}$ . Lacking of other sensible alternatives (such as firm-level years of schooling and

<sup>17</sup> Using the macro data over the period from 1953 to 1972, Tsiang introduces the ratio of the volume of trade relative to the national income into the money demand regression and finds that it has a significant effect on the demand for money in Taiwan. We note, however, that the insignificant result in our firm-level estimation is possibly due to the lack of the firm-level data on exportability (our  $EX$  is an industry-level measure).

Table 3  
Differential cash constraint model (dependent variable:  $\ln M$ )

Independent variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$\ln W$	0.753 (6.71)***	0.644 (5.27)***	0.645 (5.28)***	0.588 (4.76)***	0.611 (5.22)***	0.561 (4.73)***	0.586 (4.90)***	0.639 (5.69)***	0.540 (4.20)***	0.548 (4.10)***
$\ln INV$	0.046 (3.82)***	0.034 (2.64)***	0.034 (2.64)***	0.033 (2.62)***	0.033 (2.54)***	0.033 (2.52)***	0.035 (2.71)***	0.038 (3.01)***	0.031 (2.36)**	0.031 (2.35)**
$\Pi_F$				0.014 (2.11)**		0.013 (2.03)**	0.011 (1.84)*	0.011 (1.75)*	0.013 (2.07)**	0.013 (1.93)*
$R_N$		-0.126 (-2.72)***	-0.123 (-2.49)***	-0.153 (-3.05)***	-0.107 (-2.25)**	-0.135 (-2.80)***			-0.154 (-3.11)***	-0.157 (-2.96)***
$R_{TP}$							-0.216 (-2.21)**			
$R_{RP}$								0.094 (2.17)**		
$EX$			0.001 (0.14)	0.0004 (0.10)	0.001 (0.28)	0.001 (0.23)	0.002 (0.37)	0.003 (0.71)	0.0001 (0.02)	-0.0003 (-0.06)
$\theta$				-0.003 (-3.36)***	-0.003 (-3.35)***	-0.003 (-3.41)***	-0.003 (-3.31)***	-0.003 (-3.05)***	-0.003 (-3.05)***	
$F_P$									-0.005 (-2.76)***	
$F_R$										0.00001 (0.003)
$R^2$	0.70	0.71	0.71	0.71	0.71	0.72	0.72	0.72	0.72	0.71
$N$	1008	1008	1008	1008	1008	1008	1008	1008	992	992

Notes: All regressions are estimated using a fixed-effects model. The asymptotic covariance matrix is calculated by using White correction.  $\ln W$  and  $\ln INV$  measure, respectively, wage and investment bills;  $R_{TP}$  and  $R_{RP}$  measure, respectively, term and risk premium;  $\Pi_F$  measures profit to sales ratio and  $\theta$  measures the financial leverage ratio (debt/equity); and,  $F_P$  and  $F_R$  measure, respectively, the turnover days for funds-payable and funds-receivable.  $N$  is the number of observations. See also notes to Table 2.

Table 4  
Differential cash constraint model (dependent variable:  $\ln M$ )

Independent variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\ln E$	0.639 (9.04)***	0.469 (4.93)***	0.465 (4.88)***	0.408 (4.18)***	0.456 (4.84)***	0.499 (5.98)***	0.406 (4.01)***	0.383 (3.81)***
$\Pi_F$				0.018 (2.73)***	0.016 (2.55)***	0.016 (2.52)***	0.018 (2.73)***	0.018 (2.69)***
$R_N$		-0.153 (-3.11)***	-0.103 (-1.85)*	-0.142 (-2.50)***			-0.137 (-2.32)**	-0.155 (-2.52)***
$R_{TP}$					-0.192 (-1.76)*			
$R_{RP}$						0.072 (1.54)		
$EX$			0.008 (1.73)*	0.008 (1.64)*	0.009 (1.95)**	0.011 (1.54)	0.008 (1.73)*	0.007 (1.53)
$F_P$							-0.006 (-3.82)***	
$F_R$								0.0001 (0.05)
$R^2$	0.69	0.69	0.70	0.70	0.70	0.70	0.70	0.70
$N$	1008	1008	1008	1008	1008	1008	1008	1008

Notes: All regressions are estimated using a fixed-effects model. The asymptotic covariance matrix is calculated by using White correction.  $E = W + \phi * INV$  measures cash spending. See also notes to Tables 2 and 3.

employment tenure data), we simply utilize one and two-year lagged wage bills,  $W_{i,t-1}$  and  $W_{i,t-2}$ , as instruments in the estimation.<sup>18</sup> The results are reported in Table 5, which are largely consistent with our previous findings presented in Tables 3 and 4. In particular, there still exist significant scale economies in cash management (with the overall scale elasticities now ranging from 0.67 to 0.73 based on estimates in columns 6–10) and strong financial leverage effects (all significantly negative). The positive effects of investment bills and the profitability measure generally remain statistically significant. For other financial variables, the term and risk premia and the turnover days become statistically insignificant. Of course, by the nature of annual data, using lagged variables as instruments may lose important current information. Therefore, the IV method is adopted only to complement rather than replace the fixed-effects OLS estimation.

To further test the robustness of our empirical findings, we first account for possible sample selection problems by eliminating extreme large and extreme small firms (those ranked within the top 5 and bottom 5% in sales). While previous conclusions remain qualitatively unchanged, the degree of scale economies in cash management increases slightly by a few percentage points. Second, since some previous studies (including Mulligan) use complete log-linear specification applying to all variables (including interest rates), we re-estimate all econometric models using this alternative specification and find again that our findings are robust.<sup>19</sup>

In summary, our empirical results are consistent with the theoretical predictions obtained from our generalized differential cash constraint model. They lend strong support to our theory that firms' demand for money increases with both wage bills and investment purchases. As the coefficient estimates for wage bills far exceed those for investment purchases, the differential cash constraint hypothesis is justified empirically. Thus, our generalized differential cash constraint model can therefore be thought of as a good alternative to previous approaches to firms' demand for money. Moreover, while there are apparent economies of scale concerning the role of money in facilitating firm transactions, several profitability and financial variables are found to influence firms' money demand significantly. In particular, a lower financial leverage ratio or a higher firm profitability ratio tends to increase firms' money demand significantly.

In macroeconomic studies using Taiwanese data, the income and interest rate elasticities of money demand in Taiwan can be found in Tsiang (1977) and Shea (1983). While the income elasticity is in the range of 1.08–1.49, the interest rate elasticity falls in 0.13–0.42. Interestingly, the firm-level estimates in Tables 3–5 show much larger scale economies in cash management and more sensitive responses of money demand to the nominal interest rate. Moreover, by comparing our results with the existing literature on the demand for money by firms, our measure of scale economies is by far the largest.

What are the macroeconomic implications of our firm-level money demand estimation for monetary policy? For brevity, we would only discuss three. First, estimation based on large firms' data is very different from macro estimation. This large discrepancy suggests

<sup>18</sup> For a discussion of instrumental variable estimation in the panel data, see Hsiao (1986). In particular, our procedure follows closely to that in Bregam et al. (1995). We have also instrumented using one and two-year lagged employment data ( $L_{i,t-1}$  and  $L_{i,t-2}$ ) and one and two-year lagged computed wage payment data (by the multiple of firm employment  $L_{i,t-p}$  and industrial wage rates  $YW_{t-p}$ ). The estimates, which are available upon request, suggest that our main findings are robust.

<sup>19</sup> The results from both exercises are available upon request.

Table 5  
Differential cash constraint with instrumental variable method (dependent variable:  $\ln M$ ) – using  $(\ln W_{t-1}, \ln W_{t-2})$  as instruments

Independent variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$\ln W$	0.802 (4.49)***	0.695 (3.81)***	0.670 (3.68)***	0.655 (3.86)***	0.650 (3.67)***	0.640 (3.80)***	0.692 (3.81)***	0.680 (3.88)***	0.638 (3.79)***	0.626 (3.76)***
$\ln INV$	0.047 (2.82)***	0.033 (1.95)**	0.031 (1.87)*	0.032 (1.98)**	0.031 (1.88)*	0.032 (1.96)**	0.040 (2.45)***	0.039 (2.43)***	0.032 (1.91)*	0.035 (2.11)**
$\Pi_F$				0.025 (4.46)***		0.021 (3.70)***	0.019 (3.43)***	0.019 (3.40)***	0.021 (3.70)***	0.019 (3.26)***
$R_N$		-0.185 (-2.93)***	-0.112 (-1.58)	-0.194 (-2.72)***	-0.076 (-1.08)	-0.151 (-2.10)**			-0.154 (-2.13)**	-0.191 (-2.62)***
$R_{TP}$							0.001 (0.003)			
$R_{RP}$								0.023 (0.40)		
$EX$			0.010 (1.75)*	0.007 (1.17)	0.011 (1.89)*	0.008 (1.36)	0.014 (2.22)**	0.013 (2.29)**	0.008 (1.36)	0.007 (1.21)
$\theta$					-0.005 (-2.61)***	-0.004 (-2.58)***	-0.004 (-2.66)***	-0.004 (-2.64)***	-0.004 (-2.60)***	-0.004 (-2.58)***
$F_P$									-0.001 (-0.39)	
$F_R$										-0.004 (-1.67)*
$R^2$	0.72	0.73	0.73	0.74	0.74	0.74	0.74	0.74	0.73	0.73
$N$	756	756	756	756	756	756	756	756	756	756

Notes: All regressions are estimated using the instrumental variable method where one and two-year lagged values of  $\ln W$  ( $\ln W_{t-1}, \ln W_{t-2}$ ) are used as instruments for  $\ln W$ . The asymptotic covariance matrix is calculated by using White correction. See also notes to Tables 2 and 3.

potentially important distributional effects of monetary policy that must not be ignored in examining the macroeconomic transmissions and the welfare costs of money. For example, the presence of large scale economies in Taiwanese firms' cash management implies that there is less need for liquidities by these Taiwan Stock Exchange-listed businesses. Moreover, since the interest rate elasticity of large firms' money demand is significantly higher than conventional estimates using macro data, previous welfare cost measures of inflation are likely to suffer severe downward bias particularly because these large firms exhibit large scale economies cash management. Second, concerning normative analysis of monetary policy, inflation targeting seems to make sense from large firms' responses to the monetary policy. Finally, since firms' financial status is crucial for their money demand decisions, a thorough evaluation of monetary policy requires careful account for and assessment of the underlying financial environment. This also lends empirical support to the theoretical arguments emphasized by Chari et al. (1996).

## 5. Concluding remarks

We have revisited the issue of firm's demand for money by developing a generalized differential cash constraint model and undertaking empirical tests with a complete panel of Taiwanese firms over the period of 1990–97. We support the hypothesis of differential cash constraints and the property of economies of scale in the transaction role of money for firms where the overall scale elasticity is in the range of 0.56–0.78. The nominal interest rate has a conventional negative effect on money demand with the elasticity measures falling between 0.70 and 0.98. Several firm profitability and financial variables also play significant roles in influencing the money demand behavior, including the profit/sales ratio, the leverage (debt/equity) ratio and the term and risk premia.

In the end, we would like to acknowledge the limitations of this study. On the one hand, the data is at annual frequency, which is not suitable for studying within-the-year adjustments in cash. On the other, since our sample includes only firms listed on the Taiwan Stock Exchange, the resultant selection bias problem exists. Thus, our conclusions, especially those regarding scale economies in the transactions use of money, may not be entirely applicable to small enterprises in which cash management is arguably less effective. Nonetheless, our empirical evidence provides an interesting contrast with that in previous work, and our generalized differential cash constraint theory can be applied to performing econometric analysis using available data from other countries.

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## Appendix

The current-value Hamiltonian for the firm's optimization problem can be written as:

$$H = V(Q) + \lambda[Y(K, L) - WL - PI + RA - Q - Z] + \alpha[I - \delta K] + \beta[Z - \pi M] + \eta[M - WL - \phi PI]$$

The necessary conditions, Euler equations and the transversality conditions are given by:

$$V_Q - \lambda = 0 \quad (\text{A.1})$$

$$-P + \alpha - \eta\phi P = 0 \quad (\text{A.2})$$

$$-\lambda + \beta = 0 \quad (\text{A.3})$$

$$\lambda(Y_L - W) - \eta W = 0 \quad (\text{A.4})$$

$$\dot{\lambda} = \lambda(\gamma - R) \quad (\text{A.5})$$

$$\dot{\alpha} = (\gamma + \delta)\alpha - \lambda Y_K \quad (\text{A.6})$$

$$\dot{\beta} = (\gamma + \pi)\beta - \eta \quad (\text{A.7})$$

$$\lim_{t \rightarrow \infty} e^{-\gamma t} \lambda(t) A(t) = 0, \quad \lim_{t \rightarrow \infty} e^{-\gamma t} \alpha(t) K(t) = 0, \quad \lim_{t \rightarrow \infty} e^{-\gamma t} \beta(t) M(t) = 0 \quad (\text{A.8})$$

From (A.1) and (A.3), we obtain:

$$\lambda = \beta = V_Q \quad (\text{A.9})$$

Thus, the shadow costs of interest-bearing assets and money (i.e.,  $\lambda$  and  $\beta$ , respectively) are equal to firm's marginal valuation of output ( $V_Q$ ). Using (A.1) and (A.4), one gets:

$$\eta = \left( \frac{Y_L}{W} - 1 \right) V_Q \quad (\text{A.10})$$

Combining (A.1), (A.2) and (A.4) gives:

$$\alpha = p \left[ 1 + \phi \left( \frac{Y_L}{W} - 1 \right) V_Q \right] \quad (\text{A.11})$$

Thus, all the co-state variables and Lagrange multipliers ( $\lambda$ ,  $\beta$ ,  $\eta$  and  $\alpha$ ) are now written as functions of control and state variables in a recursive manner. Substitution of (A.9)–(A.11) into (A.6) and (A.7) yields (7a) and (7b).

In the steady state, we can use (A.5) and (5) to derive (8a) and (8b). Utilizing (A.11), (7b) and (8b), one then obtains (9). Combining (A.11) with (7a) and (9), we have (10).

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