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FINANCIAL STRUCTURE AND THE ADJUSTMENT OF CAPITAL STOCK

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ABSTRACT

In this paper we analyze the investment decision when financial structure has real effects. We assume that tax rates favor debt over equity but that the cost of debt increases with the debt-to-tangible-assets ratio. Since the cost of debt varies with the debt-to-tangible-assets ratio, investment is influenced by financial structure. Euler equations for the firm's decisions are estimated with instrumental variables utilizing data for the **U.S.** manufacturing sector from 1954 to 1980. Financial structure does not have the expected effect. The results suggest a closer examination of the influence of inflation on financial structure.

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I. Introduction

A growing body of theoretical literature analyzes links between the real and financial decisions of firms. However, empirical investigations of investment decisions assume that firms' real and financial decisions can be treated separately. In this empirical literature, financial structure does not vary endogenously. Thus, studies of the impact of tax changes do not take into account the likely response of financial structure and its effects on financial costs and, hence, on investment.

The real decisions of firms may influence their financial costs through numerous channels. Even **if** we take the view that real and financial decisions may be treated separately because the debt-to-equity ratio is indeterminate, real and financial decisions are linked in general equilibrium, since the rate of investment is affected by the rate of return on savings.

Links between real and financial decisions are more direct **if** financial structure is determinate. The debt-to-equity ratio is determinate **if** tax rates favor debt, but there are real costs that increase with the debt-to-equity ratio. Tax rates favor debt largely because of the interest deductibility of debt at the corporate level and because of the (until recently) low rate of personal capital-gains taxation. Agency problems or increased probability of costly bankruptcy imply that there are costs to increasing the debt-to-equity ratio.

In this paper, we consider the interaction between the firm's choice of capital stock (and hence its rate of investment) and its financial costs. We focus on the debt-to-tangible-assets ratio rather than on the debt-to-equity

ratio. In our model, the cost of debt varies with the debt-to-tangible-assets ratio, and physical capital is the only tangible asset. Greater amounts of physical capital reduce the cost of debt, since physical capital is useful as collateral.

We also consider the firm's choices of other productive factors. As Shapiro (1986) has pointed out, models that consider capital as the only input that is costly to adjust conclude that the capital stock must be quite costly to adjust, since it seems to respond slowly to changes in the expected profitability of capital. We consider the firm's choices of production employment, hours of production workers, and nonproduction employment, along with its choice of financial structure and capital stock. The costs of changing these inputs, including the change in the debt cost, help to determine the response of the capital stock to a change in tax rates. The estimates of adjustment costs indicate whether the debt cost is a significant determinant of the path of the capital stock.

II. Related Literature

The hypothesis that tax rates favor debt over equity at the firm level has gained wide acceptance.[1] The advantage is due to the interest deductibility of debt for corporations. Much recent work has analyzed the financing choice when there are non-debt tax shields that increase the probability that the interest tax shields may not be fully utilized (see, for example, Barnea, Talmor, and Haugen [1987] and Zechner and Swoboda [1986]). Increased leverage, on the other hand, may increase agency costs associated with debt or may increase the probability of bankruptcy. Estimates of the direct costs of bankruptcy, however, seem too low to explain observed financial structures.

Agency costs associated with debt may arise for a variety of reasons.

Asset type is an important determinant of financial structure. Scott (1977) and Myers and Majluf (1984) have indicated that stockholders may find it advantageous to issue secured debt. Scott points out that issuance of secured debt reduces the probability that certain costs, such as legal damages, will be paid in the event of bankruptcy since the claims of secured creditors have priority. Myers and Majluf indicate that there may be costs associated with issuing securities implicitly backed by assets whose value is more easily measured by insiders than outsiders. For both of these reasons, the availability of assets that can serve as collateral enhances the value of equity. This is similar to arguments made by Myers (1977) that reliance on "assets in place" versus growth opportunities enhances equity value since the value of assets in place is less dependent on discretionary investment.'

Many empirical investigations of investment decisions utilize the q theory of investment as their framework. Early work by Summers (1980) and Hayashi (1982) assumed that the capital stock was the only input that was costly to adjust. However, Shapiro (1986) and Kokklenberg (1984) consider interrelated factor demands. In these studies, real resources are absorbed when any productive input is adjusted. These models imply a much richer picture of firms' response to changes in interest rates, tax rates, or other factors that alter the return to capital.

III. The Model

We analyze a partial equilibrium model of investment where the firm maximizes the expected market value of its equity. The market value of equity is the present discounted value of the dividends to be received by the shareholders. Shareholders discount future dividends at the after-tax required rate of return on equity.

In Appendix A, we show that this objective at time O can be written as

$$\max \quad z_0 E_0 = \int_0^\infty e^{-\int_0^t \theta^*(\tau)d\tau} \gamma(t)dt \tag{1}$$

where

$$\theta^*_t = (\rho + p_t)/(1 - \tau_{ct}) \tag{2}$$

$$\gamma_t = (1 - \tau_{yt}) DIV_t/(1 - \tau_{ct}) \tag{3}$$

ρ = the after-tax real rate of return required by stockholders

p_t = the expected rate of inflation in commodity prices

τ_{ct} = marginal personal capital gains tax rate

τ_{yt} = marginal personal dividend tax rate

DIV_t = the dividend

z = the price of equity shares in terms of goods

E = the number of equity shares

We assume that the after-tax real required rate of return on equity ρ, the tax rates τ_{ct} and τ_{yt}, and the rate of inflation are exogenous to the firm. In the section on estimation we discuss expectation formation and informational assumptions. The firm's real and financial decisions at the start of period **t** will not influence θ^*_t, the after-tax rate of return required by shareholders. Rather, they influence γ_t, the dividend adjusted for taxes.

IV. Financial Structure

We assume that there is no additional equity issue and that the firm minimizes its financial costs by choosing between debt and retained earnings. At the margin, the costs of debt and retained earnings will be equal to the firm. Tax rates favor debt, but the debt cost increases with the ratio of

debt to tangible assets. The firm's financial and investment decisions thus affect the debt cost by influencing the debt-to-tangible-assets ratio.

The condition that tax rates favor debt over retained earnings can be written as

$$\frac{(1-\tau_{y0})}{(1-\tau_{c0})} > \frac{(1-\tau_{y1})}{(1-\tau_{c1}+\rho+p_1)}[1-p_1+s_0(1-\tau_{p1})] \qquad (4)$$

where s_0 = before-tax cost of debt issued at time 0.

The cost to stockholders of one dollar of retained earnings at time 0 is the foregone one dollar of dividends. The present value of this cost is the left side of expression (4). The cost of one dollar of debt issued at time 0 is the reduction in dividends paid at time 1. The present value of this cost is the right side of expression (4), using the definition of θ^* and s_0, and taking into account the reduction in the real debt burden due to inflation.

An interior solution for the firm's financial structure arises from the combination of expression (4) and the assumption that the before-tax cost of debt increases with the debt-to-tangible-assets ratio. The before-tax cost of debt issued in period t is written as

$$s_t = [a + v_1(B_t/\xi(K_t))]B_t \qquad (5)$$

where

B_t = book value of debt issued at the start of period t,

K_t = net stock of physical capital in place at the start of period t, and

$\xi(K_t)$ = book value of K_t.

a and v_1 are parameters to be estimated. We assume that all debt is rolled over each period and that interest is paid each period on the entire stock of debt. Condition (5) indicates that the before-tax cost of debt varies with the ratio of the book value of debt to the book value of the

physical capital stock. We assume that the book value of physical capital,

$\xi(K_t)$, is a function of the net stock of physical capital, K_t.

$\xi(K_t)$ and K_t will differ for a variety of reasons; for example, book

depreciation is not necessarily equal to physical depreciation. However,

we assume that the ratio between $\xi(K_t)$ and K_t, $\Delta_t = \xi(K_t)/K_t$,

is known to the firm, although it varies through time. The firm chooses K_t

directly and thus chooses $\xi(K_t)$ indirectly.

V.   Factor Demands

Following Shapiro (1986), we assume that the production function is given

by

$$\log y_t = a_0 + a_K \log K_t + a_L \log L_t + a_H \log H_t + a_N \log N_t \qquad (6)$$

$$- .5[g_{KK}(K_{t+1}-d_t K_t)^2 + g_{LL}(L_t-q_{t-1}L_{t-1})^2 + g_{HH}(H_t-H_{t-1})^2$$

$$+ \quad g_{NN}(N_t-N_{t-1})^2] + a,t + \varepsilon_t$$

where

y_t = real output,

K_t = physical capital stock at beginning of period **t,**

L_t = production employment in period **t,**

H_t = weekly hours per production worker in period **t,**

N_t = nonproduction employment in period **t,**

d_t = one minus the physical depreciation rate of capital,

q_t = one minus the quit rate, and

ε_t = shock to the production function.

Here the costs of gross adjustments in the level of the factors are

expressed in terms of output losses. We have assumed that factor demands are

not interrelated; the cost of adjusting a single input does not depend on

changes in the other inputs. The empirical results of Shapiro and Kokklenberg have been inconclusive regarding the significance of such interrelatedness. The productive time lost because of reorganizing production and installing equipment should vary with net investment plus depreciation, not just with net investment, since empirically it may be difficult to distinguish between the two. Similarly, costs are incurred in training new employees even if the level of production employment is unchanged. The cost of training new employees is distinct from the costs of increasing hours per employee (such as overtime).

The cost of production and nonproduction employment is expressed as

$$W_t^* L_t H_t + f_t^L L_t + f_t^N N_t \qquad (7)$$

where

W_t^* = wage rate for production workers inclusive of overtime,

f_t^L = nonwage cost of a production worker, and

f_t^N = cost of a nonproduction worker.

ω_1 is the overtime premium.[3] f_t^L and f_t^N are nonwage costs. For nonproduction workers, f_t^N includes salaries and fringe benefits. For production workers, f_t^L includes only fringe benefits. The wage bill, or variable cost of production employment, is written as

$$W_t^* L_t H_t = W_t L_t [H_t + \omega_0 + \omega_1 (H_t - H_t^*)] \qquad (8)$$

where

H_t^* = level of hours at which overtime starts,

$H_t - H_t^*$ = overtime hours per production employee, and

W_t = wage rate for production workers exclusive of overtime.

ω_0 and ω_1 are parameters to be estimated.[4] ω_1 should be positive if the wage bill is to increase with overtime hours. This formulation suggests that any "slow" adjustment in hours may be partially due

to an increase in the wage rate as overtime hours rise.

Gross changes in the level of investment, K_t, are financed through debt issue, retained earnings, or the decrease in the real debt burden due to inflation. This is expressed in condition (9).

$$\beta_t I_t = RE_t + (B_{t+1} - B_t) + p_t B_t \tag{9}$$

where β_t is the relative price of investment goods.

In addition, the firm receives an investment tax credit, ITC_t, on each dollar of investment expenditure at time **t** and is able to deduct depreciation expenses in accordance with the tax code. Below, D_t equals the present discounted value of all depreciation deductions associated with one dollar of investment at time **t**.

Total revenue is $\alpha_t y_t$, where α_t is the price of output at time **t**. Total revenue equals the sum of wages, nonwage payments to labor, taxes, interest, dividends, and retained earnings. In appendix A, expressions (6), (7), (8), and (9) are used to solve for the dividend. Using these results, a discrete time version of expression (1), the market value of equity at time 0, is written as

$$V_0 = \sum_{t=0}^{\infty} \Pi_{j=0}^{t} \left[\frac{1}{1+\theta^*_j}\right]\left[\frac{1-\tau_{yt}}{1-\tau_{ct}}\right]\{(1-\tau_{pt})[\alpha_t y_t - \tag{10}$$

$$(W_t L_t [H_t + \omega_0 + \omega_1 (H_t - H^*_t)] + f^L_t L_t + f^N_t N_t)]$$

$$- (1-\tau_{pt})[s + v_1(B_t/\xi(K_t))]B_t + (B_{t+1} - B_t)$$

$$+ p_t B_t + \tau_{pt} D_t \beta_t I_t - \beta_t I_t (1-ITC_t)\}.$$

Here inflation has complex effects on investment, as we would expect given previous investigations (see Feldstein [1987] and Chirinko [1987]). First, the investment tax credit is based on the historical cost of investment goods, not real expenditures. Second, depreciation deductions are also based on historical cost rather than on the replacement cost. Third, the expression

for the dividend includes a term, $p_t B_t$, that roughly accounts for the fact that inflation erodes the real debt burden.

VI. Optimal Factor Demands and Financial Structure

At the beginning of period $t = 0,1,2,3,...$ the firm maximizes the expected value of V_t conditional on information available at the start of period t and initial conditions, $K_t = K_t$, $L_{t-1} = L_{t-1}$, $N_{t-1} = N_{t-1}$, $H_{t-1} = H_{t-1}$, and $B_t = B_t$. Since B_t and K_t are given at the start of period t, the firm chooses B_{t+1} and K_{t+1} as well as L_t, N_t, and H_t.

The following first-order conditions hold for all $t = 0,1,2,...$:

$$\frac{\partial E_{t-1}(V_t)}{\partial L_t} = 0; \quad E_{t-1}\{(1-\tau_{pt})[\frac{1-\tau_{yt}}{1-\tau_{ct}}][\alpha_t y_t (a_L/L_t - g_{LL}(L_t - q_{t-1}L_{t-1})) \quad (11)$$

$$- W_t[H_t + \omega_0 + \omega_1(H_t - H^*_t)] - f_t^L]$$

$$+ [\frac{1}{1+\theta^*_{t+1}}][\frac{1-\tau_{yt+1}}{1-\tau_{ct+1}}](1-\tau_{pt+1})\alpha_{t+1}y_{t+1}g_{LL}q_t(L_{t+1}-q_tL_t)\} = 0.$$

$$\frac{\partial E_{t-1}(V_t)}{\partial H_t} = 0; \quad E_{t-1}\{(1-\tau_{pt})[\frac{1-\tau_{yt}}{1-\tau_{ct}}][\alpha_t y_t(a_H/H_t - g_{HH}(H_t - H_{t-1}) - W_t L_t(1+\omega_1))] \quad (12)$$

$$+ [\frac{1}{1+\theta^*_{t+1}}][\frac{1-\tau_{yt+1}}{1-\tau_{ct+1}}](1-\tau_{pt+1})\alpha_{t+1}y_{t+1}g_{HH}(H_{t+1}-H_t)\} = 0.$$

$$\frac{\partial E_{t-1}(V_t)}{\partial N_t} = 0; \quad E_{t-1}\{(1-\tau_{pt})[\frac{1-\tau_{yt}}{1-\tau_{ct}}][\alpha_t y_t(a_N/N_t - g_{NN}(N_t - q_{t-1}N_{t-1})) - f_t^N] \quad (13)$$

$$+ [\frac{1}{1+\theta^*_{t+1}}][\frac{1-\tau_{yt+1}}{1-\tau_{ct+1}}](1-\tau_{pt+1})\alpha_{t+1}y_{t+1}g_{NN}q_t(N_{t+1}-q_tN_t)\} = 0.$$

$$\frac{\partial E_{t-1}(V_t)}{\partial B_{t+1}} = 0; \quad E_{t-1}\{(\frac{1-\tau_{yt}}{1-\tau_{ct}} + \quad (14)$$

$$[\frac{1}{1+\theta^*_{t+1}}][\frac{1-\tau_{yt+1}}{1-\tau_{ct+1}}][-(1-\tau_{pt+1})(s+2v_1[B_{t+1}/\xi(K_{t+1})])-1+p_{t+1}]\} = 0.$$

$$\frac{\partial E_{t-1}(V_t)}{\partial K_{t+1}} = 0; \quad E_{t-1}\left\{(1-\tau_{pt})\left[\frac{1-\tau_{yt}}{1-\tau_{ct}}\right][\alpha_t y_t(-g_{KK}(K_{t+1}-dK_t))]\right. \tag{15}$$

$$+ \left[\frac{1-\tau_{yt}}{1-\tau_{ct}}\right][\beta_t(\tau_{pt}D_t-1+ITC_t)]$$

$$+ \left[\frac{1}{1+\theta^*_{t+1}}\right]\left[\frac{1-\tau_{yt+1}}{1-\tau_{ct+1}}\right]\{(1-\tau_{pt+1})(a_K/K_{t+1}+d_t(K_{t+2}-dK_{t+1})g_{KK})$$

$$+ (1-\tau_{pt+1})v_1[B^2_{t+1}/(K_{t+1}\xi(K_{t+1}))] + [\tau_{pt+1}D_{t+1}-1+ITC_{t+1}]\beta_{t+1}(-d_t)\}\bigg\} = 0.$$

$$\lim_{T\to\infty} \frac{\partial(E_{t-1}V_T)}{\partial L_T} = 0 \tag{16}$$

$$\lim_{T\to\infty} \frac{\partial(E_{t-1}V_T)}{\partial H_T} = 0 \tag{17}$$

$$\lim_{T\to\infty} \frac{\partial(E_{t-1}V_T)}{\partial N_T} = 0 \tag{18}$$

$$\lim_{T\to\infty} \frac{\partial(E_{t-1}V_T)}{\partial B_T} = 0 \tag{19}$$

$$\lim_{T\to\infty} \frac{\partial(E_{t-1}V_T)}{\partial K_T} = 0 \tag{20}$$

Each Euler equation requires that **it** is not possible to increase expected market value by further increases in K_t, L_t, N_t, H_t, or B_t. In expectation terms, marginal benefit equals marginal cost. The choices of K_t, L_t, N_t, and H_t depend directly on the expectation of their values in the next period, because adjustment costs in period t+1 depend on the change between periods.

As **I** demonstrate in appendix B, expression (14) states that the expected cost of funds is equalized between retained earnings and debt issue. The choices of debt and physical capital are linked through their joint impact on the cost of debt. An increase in K_{t+1} implies adjustment costs but increases period **t** cash flow via depreciation deductions and investment tax credits. Increases in K_{t+1} increase period t+1 output, but the overall impact of an increase in K_{t+1} on period **t+1** cash flow also depends on the

future choice of K_{t+2}. The initial conditions, the transversality conditions, (16) through (20), and the Euler equations, (11) through (15), will imply a unique solution path when combined with the assumptions that $0 < 1/(1+\theta^*) < 1$, and that the production function is concave and twice continuously differentiable in K, L, N, and H (see Lucas and Prescott [1971]).

VII.   Estimation

We estimate the parameters of the production function and the debt cost function without solving for the firm's decision rules directly. We utilize a version of Hansen and Singleton's (1982) Generalized Instrumental Variables Estimator, which, given our assumptions, is identical to ordinary nonlinear three-stage least squares. This approach presents both advantages and disadvantages.

Decision rules can be derived **if,** in addition to the assumptions mentioned above that guarantee uniqueness, 1) prices and all other variables exogenous to the firm follow covariance stationary stochastic processes known to the firm, 2) the rate used to discount the future, θ^*, is constant, and 3) the production function is quadratic.   In appendix B, I show how under these conditions the Euler equations can be solved to show that the firm's decisions are related to its expectations of variables that are not in the information set.

Although the firm makes forecasts of its future decisions based on its forecasts of future prices, taxes, etc., its actual choices of future input levels will be made after additional information has been received.

Because our discount rate varies over time, we do not utilize the decision rule technique.   However, directly estimating the Euler equations entails a loss of efficiency.   The decision rule method utilizes more information by

imposing the cross-equation restrictions between the stochastic processes, generating the forcing variables and the decision rules themselves. It may appear that the Euler equation method avoids the need to specify the stochastic processes generating the forcing variables. However, Garber and King (1983) note that Euler equation estimation requires informational assumptions similar to those of conventional simultaneous equations theory.

Garber and King point out that Euler equation methodology does not avoid the need to specify the details of the general equilibrium in which economic agents make their decisions. In their general equilibrium model, identification and estimation difficulties arise when the econometrician is unable to observe shifts in agents' objectives. In our case, the problem may arise if there are actually shocks to preferences but not production. Then, as a result of having incorrectly specified the shocks, we may end up estimating preference parameters rather than production parameters.

The form of the stochastic Euler equations (11) through (15) tends naturally to suggest use of the "generalized instrumental variables estimator" proposed by Hansen and Singleton (1982).

Note that if

$$E_{t-1} h(X_t, \underline{\theta}) = \underline{0}, \tag{21}$$

where X_t is the matrix of all endogenous and exogenous variables and $\underline{\theta}$ is the vector of parameters, then the product of each such Euler equation and instruments in the information set is also zero:

$$E_{t-1} h(X_t, \underline{\theta}) \cdot Z_t = \underline{0}. \tag{22}$$

Substituting for variables unknown at time t in the Euler equations yields

$$h(X_t, \underline{\theta}) \cdot Z_t = \underline{e}_t. \tag{23}$$

Equation (24) suggests why it is natural to interpret the $\underline{e}_t$s as

forecast errors.

$$E_{t-1}\{h(X_t,\underline{\theta}) - E_{t-1}[h(X_t, \underline{\theta})]\} = \underline{0}. \tag{24}$$

The estimator of $\underline{\theta}$ suggested by Hansen and Singleton minimizes a weighted sum of the products of the instruments and $h(X_t,\underline{\theta})$. They derive the weighting matrix that minimizes asymptotic standard errors even under conditional heteroscedasticity. I assume conditional homoscedasticity of the e_ts instead, and hence utilize nonlinear three-stage least squares.

As instruments I utilize the variables listed at the top of table 1. These include all variables dated $t-1$ but none dated t. Since all variables dated t are realized average values over period t, they cannot be in the firm's information set at the start of period t. This applies even to the tax rates, investment tax credit, and depreciation deduction schedules. Thus, the values of future endogenous variables are not known at time t. Their values will be chosen at the beginning of the next period, after new information has been received by the firm. If there are specification errors, then the e_ts are more than forecast errors. Instruments dated t are not valid if the specification error component is serially correlated.

For the system studied, 104 observations and 11 parameters will be estimated. I assume the error terms may be correlated contemporaneously across equations but not through time. The expression for the wage bill (8) is estimated along with the Euler equations, expressions (11) through (15). Since the Euler equation for debt contains no current endogenous variables, I exclude that equation from estimation. In order to utilize the appropriate routine in the Time Series Processor (Version 4.0), I "solve" each Euler equation for the corresponding future endogenous variable. Thus, the left-side variables for the transformed Euler equations are L_{t+1}, H_{t+1}, N_{t+1}, and K_{t+2}. Data are described in appendix C.

VIII. Results

The parameter estimates and a list of the instruments are presented in table 1. The sets of starting values, all of which led to the same estimates, are available from the author. Except where otherwise noted, I refer below to the results of one-tailed t tests of the hypothesis that the parameters are zero, with the alternative hypothesis that the parameters are positive. Of the 11 parameters estimated, five are significant at the 5 percent level.

Both parameters in the wage bill function, expression (8), are significant. ω_0 is significant at the 10 percent level and ω_1 is significant at the 5 percent level. The estimate of w,, 0.475, is near .5, the typical overtime premium.

The estimates of g_{NN} and g_{KK} are both significant at the 5 percent level. Neither g_{LL} nor g_{HH}, however, is significant at the 10 percent level. This confirms Shapiro's results that the only significant costs to adjusting the level of production employment and hours are the additional wages or salaries. Of the output elasticities, only the elasticity of output with respect to L, a_L, and the elasticity of output with respect to N, a_N, are significantly different from zero. Both are significant at the 5 percent level. Following Shapiro, I interpret the reasonableness of the estimates by calculating the implied changes in quarterly flows at quarterly rates in 1967 dollars using the estimated parameters and arithmetic averages of variables. For example, using average values of y and L and the estimate of a_L, I calculate that the increase in output, gross of adjustment costs, due to an extra million production employees is $1.7 billion. This amounts to $6,800 per production employee per year.

It is useful to compare the output and costs of increasing production labor input via increases in L versus increases in H. First, note that a

one-million increase in production employment increases quarterly hours by 524.87 million. Since this increase of 524.87 million hours increases output by \$1.7 billion, increasing production employment so as to increase hours by one million hours would increase output by \$3.25 million. The increase in compensation required for these additional employees is calculated from the wage bill as $W_t[H_t+\omega_0+\omega_1(H_t-H_t^*)]$ and from the fixed cost component, f_t^L.

The cost of increasing total hours per quarter by one million through increases in production employment is \$3.82 million. Increasing quarterly hours by one million via increases in hours per employee requires an increase of \$4.9 million in compensation. This is calculated from the expression for the wage bill as $W_tL_t(1+\omega_1)$.

Ignoring any adjustment costs for H or L, the lower compensation cost for L compared with H implies that it is cheaper to hire and lay off than to meet increased demand via increased hours. The estimate of g_{NN} implies that a one-million change in nonproduction employment entails .\$12 billion in quarterly adjustment costs. The fixed cost of one million nonproduction employees is \$7.97 billion, while the additional output attributed to these workers is \$7.16 billion. The average level of f_t^N implies that each nonproduction employee was paid an average of almost \$32,000 per year over the sample period.

The estimate of g_{KK} implies that changing the capital stock by \$1 billion entails adjustment costs of \$1.22 billion. The estimate of a_K is not significant at the 10 percent level; the estimate of v_1 is significant but negative.

Since explaining the physical capital choice is a primary focus in this paper, the implausibility of the estimates of a_K and v_1 is discouraging.

To see if the inclusion of the v_1 term was responsible for the insignificance of the estimate of a_K, I excluded the v_1 term and estimated the Euler equation for physical capital. The results, given in table 2, indicate that without the v_1 term, the estimate of a_K remains implausible; a_K should be significant and positive.

I also consider the possibility that I have misspecified the impact of inflation on investment. As indicated previously, inflation affects investment through its impact on depreciation deductions, on investment tax credits, on the real debt burden facing the firm, and on the cost of debt. The series for ITC and D are based on actual deductions and credits and are influenced by inflation. I have not, however, modeled the impact of inflation on the cost of debt in expression (5).

Since inflation rates seemed to shift in the late 1960s, one crude way to control the effect of inflation is by splitting the sample period. Table 2 presents the results of the estimation of the Euler equation for physical capital with the sample period split at the end of the second quarter of 1968.

The sign of the estimate of v_1 is positive in both subperiods and is significant at the 5 percent level in the earlier subperiod. The sign of a_K is negative but significant in both subperiods. In addition, Chow tests indicate rejection of the hypothesis that the coefficients are constant across the two subperiods. This result obtains whether or not the v_1 term is excluded.

IX.   Conclusions

This paper has presented a partial equilibrium model of a representative firm maximizing the expected value of its equity via its choice of production labor, nonproduction labor, hours of production labor, capital stock, and debt

issue. It differs from other efforts by its more complete treatment of the choice of financial structure. The financing choice affects the path of the capital stock in the theory presented. The Euler equations, together with an equation indicating how the average wage rate varies with overtime hours, are estimated with instrumental variables.

Of empirical studies of adjustment costs, this study is closest to that of Shapiro.[5] Shapiro, however, assumes that overtime starts at 40 hours while I assume that overtime starts at a level that varies in each period. This difference in specification may explain why Shapiro's estimate of a_H is significant while mine is 'not. Shapiro also finds a_K to be significant, possibly because he uses the Treasury bill rate plus 3 percent as θ^*, while I construct θ^* to incorporate tax rates and inflation.

The insignificance of a_K and the "wrong" sign for v_1 suggest that the the model in this paper is misspecified. A crude attempt to control for the effect of inflation on the estimates of a_K and v_1 suggests that misspecification may involve the measurement of the impact of inflation on investment. The sign of a_K, however, remains implausible for each subperiod; an increase in the stock of physical capital should increase output. Further work will be aimed at isolating the factors responsible for these results. A tentative conclusion may be that the results of other studies need to be qualified by their assumptions about the effect of financial structure on investment decisions.

Glossary of Terms

θ^* = the "discount rate" applicable to quarter t cash flow

ρ = fixed real rate of return required by stockholders

p_t = rate of commodity price inflation

τ_{ct} = marginal personal rate of capital gains taxation

τ_{yt} = marginal personal rate of dividend income taxation

τ_{pt} = corporate profits tax rate

$DIV,$ = the dividend

γ_t = cash flow

y_t = real output of manufacturing

K_t = physical capital stock at the start of period t

$L,$ = level of production employment in period t

H_t = weekly hours per production worker

N_t = level of nonproduction employment

d = one minus the quarterly rate of physical depreciation of the physical capital stock

q_t = one minus the quit rate

$\xi(K_t)$ = book value of the stock of physical capital

B_t = book value of debt

H^*_t = level of weekly hours per employee at which overtime starts

W^*_t = hourly wage rate inclusive of overtime payments

W_t = hourlywage rate exclusiveof overtime

f^L_t = the fixed cost of a production worker

f^N_t = the fixed cost of a nonproduction worker

α_t = manufacturing output price index

β_t = investment goods price index

ε_t = shock to the production function

D_t = present value of depreciation deductions

ITC_t = investment tax credit

Table 1

The Instruments

τ_{yt-1}, τ_{pt-1}, Θ^*_{t-1}, τ_{ct-1}, q_{t-1}, $(H_{t-1}-H^*_{t-1})$,

H_{t-1}, N_{t-1}, f^L_{t-1}, K_t, B_t, $\xi(K_t)$, D_{t-1}, ITC_{t-1}, β_{t-1},

time(trend), 1(constant), W_{t-1}, y_{t-1}, f^N_{t-1}.

Estimates of Parameters in the Euler Equations and the Wage Bill
(expressions [11], [12], [13], [15], and [8])

ω_0	0.101 (1.659)	intercept in wage bill function
ω_1	0.475 (25.41)	overtime premium
a_L	0.1686 (7.52)	production worker elasticity
a_H	0.697 (0.0239)	production hours elasticity
a_N	0.2518 (20.64)	nonproduction worker elasticity
a_K	−0.0174 (−0.5845)	physical capital elasticity
g_{LL}	0.0764 (0.907)	production labor adjustment cost
g_{HH}	1.382 (−0.017)	hours adjustment cost
g_{NN}	0.9455 (2.392)	nonproduction worker adjustment cost
g_{KK}	0.0018 (2.473)	capital adjustment cost
v_1	−0.682 (−1.657)	marginal cost of borrowing with respect to book debt/book capital

NOTE: Asymptotic t-statistics are in parentheses.
Number of observations: 104.

Table 2

Estimates of Parameters in the Euler Equation for Physical Capital,
Expression (15)

Period:	1954:IIIQ–1968:IIQ	1968:IIIQ–1980:IIQ	1954:IIIQ–1980:IIQ
Parameter	Estimates Including v_1		
a_K	-0.2729 (-2.569)	-0.5632 (-1.709)	-0.01135 (-0.4669)
g_{KK}	0.0021 (1.769)	0.0013 (2.539)	0.0013 (3.0267)
v_1	2.1728 (2.412)	1.9424 (1.474)	-0.5289 (-1.786)
SSR	7.328	6.813	22.261
NOBS	56	48	104
Parameter	Estimates Excluding v_1		
a_K	-0.3820 (-0.422)	-0.1110 (-0.3248)	-0.0597 (-4.064)
g_{KK}	0.0138 (0.4063)	0.0009 (3.3983)	0.0010 (3.7689)
SSR	6.501	8.579	26.847
NOBS	56	48	104

NOTE: Asymptotic t-statistics are in parentheses.
SSR: Sum of squared residuals.
NOBS: Number of observations.

Footnotes

1. Haugen and Senbet (1986) provide a useful review of this literature.

2. The theoretical importance of collateral in a general equilibrium model has been investigated by Bernanke and Gertler (1986). In their model, the agency cost of investment is lower with greater collateral.

3. I assume that all workers work H_t^* straight-time hours. With the data I use, $H_t - H_t^*$ is always positive.

4. ω_0 is included to permit a more general specification of the response of overtime wages to an increase in hours.

5. Shapiro's study differs from that mine in that he
1) imposes $a_k + a_L + a_N = 1$,
2) uses a different list of instruments,
3) uses a different measure of the cost of capital,
4) assumes that maximization of the market value of debt plus equity is the objective of the firm, implying that τ_y and τ_c do not enter the problem, and
5) specifies the wage bill function differently.\

Appendix A

Here we derive expression (1) in the text. This derivation follows Summers (1980).

The return on the equity of the firm has two components. One is after-tax capital gains $(1-\tau_c)\dot{V}$. The other is after-tax dividends 1 - 1The total must equal the return required by stockholders p, adjusted for the rate of inflation. This implies

(A1) $(\rho+p_t)V_t = (1-\tau_c)\dot{V}_t + (1-\tau_{yt})DIV_t.$

To prevent the solution to (A1) from exploding, we assume

(A2) $\lim V, \; e^{-\int_t^s [(\rho+p_u)/(1-\tau_{cu})]du} = 0.$

Then, the value of the firm's equity at time **t** can be written as

(A3) $V_t = \int_t^\infty \left[\dfrac{(1-\tau_{ys})}{(1-\tau_{cs})}\right]DIV_s e^{-\int_t^s [(\rho+p_u)/(1-\tau_{cu})]du} \, ds.$

Second, we derive the expression for dividends, embedded in expression (10), in the text. First, note that revenues equal the sum of wages, nonwage payments to labor, taxes, interest, dividends, and retained earnings.

(A4) $\quad \alpha_t y_t = W_t L_t [H_t + \omega_0 + \omega_1 (H_t - H^*_t)] + f^L_t L_t + f^N_t N_t$

$$+ \tau_{pt}\{\alpha_t y_t - (W_t L_t [H_t + \omega_0 + \omega_1 (H_t - H^*_t)] + f^L_t L_t + f^N_t N_t)$$

$$- (s + v_1 [B_t / \xi(K_t)]) B_t\} + DIV_t + RE_t$$

$$+ (s + v_1 [B_t / \xi(K_t)]) B_t.$$

Next, as indicated in expression (9) in the text, all investment is financed through retained earnings, new debt issue, or the decline in the real burden of debt due to inflation. The term $p_t B_t$ is the revenue accruing to the firm because the bonds are assumed to be denominated in nominal terms.

Substituting for RE in (A4) and solving for RE yields expression (10). Expression (A3) implies that the capital gains tax rate influences the value of the firm only **if** the value of the firm is expected to change. For example, suppose all terms entering into V_0 are constant. Then (A1) can be solved as follows:

(A5) $\quad V_0 = \dfrac{(1-\tau_y) DIV}{(1-\tau_c)} \displaystyle\int_0^\infty e^{-\int_0^t [(\rho+p)/(1-\tau_c)] du} \, dt$

$$= \dfrac{(1-\tau_y) DIV}{(1-\tau_c)} \int_0^\infty e^{-[(\rho+p)/(1-\tau_c)] \int du} \, ds$$

$$= \dfrac{(1-\tau_y) DIV}{(1-\tau_c)} \int_0^\infty e^{-[(\rho+p)/(1-\tau_c)] t} \, ds$$

$$= \dfrac{(1-\tau_y) DIV}{(1-\tau_c)} \left[\dfrac{e^{-[(\rho+p)/(1-\tau_c)] t}}{-(\rho+p)/(1-\tau_c)} \right]_0^\infty$$

$$= \dfrac{(1-\tau_y) DIV}{(1-\tau_c)} \left(\dfrac{1}{\rho+p} \right).$$

However, suppose that at time $T > 0$ dividends increased. Then the value of the firm at time T will rise, implying capital gains between time 0 and time T. In this case, the value of the firm at time 0 can be written as

$$(A6) \quad V_0 = \frac{(1-\tau_y)DIV_0}{(1-\tau_c)} \int_o^T e^{-\theta * \int_0^t d\tau} \, dt + \frac{(1-\tau_y)DIV_1}{(1-\tau_c)} \int_T^\infty e^{-\theta * \int_0^t d\tau} \, dt$$

$$= \frac{(1-\tau_y)}{(1-\tau_c)} [\, \frac{DIV_0}{\theta_0} + \frac{e^{-\theta T}}{\theta} (DIV_1 - DIV_0)]$$

$$= \frac{(1-\tau_y)}{(1-\tau_c)} \frac{DIV_0}{(\rho+p)} + \frac{(1-\tau_y)}{(1-\tau_c)} [\, \frac{e^{-\theta T}}{\theta} (DIV_1-DIV_0)]$$

$$= \frac{(1-\tau_y)DIV_0}{(\rho+p)} + \frac{(1-\tau_y)}{(\rho+p)} [\, e^{-[(\rho+p)/(1-\tau_c)]T} (DIV_1-DIV_0)]$$

This implies that $\frac{\partial[(\partial V_0/\partial Div)]}{\partial \tau_c} < 0$.

The first-order condition for production employment (11), can be solved subject to the transversality condition (16) and the initial condition to yield a decision rule for production employment. Assuming all terms in expression (11) other than L_{t+1} are in the information set at the start of period t, ▌ can replace expression (11) with the following expression:

(B1) $\frac{(1-\tau_{yt})(1-\tau_{pt})[\alpha_t y_t(a_L/L_t-g_{LL}(L_t-q_{t-1}L_{t-1}))-W_t[H_t+\omega_0+\omega_1(H_t-H^*_t)]]}{(1-\tau_c)}$

$\quad + [\frac{1}{1+\theta^*_{t+1}}][\frac{1-\tau_{yt+1}}{1-\tau_{ct+1}}][(1-\tau_{pt+1})\alpha_{t+1}y_{t+1}g_{LL}q_t \ E_{t-1}(L_{t+1}-q_tL_t)] = 0.$

This can be rewritten as

(B2) $g_{LL}A_{1t}E_{t-1}(L_{t+1}-q_tL_t)-g_{LL}A_{2t} \ G \ E_{t-1}[L_{t+1}-q_tL_t]$

$\quad = -a_LA_{2t} \ E_{t-1}(1/L_t) + (A_{2t}/\alpha_t y_t) \ E_{t-1}\{W_t[H_t+\omega_0+\omega_1(H_t-H^*_t)]+f^L_t\}$

where G is the lag operator. ▌ have assumed that A_{1t} and A_{2t} are in the information set at the start of period t. A_{1t} and A, are defined as follows:

(B3) $A_{1t} = (\frac{1}{1+\theta^*_{t+1}})(\frac{1-\tau_{yt+1}}{1-\tau_{ct+1}})(1-\tau_{pt+1})\alpha_{t+1}y_{t+1}q_t$

(B4) $A_{2t} = \frac{(1-\tau_{yt})(1-\tau_{pt})\alpha_t y_t}{(1-\tau_{ct})}.$

Expression (B2) can be rewritten as

$$\text{(B5)} \quad E_{t-1}(L_{t+1} - q_t L_t)[1 - (A_{2t}/A_{1t})G] = -\frac{a_L}{g_{LL}}\frac{A_{2t}}{A_{1t}} E_{t-1}(1/L_t)$$

$$+ \frac{\omega_0}{g_{LL}}\frac{A_{2t}}{A_{1t}} E_{t-1}\left[\frac{W_t}{\alpha_t y_t}\right] + \left(\frac{1}{g_{LL}}\right)\frac{A_{2t}}{A_{1t}} E_{t-1}\left[\frac{W_t H_t}{\alpha_t y_t}\right]$$

$$+ \frac{\omega_1}{g_{LL}}\frac{A_{2t}}{A_{1t}} E_{t-1}\left[\frac{W_t(H_t - H^*_t)}{\alpha_t y_t}\right] + \left(\frac{1}{g_{LL}}\right)\frac{A_{2t}}{A_{1t}\alpha_t y_t} E_{t-1}(f^L_t).$$

In order to satisfy the transversality condition (16), I must solve either forward or backward, depending on the magnitude of A_{2t}/A_{1t}. Below, I assume that $A_{2t}/A_{1t} < 1$.

$$\text{(B6)} \quad L_{t+1} = q_t L_t - \left(\frac{a_L}{g_{LL}}\right)\frac{A_{2t}}{A_{1t}} \sum_{i=0}^{\infty} \left(\frac{A_{2t}}{A_{1t}}\right)^i E_{t-1}(1/L_{t+i})$$

$$+ \left(\frac{1}{g_{LL}}\right)\frac{A_{2t}}{\alpha_t y_t A_{1t}} \sum_{i=0}^{\infty} \left(\frac{A_{2t}}{A_{1t}}\right)^i E_{t-1}[W_{t+i}H_{t+i} + f^L_{t+1}]$$

$$+ \left(\frac{\omega_0}{g_{LL}}\right)\frac{A_{2t}}{\alpha_t y_t A_{1t}} \sum_{i=0}^{\infty} \left(\frac{A_{2t}}{A_{1t}}\right)^i E_{t-1}W_{t+i}$$

$$+ \left(\frac{\omega_1}{g_{LL}}\right)\frac{A_{2t}}{A_{1t}\alpha_t y_t} \sum_{i=0}^{\infty} \left(\frac{A_{2t}}{A_{1t}}\right)^i E_{t-1}[W_{t+i}(H_{t+i} - H^*_{t+i})].$$

Estimation of expression (B6) rather than the Euler equation (11) would be complicated by a variety of factors. First, since A_{2t}/A_{1t} may vary through time, it is possible that for a given t, for example t_0, (B5) would have to be solved forward while for another t, t_1, (B5) would have to be solved backward. Second, estimation of expression (B5) would require a specification of the form of the expectations appearing on the right side.

All of the data employed are seasonally adjusted, quarterly data measured at quarterly rates and pertaining to all manufacturing, except where noted.

K_t is the stock of physical capital (billions of 1967 dollars) at the start of period t. It is calculated by the perpetual inventory method:

$$Kt = K_{t-1} - dK_{t-1} + I_{t-1}/IMPDEF_{t-1}.$$

d is a fixed $(d_t = d$ for all $t)$ rate of physical deterioration for structures and equipment in all manufacturing estimated by Jorgenson and Stephenson (1967). I_t is investment on new plant and equipment in manufacturing published by the Bureau of Economic Analysis (BEA), and IMPDEF is the investment price deflator for fixed nonresidential investment expenditures published by BEA in the Survey of Current Business (SCB). The net additions to the capital stock are expressed in 1967 prices. The starting value for K, $K_{1954:1Q}$, is the net stock of structures and equipment in manufacturing at the end of 1953 in 1967 prices as published in SCB.

L_t is the average number of production workers (in millions) employed in a given quarter. It is obtained by averaging the monthly data published by the Bureau of Labor Statistics in Employment and Earnings (EE). In order that all terms in the Euler equations and the expression for the cash flow be in billions of dollars, I multiply L by .001.

N_t is the average number of nonproduction employees (in millions)

over the quarter. The monthly number is calculated as the difference between total employment and production worker employment for the manufacturing sector. The quarterly level is the average of the levels for the three months in the quarter. The source is EE. As for L, N must be multiplied by .001 in the Euler equations.

q_t is the quit rate for employment. It is published in EE on a monthly, seasonally unadjusted basis. I seasonally adjust the arithmetic average of the three-month data in each quarter using an X-11 seasonal adjustment procedure.

H_t is the average number of hours per week for production employment. I use the average of weekly hours over the quarter. H, which includes overtime hours, is published in EE. In order that all terms in the Euler equations and the expression for cash flow be at quarterly rates, I multiply H by the average number of weeks in a quarter.

H, – H*, is the number of overtime hours per production employee per week. This series is available in EE. As for H, this series is scaled up by the average number of weeks per quarter.

W, is the average hourly wage rate for production workers. This is calculated as the average of the monthly data over the quarter. The monthly data are published in EE. W_t excludes overtime payments.

W*, is the average hourly wage rate for production workers including overtime. The quarterly average is calculated as an average of the monthly averages. The data are published in EE. Since these data are available only from 1956 onward, I extrapolate back to 1954 by 1) regressing the available data on a constant and a trend, 2) using the estimated trend coefficient to extrapolate backwards from the estimated intercept. Since this series is available only on an unadjusted basis,

the entire series from 1954 onward was seasonally adjusted using an X-11 procedure.

f_t^L is the fixed payment per production employee (billions of dollars per million employees). This is calculated from quarterly National Income and Product Account data. I calculate the total fixed cost to the sum of production and nonproduction employees as the difference between total compensation and the sum of wages and salaries and employer contributions to social insurance. This total is then divided by total employment to yield $f,$.

f_t^N is the fixed cost per nonproduction employee (billions of dollars per million employees). This is calculated as f_t^L plus a salary component. The salary component is calculated as wages and salaries minus wages paid to production employees, then divided by the average level of nonproduction employment. The wage bill for production employment is the product of average hourly wages, the number of production employees, and the average hours per production employee per quarter.

ρ is the real rate of return required by stockholders over a quarter. This is calculated from data on common stock returns published by Ibbotson and Sinquefeld (1982). It is the difference between the quarterly total rate of return on common stocks and the quarterly rate of change in the consumer price index. The quarterly total rate of return is κ_T where $(1 + \kappa_T)^{27 \times 4}$ = the ratio between the end-of-1980 index on total returns on common stock and the end-of-1953 index on total returns. The quarterly rate of change in the consumer price index is calculated as κ_P where $(1 + \kappa_P)^{27 \times 4}$ = the ratio between the end of 1980 consumer price index and the end of 1953 consumer price index.

Thus, p is a quarterly rate of return constant from 1954 to 1980. p
is calculated from seasonally unadjusted data.

p_t is the rate of change in the consumer price index for urban
workers over period t.   This is available in SCB.

τ_y is the marginal personal dividend income tax rate.   This
series is calculated by Estrella and Fuhrer (1983) from annual individual
income tax returns.   Thus, τ_t is available only on an annual basis.
I assume that the rate for each quarter is equal to the rate for the
entire year.

τ_c is the personal capital gains tax rate.   I follow Summers'
(1980) and Bailey's (1969) treatment of the effect of deferral and the
lack of constructive realization at death on the effective tax rate.
Bailey concludes that from 1932 to 1969, each of these factors halved the
effective rate.   Since over this period the statutory tax rate on capital
gains was half that on dividends, I use 12.5 percent of the dividend tax
rate from Estrella and Fuhrer as τ_c for 1954 to 1969.   I follow
Summers and cite the estimate of the NBER TAXSIM model that the 1969
capital gains reform made the rate 50 percent higher or 18.75 percent of
the dividend rate.

τ_p is the corporate profits tax rate.   I use the statutory
corporate profit tax rate as published in Pechman (1983).   I assume that
quarterly rates are equal to the annual rate.

y_t is the output of the manufacturing sector (billions of
dollars).   I use the Federal Reserve Board's index of manufacturing
production and inflate the product of y and a so that the average of
a and y for 1967 equals actual 1967 manufacturing output.   1967
manufacturing output is calculated as equal to 1967 value of shipments

plus the change in manufacturing inventories over 1967. Both the shipments and inventory data are published by BEA in Business Statistics. Both are unadjusted for seasonal variation. The inventory data is on a book value basis. I seasonally adjust y using an X-11 procedure. The production index is published monthly, and I use the average level of the index over the quarter.

a is the price of manufacturers' goods. I use the Producer Price Index for manufacturing published in Business Statistics. This index is published on a monthly basis, and I use the average index level for the quarter. Since this index is available only on an unadjusted basis, I adjust the quarterly data using an X-11 procedure.

ß is the price of investment goods. I use the implicit price deflator for fixed investment for the nonresidential sector. ß is based so that the product of ß and I is measured in 1967 dollars.

I is investment in plant and equipment. As indicated above, I use BEA's measure of investment expenditure on plant and equipment.

ITC_t is the investment tax credit at time t from one dollar of investment expenditure at time t. I use the series calculated by Jorgenson and Sullivan (1981) for the entire corporate sector. Their series takes account of the distribution of investment between structures and equipment as well as the distinction between usable and unusable tax credits. This series is thus an "effective" tax credit rate. It is published on an annual basis, and I assume the quarterly rates are equal to the annual rate.

D_t is the present value at time t of all current and future depreciation deductions from one dollar of investment at time t. Jorgenson and Sullivan publish this series on an annual basis. I assume

that the quarterly rates equal the annual rate. Jorgenson and Sullivan calculate their series from a simulation of the corporate sector taking account of the distribution of investment across investment types. They also take into account evidence regarding accounting practices, capital lifetimes, and salvage values.

$\xi(K_t)$ is the book value of capital at time t (billions of dollars). I use the series on the book value of "depreciable and amortizable fixed assets, including construction in progress" published in the Quarterly Financial Report (QFR) by the Bureau of the Census. The data were supplied by Data Resources Inc. Below I discuss how I compensated for several discontinuities within the series. After this adjustment, I seasonally adjust the data.

B_t is the book value of debt (billions of dollars). I use the series on short term debt ("original maturity of 1 year or less"), "installments due in one year or less on long term debt" and "long term debt" (due in more than one year) published in the QFR. I adjust for discontinuities in these series and then seasonally adjust the total of these series. Thus, B_t excludes "trade accounts" and "deferred taxes" and other liabilities.

The QFR series on the book value of debt and the book value of the capital stock contained two breaks in continuity. In 1967 newspapers were added to the sample and DRI did not continue the series forward. In 1974 the entire sampling procedure and questionnaire were changed, causing another break in the series. A visual examination of the series suggested that I make a level adjustment for the 1973:IVQ to 1974:IQ break. I accomplished this using the overlap data available for those two quarters.

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