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THE RELATION BETWEEN FIRM GROWTH AND Q WITH MULTIPLE CAPITAL GOODS: THEORY AND EVIDENCE FROM PANEL DATA ON JAPANESE FIRMS

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ABSTRACT

We derive from a model of investment with multiple capital goods a one-to-one relation between the growth rate of the capital aggregate and the stock market-based Q. We estimate the growth-Q relation using a panel of Japanese manufacturing firms taking into account the endogeneity of Q. Identification is achieved by combining the theoretical structure of the Q model and an assumed serial correlation structure of the technology shock which is the error term in the growth-Q equation. For early years of our sample, cash flow has significant explanatory power over and above Q. The significance of cash flow disappears for more recent years for the heavy industry when Japanese capital markets was liberalized. The estimated Q coefficient implies that the adjustment cost is less than a half of gross profits net of the adjustment cost.

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1. INTRODUCTION AND SUMMARY

This paper uses a panel of several hundred Japanese manufacturing firms to estimate the relation between investment and Q. The investment-Q relation is a first-order condition for the firm's dynamic optimization with adjustment costs and states that the marginal adjustment cost of investment be equal to the shadow price of capital. For competitive firms under constant returns to scale, this relation is operational because the unobservable shadow price is directly linked to the stock market valuation of existing capital (Lucas and Prescott (1971) and Hayashi (1982)), which allows one to estimate the parameters that characterize the adjustment cost function. The estimated parameters are structural in the sense of Marschak and Lucas: they are invariant to the structure of the environment faced by the firm because it is fully captured by the shadow price.

Despite its considerable theoretical appeal, empirical performance of the Q-based investment equation has been disappointing. Studies based on aggregate time-series data (see Chirinko (1988) for a review) and recent micro studies (including Blundell, Bond, Devereux and Schiantarelli (1987) for the U.K. and Fazzari, Hubbard and Petersen (1988) for the U.S.) indicate that Q is at best one of the few significant explanatory variables for investment. The Q coefficient is implausibly small, while other variables like output, profits or cash flow often prove to be more strongly associated with investment.

We think that it is yet too early to discredit the model of dynamic optimization with adjustment costs under perfect competition — upon which the investment-Q relation is based — for a couple of reasons. First, with an exception of Blundell *et. al.* (1987), existing studies do not seem to have examined carefully possible biases due to the fact that Q is endogenous. As we will argue in section 4 and is summarized below, the Q model predicts that ordinary least squares *should* find variables like cash flow and output to be significant if added to the investment equation along with Q. Second, the estimated Q-based equation may be mis-specified. In all empirical studies to date, the investment measure is the sum of nominal investments.[1] As Wildasin (1984) has shown, one has to invoke a very stringent set of assumptions including the Hicks aggregation condition to derive a one-to-one relation between the sum of investments and Q that is independent of the composition of investments.

These two issues are fully addressed in the paper. Regarding the latter issue, the investment measure in our Q-based equation is the growth rate of a scalar index of multiple capital inputs, not the sum of investments, and the denominator in the Q ratio is this capital aggregate, not the sum of nominal capital stocks. We derive our Q-based investment equation from a model of optimal capital accumulation with multiple capital goods, previously considered by Epstein (1983), in which adjustment costs depend on the change in this capital aggregate. This provides a bridge between investment theory and the productivity literature, because the capital aggregate in our Q-based equation is precisely the quantity index of capital inputs routinely calculated in the literature on productivity growth.[2]

The issue of endogeneity of Q is taken seriously in our estimation of the firm growth-Q relation. The error term in the growth-Q relation is a technology shock to the profit function that subsumes adjustment costs. Variables like output, profits, and cash flow are directly affected by this shock and hence will pick up significant regression coefficients when added to the growth-Q equation. This rules out the use of "extraneous" instruments. We achieve identification by combining the structure of the Q model and an assumed serial correlation structure of the error term. We eliminate the permanent component of the error term by taking first differences of the growth-Q relation, while correlation of the temporary component with Q is circumvented by the use of lagged (and for some cases future) endogenous variables as instruments.

Our Q model with multiple capital goods is confronted by micro data on several hundred Japanese manufacturing firms listed on the Tokyo Stock Exchange for a ten year period from 1977 to 1986. Our data set has a few distinctive advantages. First, there is a breakdown of investment expenditure between several asset types, which makes it possible for us to carry out an explicit aggregation of capital goods. Second, unlike most western countries, mergers and acquisitions are infrequent in Japan, so there is very little attrition in our data set. Third, the virtual lack of mergers and acquisitions also means that almost all the firms that remain in the sample grew at the same margin — through capital accumulation, not through acquisitions. Fourth, the unit of observation is a listed firm defined by *un*consolidated accounts. That is, subsidiaries as well as parent companies are traded.[3] The Q model is arguably better suited to this smaller individual unit than to a whole of a collection of companies headed by the parent company.

We estimate the Q model for two industry groups: heavy and light industries. Our empirical results indicate that cash flow has significant explanatory power over and above Q even after a removal of the simultaneity bias, although Q is statistically more significant than cash flow. If the sample period is restricted to the last three years of the data, the period in which Japanese financial markets had been substantially de-regulated, then cash flow is no longer significant for the heavy industry and there is no sign of mis-specification. For the light industry, cash flow coefficients are very large and significant, which suggests that the light industry may not be competitive as assumed by the theory.

The organization of the paper is as follows. Our theoretical model of Q with multiple capital goods is presented in Section 2. Measurement and econometric issues are discussed in sections 3 and 4, respectively. Section 5 reports our empirical results.

2. A Q MODEL WITH MULTIPLE CAPITAL GOODS

We consider a discrete-time, stochastic model of a perfectly competitive firm with adjustment costs and multiple capital goods. The firm is assumed to maximize the expected present value of net cash flow:

$$(2.1) \qquad W_t = E_t\left\{\sum_{j=0}^{\infty} \beta_{tj}\cdot\left[\Pi(K_{t+j},K_{t+j+1};p_{t+j},u_{t+j}) - \sum_{i=1}^{n} PK_{i,t+j}I_{i,t+j}\right]\right\}$$

$$\text{subject to} \qquad K_{i,t+j+1} = (1-\delta_i)K_{i,t+j} + I_{i,t+j} \qquad (i = 1,\ldots,n),$$

where E_t is the expectations operator conditional on information available at time t, $K_t = (K_{1t},\ldots,K_{nt})$ is an n-vector of capital stocks, I_{it} is gross investment in the i-th capital, PK_{it} is its price, δ_i is the physical depreciation rate, and β_{tj} is the (possibly stochastic and time-varying) real discount factor applicable in period t to j-period-ahead payoffs with $\beta_{t0} = 1$ and $\beta_{tj} = \beta_{t1}\cdot\beta_{t+1,1}\cdot\ldots\cdot\beta_{t+j-1,1}$. The profit function $\Pi(K_t,K_{t+1};p_t,u_t)$ for period t depends on p_t (real factor prices) and u_t (technology shock) as well as on the quasi-fixed factor K_t. It also depends on the next-period capital stock K_{t+1} with $\partial\Pi(K_t,K_{t+1};p_t,u_t)/\partial K_{t+1} < 0$ because of the adjustment costs in changing the level of the capital stocks. To ensure interior solution, we assume that $\Pi(K_t,\cdot;p_t,u_t)$ is concave.

Corporate taxes can be incorporated with suitable re-interpretation of the same notation established above. First, the capital goods price PK_{it} is understood to be after the following tax adjustment:

$$(2.2) \qquad PK_{it} = \frac{(1-z_{it})PK'_{it}}{(1-\tau_t)P_t} \qquad (i = 1,..,n),$$

where PK'_{it} is the tax-unadjusted price of capital good i, P_t is output price, τ_t is the corporate tax rate, and z_{it} is the expected present value of tax saving due to depreciation allowances on a dollar of investment in capital good i in period t. Second, the real discount factor is adjusted for the corporate tax rate and inflation:

$$(2.3) \qquad \beta_{tj} = \beta^N_{tj}\cdot\left[\frac{(1-\tau_{t+j})P_{t+j}}{(1-\tau_t)P_t}\right],$$

where β^N_{tj} is the nominal discount factor. Third, as noted in Hayashi (1982), the market value of the firm differs from W_t by the present value of accounting depreciation yet to be claimed, A_t. That is,

$$(2.4) \qquad \text{value of the firm at } t = W_t + A_t.$$

Since A_t is given to the firm at t, maximizing the value of the firm is equivalent to maximizing W_t defined in (2.1). For the rest of the paper it is understood that the notation already reflects these tax adjustments.

For our purposes it will prove more convenient to write the objective function in (2.1) in a form that does not involve investment. To do this, note that the present value of investment expenditure can be re-written as

$$(2.5) \quad E_t\left(\sum_{j=0}^{\infty}\beta_{tj}PK_{i,t+j}I_{i,t+j}\right) = E_t\left\{\sum_{j=0}^{\infty}\beta_{tj}PK_{i,t+j}\cdot[K_{i,t+j+1}-(1-\delta_i)K_{i,t+j}]\right\}$$

$$= -PK_{it}\cdot(1-\delta_i)K_{it} + E_t\left(\sum_{j=0}^{\infty}\beta_{tj}c_{i,t+j}K_{i,t+j+1}\right),$$

where

$$(2.6) \qquad c_{i,t+j} = PK_{i,t+j} - E_{t+j}\left(\beta_{t+j,1}\cdot(1-\delta_i)PK_{i,t+j+1}\right) \qquad (i = 1,\ldots,n),$$

is none other than the Jorgensonian *user cost of capital.* Combining (2.1) and (2.5), we obtain

$$(2.7) \qquad V_t \equiv W_t - \sum_{i=1}^{n} PK_{it}\cdot(1-\delta_i)K_{it}$$

$$= E_t\left\{\sum_{j=0}^{\infty} \beta_{tj}\cdot\left[\Pi(K_{t+j},K_{t+j+1};p_{t+j},u_{t+j}) - \sum_{i=1}^{n} c_{i,t+j}K_{i,t+j+1}\right]\right\}.$$

This V_t is the present value of rents to be earned from the quasi-fixed nature of capital due to adjustment costs. Since the value of initial capital stocks $\Sigma PK_{it}(1-\delta_i)K_{it}$ is given, value maximization is equivalent to maximizing the rent V_t.

To make the theory operational, we place two restrictions on the profit function that allow us to link the market value of the firm, which is a *scalar* measure of profitability of the firm as a whole, to some index of the growth of the firm. The first restriction is that capital inputs are *weakly separable* in the following sense:

$$(2.8) \qquad \Pi(K_t,K_{t+1};p_t,u_t) = \Pi^*[\phi(K_t),\phi(K_{t+1});p_t,u_t],$$

where $\phi(K_t)$, called the *capital aggregator*, is homogeneous of degree one. This specification, considered previously by Epstein (1983), is a natural extension to the case with adjustment costs of the standard assumption in the productivity literature that capital inputs are weakly separable from variable factor inputs. This assumption allows us to break the maximization problem into two stages. The "top" stage is to allocate the scalar capital aggregate over time. The "bottom" stage is a static problem of partitioning the aggregate into the individual capital stocks to minimize the capital cost:

(2.9) $$\min_{K_{t+1}} \sum_{i=1}^{n} c_{it}K_{i,t+1} \quad \text{subject to} \quad \phi(K_{t+1}) = \phi_{t+1},$$

where ϕ_{t+1} is a scalar whose value is given in the top stage. Since the capital aggregator $\phi(.)$ is homogeneous of degree one, the minimized capital cost is proportional to ϕ_{t+1}:

(2.10) $$\sum_{i=1}^{n} c_{it}K_{i,t+1} = \gamma(c_t)\phi_{t+1},$$

where $c_t = (c_{1t},\ldots,c_{nt})$ is the vector of user costs.

The second restriction on the profit function is constant returns to scale, which implies that the function Π^* in (2.8) can be written as:

(2.11) $$\Pi^*(\phi_t,\phi_{t+1};p_t,u_t) = \pi(\phi_t/\phi_{t+1};p_t,u_t)\phi_{t+1}.$$

Thus under constant returns to scale and weak separability the top stage is the following maximization problem:

(2.12) $$V_t = \max E_t\left\{\sum_{j=0}^{\infty}\beta_{tj}\cdot\left[\pi\left(\frac{\phi_{t+j}}{\phi_{t+j+1}};p_{t+j},u_{t+j}\right) - \gamma(c_{t+j})\right]\phi_{t+j+1}\right\}.$$

The control variable for period t is ϕ_{t+1}. The current state consists of ϕ_t and a first-order Markov process s_t of which all prices and shocks $(p_t,c_t,\beta_{t-1,1},u_t)$ are functions. If $V(\phi_t,s_t)$ is the value function, then the envelope equation, which one can obtain by differentiating (2.12) with respect to ϕ_t, is (see Benveniste and Scheinkman (1979) for derivation):

(2.13) $$\frac{\partial V(\phi_t,s_t)}{\partial \phi_t} = \pi'(\phi_t/\phi_{t+1};p_t,u_t),$$

where $\pi'(.;p_t,u_t)$ is the derivative of π. This says that optimal firm growth is such that the marginal adjustment cost π' equals the marginal valuation of the capital aggregate ("marginal Q"). That marginal Q in turn equals "average Q" is proved in the following lemma, which is a generalization of Hayashi (1982) to the stochastic case and which actually is a restatement of a result stated without proof in Lucas and Prescott (1971).

LEMMA: *$V(\phi_t, s_t) = Q(s_t)\phi_t$* under (2.11).

PROOF: Let $h(\phi_t, s_t)$ be the optimal policy function for the control ϕ_{t+1}. Take any two arbitrary values, ϕ'_t and ϕ''_t, and consider the following (possibly suboptimal) policy rule:

$$\bar{h}(\phi, s) = h\left(\frac{\phi'_t}{\phi''_t}\cdot\phi, s\right)\cdot\frac{\phi''_t}{\phi'_t}. \tag{2.14}$$

For any given realization of the sequence $\{s_v\}$ $(v \geq t)$, let $\{\phi'_v\}$ $(v \geq t)$ be the time path generated by the optimal policy rule starting from ϕ'_t. Let $\{\phi''_v\}$ $(v \geq t)$ be the time path generated by (2.14) for the *same* realization of $\{s_v\}$ $(v \geq t)$ starting from ϕ''_t. Then:

$$\phi''_{t+1} = h[(\phi'_t/\phi''_t)\cdot\phi''_t, s_t](\phi''_t/\phi'_t) = h(\phi'_t, s_t)(\phi''_t/\phi'_t) = \phi'_{t+1}\cdot(\phi''_t/\phi'_t), \quad \text{and}$$

$$\phi''_{t+2} = h[(\phi'_t/\phi''_t)\cdot\phi'_{t+1}\cdot(\phi''_t/\phi'_t), s_{t+1}](\phi''_t/\phi'_t) = h(\phi'_{t+1}, s_{t+1})(\phi''_t/\phi'_t)$$
$$= \phi'_{t+2}\cdot(\phi''_t/\phi'_t), \text{ etc.},$$

so that, for all $v \geq t$, $\phi''_v = \phi'_v\cdot(\phi''_t/\phi'_t)$ and $\phi''_v/\phi''_{v+1} = \phi'_v/\phi'_{v+1}$. This implies that the term in brackets in (2.12), $\pi-\gamma$, takes on the same value under the two paths $\{\phi'_v\}$ and $\{\phi''_v\}$ for the same given realization of $\{s_v\}$ $(v \geq t)$ and that V_t under $\{\phi''_v\}$ is (ϕ''_t/ϕ'_t) times V_t under $\{\phi'_v\}$. Since $\{\phi''_v\}$ is possibly suboptimal while $\{\phi'_t\}$ is optimal, we have the following inequality.

$$V(\phi''_t, s_t) \geq V(\phi'_t, s_t)\cdot(\phi''_t/\phi'_t). \tag{2.15}$$

Now interchange ϕ' with ϕ'' to obtain the reverse inequality, and assert that (2.15) must hold with equality. Since the equality holds for any arbitrary choice of ϕ'_t and ϕ''_t, the desired result follows. Q.E.D.

We are now ready to summarize the results in this section as follows.

PROPOSITION: *If the firm is competitive and if capital stocks enter into the linear homogeneous profit function only through the capital aggregator* $\phi(.)$ *as indicated in (2.8) and (2.11), then there is a one-to-one relation between* ϕ_t/ϕ_{t+1} *and average Q:*

$$\pi'(\phi_t/\phi_{t+1};p_t,u_t) = Q_t, \tag{2.16}$$

where Q_t *is defined by*

$$Q_t = \frac{W_t - \sum_{i=1}^{n} PK_{it}\cdot(1-\delta_i)K_{it}}{\phi_t}, \tag{2.17}$$

and is independent of the initial capital stocks: $Q_t = Q(s_t)$. *Furthermore, the marginal rate of substitution in the capital aggregate between any two capital inputs equals their respective user costs:*

$$\frac{\partial\phi(K_{t+1})/\partial K_{i,t+1}}{\partial\phi(K_{t+1})/\partial K_{1,t+1}} = \frac{c_{it}}{c_{1t}} \qquad (i,1 = 1,..,n). \tag{2.18}$$

PROOF: The former part of the proposition is immediate from (2.7), (2.13) and the Lemma. The second part, equation (2.18), is the first-order condition for the bottom stage optimization (2.9). Q.E.D.

REMARK 1: It is perhaps more useful to write Q_t as

$$Q_t = \frac{W_t - \sum_{i=1}^{n} PK_{it}\cdot(1-\delta_i)K_{it}}{\sum_{i=1}^{n} PK_{it}\cdot(1-\delta_i)K_{it}}\cdot\frac{\sum_{i=1}^{n} PK_{it}\cdot(1-\delta_i)K_{it}}{\phi_t} = (q_t - 1)P_{\phi t}, \tag{2.19}$$

where q_t is the so-called *Tobin's q*

$$(2.20) \qquad q_t = \frac{W_t}{\sum_{i=1}^{n} PK_{it}\cdot(1-\delta_i)K_{it}},$$

and $P_{\phi t}$ is the implicit deflator for the capital aggregate defined by

$$(2.21) \qquad P_{\phi t}\cdot\phi_t = \sum_{i=1}^{n} PK_{it}\cdot(1-\delta_i)K_{it}.$$

REMARK 2: To observe Q_t, we need to calculate the capital aggregate ϕ_t. The second part of the Proposition is what makes our result operational. Equation (2.18) implies that we can employ the standard theory of index numbers to construct the index $\phi(K_t)$ using the user costs as weights, without specifying the functional form for $\phi(.)$. The series thus constructed is exactly the quantity index of capital inputs routinely calculated in the literature on productivity growth.

3. MEASUREMENT

Measurement of the asset-aggregated, tax-adjusted Q as defined by (2.17) requires several steps. First, all financial assets are netted out against liabilities, because the financial market valuation of the equity component of the firm reflects those assets. This requires us to evaluate all the asset and liability items of the firm's balance sheet at market prices. Second, the capital stock K_{it} is constructed for each capital good. Third, tax parameters (z_{it}, τ_t, A_t) are calculated and the tax adjustment (2.2)-(2.4) is performed. Fourth, an index of capital aggregate is constructed.

We carried out these steps for individual Japanese manufacturing firms. A complete description of our data set is in the Appendix. Here, we briefly highlight its main features.

Capital Stocks. Our data on the company financial statements are detailed enough to provide a breakdown of gross investment between seven capital goods: (1) nonresidential buildings, (2) structures, (3) machinery, (4) transportation equipments, (5) instruments & tools, (6) land, and (7) inventories. Thus we were able to apply different physical depreciation rates to construct the capital stock by the perpetual inventory method by capital good. For capital goods (3), (4) and (5), which are internationally tradable, we use the depreciation rates we derived from Hulten and Wykoff (1979,1981). Our depreciation rates are: 4.7% for (1), 5.64% for (2), 9.489% for (3), 14.70% for (4) and 8.838% for (5). The book value of capital for the 1962 fiscal year is used as the benchmark for the perpetual inventory method. Gross investment equals the change in the book value of net capital stock plus accounting depreciation. Prior to 1977, accounting depreciation is not available by asset, making it necessary to do some imputations. Afterwards a complete breakdown of gross investment into the seven asset types is available. For this reason we take the sample period for estimation to be 1977-1986. Thus for estimation purposes we will utilize only the recent part of the data construction period (1962-1986). This also serves to minimize the effect of the 1962 benchmark on the calculated capital stock in the estimation period.

The Capital Aggregate. Our capital aggregate is the familiar Divisia index, which exploits the following first-order approximation:

$$\phi(K_{t+1}) - \phi(K_t) \quad \sum_{i=1}^{n} \frac{\partial\phi(K_{t+1})}{\partial K_{i,t+1}} \cdot (K_{i,t+1} - K_{it}). \tag{3.1}$$

The latter part of the Proposition in section 2, summarized in (2.18), implies that $\partial\phi(K_{t+1})/\partial K_{i,t+1} = \lambda_t c_{it}$ for some λ_t that does not depend on i. Use this and Euler's theorem $\phi(K_{t+1}) = \Sigma_i[\partial\phi(K_{t+1})/\partial K_{i,t+1}]K_{i,t+1}$ on (3.1) to obtain

$$\text{(3.2)} \qquad \frac{\phi(K_{t+1}) - \phi(K_t)}{\phi(K_{t+1})} \quad \sum_{i=1}^{n} \frac{c_{it}\cdot(K_{i,t+1} - K_{it})}{\sum_{l=1}^{n} c_{lt}K_{l,t+1}}.$$

The user cost of capital c_{it} defined in (2.6) is unobservable because it depends on the expectations about the next period's real capital goods prices and the discount factor. Using (2.2) and (2.3), we can derive from (2.6) the following expression for c_{it}:

$$\text{(3.3)} \qquad c_{it} = \left[1 - (1-\delta_i)E_t(\beta^R_{tl})\right] \frac{(1-z_{it})PK'_{it}}{(1-\tau_t)P_t},$$

where

$$\text{(3.4)} \qquad \beta^R_{itl} = \beta^N_{tl} \frac{(1-z_{i,t+1})PK'_{i,t+1}}{(1-z_{it})PK'_{it}}.$$

Here, β^N_{tl} is the nominal one-period discount factor from t to t+1, PK'_{it} is the tax-*un*adjusted nominal price of the i-th asset, P_t is the output price, and β^R_{itl} is the asset-specific real one-period discount factor. We assume that $E_t(\beta^R_{itl})$ is constant over time, and take $E_t(\beta^R_{itl})$ to be the time average of β^R_{itl} over the estimation period. We also calculated the user costs under perfect foresight. This, however, produced a quite volatile Divisia index with negative values for a fraction of firms in the sample. The results we report are based on the user costs with time-invariant β^R_{itl}. The Divisia index is normalized so that its implicit price index $P_{\phi t}$ (see (2.19)-(2.21)) equals unity for 1980. Thus $Q_t = q_t - 1$ for 1980.

Entity of the "Firm". The firm can grow at several margins: expansion of existing establishments, building new factories, and acquiring other firms. The model of optimal capital accumulation of section 2 is arguably more applicable at the establishment level than at the firm level. If so, the entity of the firm in our sample should be close to an establishment, or at least they should grow at the same margin. In this respect our data on Japanese firms are close to being ideal: the stocks listed on the Tokyo Stock Exchange correspond exactly to unconsolidated accounts on which our calculation is based, and less than 7% of listed manufacturing firms were acquirers during the sample period. It might appear that our use of unconsolidated financial statements is unwarranted because the theory may not apply to a (listed) subsidiary whose investment decision is governed by the parent company. However, it seems obvious that value maximization for the parent company calls for value maximization for its subsidiaries as well. An adjustment cost shock to a subsidiary will be reflected in the value of its shares owned by the parent company, but it is exactly offset by the parent company's share prices, leaving the parent company's Q unaffected by the shock to its subsidiaries. Thus, the theory should apply with equal force to all the firms in the sample (except for the acquirers) provided that, as done in our calculation of Q to the extent possible, stocks of affiliates (subsidiaries and parent companies) held by the firm are valued at market prices.

Sample Selection. As explained above, the nature of raw data determined the sample period for estimation to be a ten-year period 1977-86 (or to be more precise, from the fiscal year that ends between April 1977 and March 1978 to the fiscal year that ends between April 1986 and March 1987). Of 942 manufacturing firms listed on the Tokyo Stock Exchange in 1977, 62 firms ceased to be listed by the end year of the sample and trading was suspended temporarily for 2 firms. We drop them as their stock prices are not available. We then eliminate 142 firms that changed the fiscal year during the data construction period (1962-86) and drop 48 acquirers. This leaves 688 firms. One of them is a very clear outlier in terms of the growth rate of capital due to a massive divestment in 1986. Thus the final sample size has 687 firms.

As a by-product of our calculation of Q, Table I displays our estimate of the market value of balance sheet items and (tax-adjusted) Tobin's q, which may be of some independent interest. One notable feature is the large value of financial assets. This is primarily due to the fact that financial statements are unconsolidated.

4. ECONOMETRIC ISSUES

In this section we discuss some econometric issues regarding the estimation of the growth-Q relation in micro data on firms that belong to the same industry. At this stage we introduce individual firm subscript "f".

We derived the growth-Q relation from the profit function π in (2.11). To facilitate comparison of our estimation equation with the investment equations in the literature, we write π as a function of the *growth rate of the firm* g_{ft} defined by

$$(4.1) \qquad g_{ft} = \frac{\phi_{f,t+1} - \phi_{ft}}{\phi_{f,t+1}} = 1 - \frac{\phi_{ft}}{\phi_{f,t+1}}.$$

Since real factor prices p_t are common to all firms in the same industry, the dependence of π on p_t is captured by the time subscript t. Our parameterization of π as a function of the growth rate is the following quadratic form:

$$(4.2) \qquad \pi(g_{ft};p_t,u_{ft}) = a_{0ft} - \left(\frac{a_{2t}}{2}\right)\left(g_{ft} - u_{ft} - a_{1t}\right)^2, \quad a_{2t} > 0.$$

The term $u_{ft}+a_{1t}$ is the base growth rate that minimizes the adjustment cost implicit in the profit function. This technology shock u_{ft} to the profit function can be correlated with a_{0ft}. The concavity of the profit function requires that a_{2t} be positive. Under this parameterization the envelope equation (2.16) turns into the following growth-Q equation:

$$g_{ft} = a_{1t} + \left(\frac{1}{a_{2t}}\right)Q_{ft} + u_{ft}. \tag{4.3}$$

That the error term u_{ft} in the growth-Q equation originates from the shock to the profit function creates a serious identification problem. As emphasized in section 2, Q is a function of the technology shock and hence is *econometrically endogenous*. So are a wide range of variables pertaining to the firm such as output, profits and cash flow, which also depend on the technology shock. It follows that the coefficients of those variables will be statistically significant if they are added to a regression of firm growth on Q. Another problem, usually ignored in inferences using individual firm data, is that the data are not a random sample, so that the error term can be correlated *across firms*.

Under these circumstances, identification and inference can be achieved more plausibly by some *a priori* restriction on the serial correlation structure of the error term. We assume that the error term u_{ft} can be written as a sum of a permanent component and a temporary component, $v_f + w_{ft}$, where w_{ft} is serially uncorrelated.[4] As we will see, this assumption turns out to be consistent with the data. We further assume that correlation of the error term across firms due to the non-random nature of the sample occurs in the permanent component but not in the temporary component, so that $(w_{f1},\ldots,w_{fT})$ is a random drawing from a common sample path space, where T is the length of the panel.

Taking first differences of (4.3) and noting that $u_{ft} = v_f + w_{ft}$, we obtain the following T-1 equations:

$$(4.4) \qquad g_{f,t+1}-g_{ft} = b_t + \left(\frac{1}{a_{2,t+1}}\right)Q_{f,t+1} - \left(\frac{1}{a_{2t}}\right)Q_{ft} + (w_{f,t+1}-w_{ft})$$

$$(t = 1,..,T-1).$$

where $b_t = a_{1,t+1}-a_{1t}$. In matrix notation this system of T-1 equations can be written compactly as

$$(4.4') \qquad y = Z\delta + \epsilon$$

where, with N being the sample size,

$$y = (y_1', \ldots, y_{T-1}')',$$

$$y_t = (g_{1,t+1}-g_{1t}, \ldots, g_{N,t+1}-g_{Nt})',$$

$$Z = \left[\begin{array}{cccc|ccccc} \iota & & & & -Q_1 & Q_2 & & & \\ & \iota & & & & -Q_2 & Q_3 & & \\ & & \ddots & & & & \ddots & \ddots & \\ & & & \iota & & & & -Q_{T-1} & Q_T \end{array}\right]$$

$$Q_t = (Q_{1t}, \ldots, Q_{Nt})',$$

ι = column vector of N ones,

$$\delta = (b_1,..,b_{T-1}; 1/a_{21},..,1/a_{2T})',$$

$$\epsilon = (\epsilon_1', \ldots, \epsilon_{T-1}')'$$

$$\epsilon_t = (w_{1,t+1}-w_{1t}, \ldots, w_{N,t+1}-w_{Nt})'.$$

The Q in equation (4.4) is still endogenous, so we have to find instruments. To this end we strengthen the serial correlation property of w_{ft}. We consider two cases:

(i) $\{w_{ft}\}$ is serially independent.

(ii) $\{w_{ft}\}$ is a martingale difference sequence.

Under (ii) (and hence under (i)), lagged endogenous variables are valid instruments. A set of valid instruments x_{ft} for the t-th equation in (4.4) for case (ii) is:

(4.5) $$x_{ft} = (1; g_{f1},\ldots,g_{f,t-1}; Q_{f1},\ldots,Q_{f,t-1}).$$

The variance of w_{ft} could depend on lagged variables under (ii), so our estimation will allow for conditional heteroskedasticity.

We now claim that, under the stronger assumption of (i), *future* values $(g_{fv}, Q_{fv};\ v = t+2,\ldots,T)$, too, can be used as instruments. To see this, consider, for example, correlation between w_{ft} and future Q. It is true that w_{ft} affects current and future *levels* of capital stocks. However, as asserted in the Proposition in section 2, optimal investment rule is such that Q is independent of the capital stocks; Q depends only on the state of nature that is exogenous to the firm. Since w_{ft} does not affect the future exogenous state under (i), we conclude that w_{ft} and Q_{fv} $(v > t)$ are independent. Note, however, that this argument is not valid under the weaker assumption (ii). Under (ii), w_{ft} can change the second and higher moments of the distribution of w_{fv} $(v > t)$ and thus could affect Q_{fv} which is a possibly nonlinear function of w_{fv}. We can repeat the same line of argument for g (growth *rate*) because it, too, is independent of the *level* of the capital stocks. Therefore, under (i), the set of instruments x_{ft} for the t-th equation in (4.4) can include future values:

(4.6) $$x_{ft} = (1; g_{f1},\ldots,g_{f,t-1}, g_{f,t+2},\ldots,g_{fT}; Q_{f1},\ldots,Q_{f,t-1}, Q_{f,t+2},\ldots,Q_{fT}).$$

There is no need to allow for conditional heteroskedasticity under (i); if there were conditional heteroskedasticity, future variables could not have been valid instruments in the first place.

Our estimation strategy can accommodate serially uncorrelated measurement error in Q by simply including it as part of the error term w_{ft}. If, in addition, there is serially uncorrelated measurement error in g, then the Q measurement error will have a long moving average component, since ϕ, the integral of g, is the denominator in Q. But the variance of the moving average should be negligibly small relative to that of the g measurement error itself. Therefore, even if there is measurement error in both g and Q, our assumption that w_{ft} is serially uncorrelated will be a good approximation.

To summarize, we will estimate the system of T-1 equations (4.4) under two alternative assumptions about the serial correlation property of the error term w_{ft} that consists of the technology shock and possibly measurement error. Under the martingale difference assumption (ii), the estimation technique is Hansen's (1982) GMM (generalized methods of moments), which allows for conditional heteroskedasticity. The instrument set for the t-th equation is (4.5), which excludes future endogenous variables. The GMM estimator $\hat{\delta}$ of the coefficient vector δ in (4.4') minimizes

(4.7) $$J = N\cdot(\epsilon'X/N)V^{-1}(X'\epsilon/N),$$

where N is the sample size, ϵ is the stacked error vector defined below (4.4'), and X is a block diagonal matrix of instruments given by

(4.8) $$X = \begin{bmatrix} X_1 & & \\ & \ddots & \\ & & X_{T-1} \end{bmatrix} \quad \text{with} \quad X_t = \begin{bmatrix} x_{1t} \\ \vdots \\ x_{Nt} \end{bmatrix}.$$

An optimal choice of V is

(4.9) $$V = \text{sample covariance matrix of } (\epsilon_{f1}x_{f1},\ldots,\epsilon_{f,T-1}x_{f,T-1}),$$

where $\epsilon_{ft} = w_{f,t+1} - w_{ft}$. The GMM estimator is given by

(4.10) $$\hat{\delta} = (Z'XV^{-1}X'Z)^{-1}Z'XV^{-1}X'y,$$

where y and Z are defined below (4.4'). As shown by Hansen (1982), the minimized value of J in (4.7) is asymptotically distributed as a Chi-square with m-n degrees of freedom where m is the total number of instruments (orthogonality conditions) and n is the number of parameters. This J statistic will be utilized to test the set of over-identifying restrictions that there are more orthogonality conditions than there are parameters.

The estimation method under the serial independence assumption (i) is a specialization of the GMM in that under conditional homoskedasticity the expression (4.9) for the optimal choice of V reduces to

$$\text{(4.9')} \qquad (t,v) \text{ block of } V = \hat{\sigma}_{tv} \cdot (X_t X_v'/N) \qquad (t,v = 1,\ldots,T-1),$$

where $\hat{\sigma}_{tv}$ is a consistent estimate of $\text{Cov}(\epsilon_{ft}, \epsilon_{fv})$. The instrument set x_{ft} for the t-th equation is (4.6), which includes lagged *and* future endogenous variables that do not overlap with the time periods over which the first difference is taken.

In either case, an initial consistent estimate of residuals is needed to calculate V. To this end we obtain an initial consistent estimate of δ with a V given by (4.9') where $\hat{\sigma}_{tv}$ is:

$$\text{(4.11)} \qquad \hat{\sigma}_{tv} = \begin{cases} 1 & \text{if } t = v \\ -0.5 & \text{if } |t-v| = 1 \\ 0 & \text{otherwise,} \end{cases}$$

which is the correlation matrix for $\epsilon_{ft} = w_{f,t+1} - w_{ft}$ under our assumption of no serial correlation in w_{ft} if the variance of w_{ft} is constant over time. This particular choice of the initial estimate did not affect our results; we also used the identity matrix for $(\hat{\sigma}_{tv})$ in the initial estimation to obtain very similar results.

5. RESULTS

We now apply our estimation method to the sample of 687 manufacturing firms. Estimation must be carried out separately for each industry within the manufacturing sector if the parameter value varies across industries. As a practical matter, our industry breakdown cannot be too fine because in the heteroskedasticity-robust estimation the sample size must be greater than the size of the V matrix in (4.9), which for some specifications is as large as 116. We therefore divide the whole sample into just two industries: the "heavy" industry (consisting of primary metal, metal products, machinery, electrical appliances, and transportation equipments), and the "light" industry (food, textile, paper, chemical and other). The sample size is 392 for the heavy industry and 295 for the light industry.

Table II reports for each industry sample means and standard deviations of three variables: g_t (growth rate of the capital aggregate defined in (4.1)), Q_t (average Q defined in (2.17)), and CF_t (cash flow rate, defined as the ratio of cash flow to the capital aggregate ϕ_{t+1}).[5] The cash flow rate, the variable often used in the literature as a candidate to compete with Q in explaining investment, will be used below to test the Q model. Predictably, g is much less volatile (in terms of the cross-section standard error) than Q, but the fact that it is more volatile than CF (whose denominator is the level of the capital aggregate ϕ) is consistent with our presumption made in the previous section that measurement error may be much more serious in the growth rate of the capital aggregate than in the level.

We first present parameter estimates for case (i) where w_{ft} in the estimation equation (4.4) is serially independent. The instrument set x_{ft} for period t is given by (4.6) and conditional homoskedasticity is imposed. Since the length of the panel T is ten years (hence nine equations to be estimated), there are seventeen instruments (including the constant) for each year. Thus the total number of orthogonality conditions is 153 (= 17×9) and the number of parameters is nineteen (nine intercepts and ten Q coefficients). Column 1 of Table III reports estimated Q coefficients ($1/a_{2t}$, t = 1,2,...,T) and related statistics under conditional homoskedasticity for the two industries. The Q coefficients are in the same order of magnitude as those estimated by Blundell *et. al.* (1987). The serial (cross-equation) error correlation matrix calculated from the residuals (not reported in the Table) has its off-diagonal elements right above and below the diagonal elements very close to -0.5 and other off-diagonal elements mostly less than 0.1 in absolute value, which is consistent with our maintained assumption of no serial correlation in w_{ft}. This is a feature shared by all the specifications we estimated. The hypothesis that the Q coefficient is constant over time is emphatically rejected, underscoring the importance of allowing a_{2t} in (4.2) to vary over time with real factor prices. The p value for the J statistic quite clearly signals failure of the over-identifying restrictions for either industry.

The failure of the over-identifying restrictions can be due to our use of future endogenous variables as instruments. We therefore turn to case (ii) where only lagged endogenous variables are used as instruments as in (4.5) and where conditional heteroskedasticity is allowed for. Since no instruments are available for the estimation equation (4.4) for the first year making the equation unidentifiable, we drop it from our estimation, leaving eight equations and nine Q coefficients. Column 2 of Table III reports the GMM estimate of the Q coefficients. They are almost uniformly higher than in case (i). According to the J statistic, there is no sign of mis-specification for the heavy industry. For the light industry, however, the J statistic signals failure of the over-identifying restrictions.

Another standard test of mis-specification is to augment the estimation equation to include variables that should be irrelevant. The variable often found to be significant in the Q-based investment equation is the cash flow rate CF_t. We enter CF into (4.4) in the same way Q enters the estimation equation. Also, we add lagged CF to the set of instruments. Results for this specification are reported in Column 3. For either industry, the cash flow coefficients are strongly jointly significant, which constitutes a rejection of the Q model.

That cash flow is insignificant for recent years of the sample is an interesting finding, because those years are the period of relatively unregulated financial markets in Japan. As documented in, *e.g.*, Hoshi, Kashyap and Shcafstein (1989), the early 1980s witnessed a series of liberalizations of capital markets in Japan that made it easier for firms to raise capital directly through corporate bonds, most notably the lifting of the ban on non-collateralized bonds in 1983. Although the model presented in this paper is not rich enough to address the issue of bank loans versus direct external financing, it seems clear that the model is better suited to the world with unregulated capital markets. The last column in Table III reports our estimates for the period 1984-86. We estimate by GMM the system of two equations, one for 1984-85 and the other for 1985-86, with or without the cash flow rate in the equations. For the heavy industry, the cash flow rate turned out to be jointly insignificant (p value = 0.1237), so we report results with CF dropped from the equations (but not from the instrument set). The over-identifying restrictions are easily accepted. Results for the light industry, however, is very much different: the cash flow coefficients are significant and quantitatively large.

The poor performance of the Q model for the light industry may be attributable to the fact that the market for this industry is mostly domestic and more or less protected from international competition. In fact, the average fraction of exports in sales for 1984-86 is only 6% for the light industry, while it is 17% for the heavy industry. As shown in Hayashi (1982), if the firm is not competitive, then average Q differs from marginal Q by monopoly rent, and it is marginal Q that is relevant for investment.[6] Cash flow can be significant because of its correlation with monopoly rent.

Are our estimated Q coefficients in the right order of magnitude? Take, for example, the Q coefficient for the heavy industry in 1984 reported in column 4 of Table III. The point estimate of 0.029 implies that a_{2t} in (4.2) is as large as 34, which, coupled with the fairly large standard deviation of the growth rate g_{ft} reported in Table II, appears to make the adjustment cost (the squared term in (4.2)) implausibly large. However, what matters for the adjustment cost is not the growth rate g_{ft} itself but the deviation from the base level, $g_{ft}-u_{ft}-a_{1t}$. As clear from (4.3), the technology shock u_{ft} and the growth rate g_{ft} can be positively correlated, making $g_{ft}-u_{ft}-a_{1t}$ less volatile than g_{ft} itself. The size of the squared term in (4.2) can be calculated readily. Substituting (4.3) into (4.2), the gross pre-tax profit rate π can be written as:

(5.1) $$\pi = a_{0ft} - \frac{1}{2}\left(\frac{1}{a_{2t}}\right)Q_{ft}^{2}.$$

Thus the sample mean of the adjustment cost — the squared term in (5.1) — equals a half the Q coefficient times the mean square of Q. For 1984 it is about 9%, which is a reasonably small fraction of the gross profit rate π (whose sample mean is 21% for 1984 in our data).

APPENDIX: DATA CONSTRUCTION

This appendix describes the calculation of the variables used in the estimation.

Data Source There are three primary data sources. For company financial statements data we use the tape compiled by the Japan Development Bank. We obtained share prices from the Nihon Keizai Shimbun's NEEDS database. The price index for output and investment goods are taken from components of the WPI (wholesale price index).

Industry Classification For the purpose of forming price indexes of output and capital goods, we employ the following ten manufacturing industry classification: (1) food, (2) textile, (3) paper, (4) chemical, (5) primary metal, (6) metal products, (7) machinery, (8) electrical appliances, (9) transportation equipments, and (10) other.

Price of Output (P) This is the component of the WPI for the industry to which the company belongs. The price index is at the beginning of the fiscal year and is normalized to unity for 1980.

Price of Capital Goods (PK) The seven-asset breakdown of capital goods is: (1) nonresidential buildings, (2) structures, (3) machinery, (4) transportation equipments, (5) instruments & tools, (6) land, and (7) inventories. The price index for (1) and (2) is taken to be the construction material component of the WPI. The machinery component of the WPI has several subcomponents. We use the capital formation matrix of the 1975 Input-Output table by industry as the fixed weight to calculate the price index for machinery. The same procedure is used to construct the price index for instruments & tools. The transportation equipment component of the WPI is used as the price index for transportation equipments. We use the index of urban land prices compiled by the Japan Real Estate Research Institute for the price of land. The price index for inventories is the output price P. The value of the price index is for the first month of the fiscal year of the firm.

Nominal Investment For the first five assets, which are depreciable, calculation of nominal investment is complicated. We first establish the notation.

KGB_t = book value of gross capital stock at the beginning of year t,

KNB_t = book value of net capital stock at the beginning of year t,

AD_t = book value of accumulated depreciation at the beginning of year t,

DEP_t = accounting depreciation during year t,

ACQ_t = acquisition of assets during year t,

SR_t = acquisition value of assets that are sold or retired during year t,

$ADSR_t$ = book value of accumulated depreciation for assets that are sold or retired during year t,

$NR_t = SR_t - ADSR_t$, remaining book value of asset sold or retired,

CNR_t = our estimate of the replacement value of NR_t.

The items SR_t and $ADSR_t$ require some explanation. Let T be the asset life for tax purposes. SR_t is the acquisition value (with no allowance for depreciation) of assets that are either retired (on book) at the retirement age T or retired/sold before age T. $ADSR_t$ is the accumulated depreciation on assets whose acquisition value is counted in SR_t.

As a matter of accounting identity, we have, for each asset type,

(A1) $KGB_{t+1} = KGB_t + ACQ_t - SR_t$,

(A2) $AD_{t+1} = AD_t + DEP_t - ADSR_t$,

(A3) $KNB_t = KGB_t - AD_t$.

The definition of nominal investment ($NOMI_t$) is

(A4)
$$\begin{aligned} NOMI_t &= KNB_{t+1} - KNB_t + DEP_t \\ &= KGB_{t+1} - KGB_t - (AD_{t+1} - AD_t) + DEP_t \quad \text{(by (A3))} \\ &= KGB_{t+1} - KGB_t + ADSR_t \quad \text{(by (A2))} \\ &= ACQ_t - (SR_t - ADSR_t) = ACQ_t - NR_t. \quad \text{(by (A1))} \end{aligned}$$

This definition of nominal investment has two problems. First, suppose there is no sale of assets. What we think of investment then is ACQ_t. If all assets have been depreciated by the straight line method, then $NR_t = SR_t - ADSR_t$ is zero and $NOMI_t$ in fact equals ACQ_t. But under the declining balance method $SR_t - ADSR_t$ is 10% of retiring assets. Second, if there is sale of assets, the term NR_t captures only the book value of the remaining value of assets sold.

Because of data availability, we computed $NOMI_t$ in three different ways. (1) Until the fiscal year ending September 1969, we only have KNB by asset and DEP aggregated over the five assets. (2) From October 1969 until March 1977, we have in addition KGB and AD by asset, and SR and ADSR aggregated over assets. (3) Since April 1977 we have all the items (especially the breakdown of DEP into the five assets) in (A4).

(1) From the first two successive fiscal years for which AD_t is available (which are after September 1969), we can calculate the implied accounting depreciation rate $d = (AD_{t+1} - AD_t)/KNB_t$ for each asset. This is used as weights to distribute proportionately total depreciation between five assets. Until September 1969, $NOMI_t$ is calculated by the first line of (A4).

(2) From October 1969 until March 1977, we use the third line of (A4) to calculate $NOMI_t$ for each asset. To obtain a breakdown of total ADSR between assets, we assume that the ratio of $ADSR_t$ to AD_t is the same across assets.

(3) For the period since April 1977, we can address the two problems about NR_t mentioned above. The question is how to estimate CNR_t for each asset. If δ_B is the accounting depreciation rate and DS(x,t) is the fraction of assets acquired at year t that gets sold off x years later, NR_t and CNR_t are written as:

(A5) $$NR_t = \sum_{x=0}^{\infty} PK_{t-x} \cdot DS(x,t-x) \cdot NOMI_{t-x} \cdot (1-\delta_B)^x,$$

(A6) $$CNR_t = \sum_{x=0}^{\infty} PK_t \cdot DS(x,t-x) \cdot NOMI_{t-x} \cdot (1-\delta)^x,$$

where δ is the physical depreciation rate. This assumes that the declining balance method is used for depreciating all assets. The summation does not stop at x = T (asset life for tax purposes), to accommodate the 10% scrap value. If $\delta = \delta_B$ and if DS(x,t-x) does not depend on x, then it can be easily shown that $CNR_t = NR_t PK_t K_t / KNB_t$, where K_t is the reproduction cost of capital calculated by the perpetual inventory method from the past stream of nominal investments to be explained below. For each asset, we use the last line of (A4) with NR_t replaced by CNR_t.

For land and inventories, their nominal investment can explained more conveniently in the subsection on reproduction cost of capital.

Physical Depreciation Rates (δ) Estimation of the physical depreciation rates for our five depreciable assets (assets (1)-(5)) involves conceptual as well as practical problems. Our investment measure (A4) differs from investment expenditure in that our measure is after deduction of not only "mandatory retirements" (i.e., retirement of assets when the asset's age reaches the asset life for tax purposes) and "early retirements" due to premature deaths. The depreciation rates published by Hulten and Wykoff (1981, Table 1) are appropriate for the expenditure measure of investment because they are adjusted rates, that is, after a removal of an estimate of retirements from the *un*adjusted depreciation rate that is obtained from surviving assets. The depreciation rate appropriate for our investment measure is the unadjusted rate, which can be found in Hulten and Wykoff (1979) and which formed a basis for their calculation of adjusted rates in Hulten and Wykoff (1981).

However, their unadjusted rates are available for only several assets, numerous enough for us to assign different depreciation rates to the five depreciable asset types, but not enough, we thought, to assign different depreciation rates between industries for a given asset type. We thus decided to use depreciation rates common to all firms. For assets (3), (4) and (5), which are internationally tradable, we calculate the depreciation rates from Hulten and Wykoff (1979, 1981) as follows. We first compared the Hulten-Wykoff unadjusted rates to their adjusted rates for the same asset and found that the adjusted rates are lower by about 40% more or less uniformly across assets. Second, for each of the three asset type, we calculated the average of the Hulten-Wykoff (1981) adjusted rates over assets belonging to the same asset type, using the 1975 Input-Output Table for the entire manufacturing sector as weights. Third, the three depreciation rates thus obtained are reduced by 40% to obtain our final estimate.

For nonresidential buildings and structures, Dean, Darrough, and Neef (1987) report several estimates of the physical depreciation rate based on alternative aggregate investment series. We use the ones based on the Census on Manufacturing investment series, whose investment measure is conceptually similar to ours. The depreciation rate for nonresidential building is 4.7% and that for structures is 10.0%. We felt that the depreciation rate of 10% for structures was a bit on a high side, because the depreciation rate calculated from book values for structures in our data is only 20% higher than the building depreciation rate. We therefore multiply the building depreciation rate by 1.2 to obtain our estimate of the structures depreciation rate. For land and inventories, the depreciation rate is zero.

Reproduction Cost of Capital (K) We carry out the perpetual inventory calculation for each asset. Let K_t = real capital stock for year t, PK_t = price index at the beginning of year t, δ = physical depreciation rate. The perpetual inventory method is a recursion given by

$$PK_t K_{t+1} = (1-\delta) PK_t K_t + NOMI_t. \tag{A7}$$

We initiated the perpetual inventory accounting in the base year of 1962 with the benchmark value for $PK_t K_t$ being the book value of capital at the end of the 1961 fiscal year. For companies that were started up after 1962, the base year is the year following the starting year. During the process of perpetual inventory accounting, we encountered negative K_t for some assets. In that event $PK_t K_t$ is set at the book value.

For inventories, we categorize three inventory valuation methods: (1) FIFO, (2) Average method, (3) LIFO. Any other inventory valuation methods are forced to fall into either one of the three methods. The FIFO requires no inflation adjustment. The average method uses an average price for the inventories over the fiscal year to obtain the value at the end of the fiscal year. Our estimate of the market value of inventories under (2) takes into account the inflation during the fiscal year by applying to the book value the inflation factor which is the ratio of the price index at the end of the year to the price index averaged over the fiscal year. For the LIFO, we follow the standard LIFO recursion:

$$PK_t K_{t+1} = \begin{cases} PK_t K_t + (KB_{t+1} - KB_t)\cdot(PK_t/PK_{t+1}) & \text{if } KB_{t+1} \geq KB_t, \\ PK_t K_t + (KB_{t+1} - KB_t) & \text{if } KB_{t+1} < KB_t. \end{cases} \tag{A8}$$

where KB_t is the book value at the beginning of year t. If a company uses more than one accounting method, we take the simple average of the market values calculated under the respective methods. This procedure is applied to finished goods, goods in process and materials. For any inventory accounting method, nominal investment is $NOMI_t = PK_t\cdot(K_{t+1} - K_t)$.

For land, we use the following modification of the perpetual inventory method:

(A9) $$PK_tK_t = PK_tK + (KB_{t+1} - KB_t)(PK_t/PK'_t),$$

where PK'_t is equal to PK_t if $KB_{t+1}-KB_t > 0$ and to PK for the year when KB increased most recently prior to t (this idea was borrowed from Hoshi and Kashyap (1987)). The choice of the benchmark is very important for land because the discrepancy between the market price and the acquisition price is great even in as far back as 1960. To obtain a factor that converts the book value into the market value, we look at the balance sheet for nonfinancial corporations in the National Income Accounts and the corresponding balance sheet in the Corporate Statistics Annual (Ministry of Finance). The former gives an estimate of the market value of land and the latter its book value for nonfinancial corporations as a whole. The earliest market value data in the National Income Accounts is at the end of 1969. The book-to-market value conversion factor is obtained by dividing the market value of land in the National Accounts data for 1969 by the book value in the Corporate Statistics Annual. The population of the nonfinancial corporate sector in the National Accounts differs slightly from that in the Corporate Statistics Annual. We use the difference in the book value of equity between the two data sources to adjust for the difference in the population. This adjusted conversion factor (which equals 7.582446) is applied to the 1969 book value of land of each company to get the benchmark market value of land. Nominal investment in land is $NOMI_t = PK_t \cdot (K_{t+1}-K_t)$.

Tax Rate (τ) There is a local corporate tax called the enterprise tax, whose rate we denote as v_t. Other corporate taxes include the national corporate tax, whose statutory rate is the same across regions, and the local corporate tax, whose rate depends on the company's address. If u_t is the combined rate for the corporate taxes other than the enterprise tax, it equals 1.207×(statutory national rate) if the company is located in specially designated regions and 1.173×(statutory national rate) otherwise. The enterprise tax rate v_t takes into account the regional variation depending on the company's address. The enterprise tax paid this year is deductible from income next year. Thus the effective enterprise tax rate is lower than v_t. If this is taken into account, the "effective" corporate tax rate, τ_t, under static expectations about the interest rate and future tax rates is t $= (u_t+v_t)(1+r_t)/(1+r_t+v_t)$, where r_t is a short term nominal interest rate.

(See Hayashi (1985) for more details.)

Present Value of Tax Saving from Depreciation Allowance (A and z) We assume that companies can initiate write-offs in the year of purchase. Also, the tax break called the special depreciation is taken into account. Companies can credit a certain fraction (s_{1t}) of new investment to a reserve called the special depreciation reserve. This is a "tax-free reserve" in that the amount credited is deductible from taxable income but that the same amount must be added back to income over a certain number of years TS (which we take to be ten years). This represents an implicit interest free loan granted by the tax bureau: the stream of repayment on a loan of one yen is 1/TS over TS years. Companies can also immediately write off a certain fraction (s_{2t}) of new investment and then apply the standard depreciation formula to the remaining value of investment. The ratio of the increase in the special depreciation reserves to ACQ_t is our estimate of s_{1t}. The amount of the second kind of special depreciation is identified as the excess of reported accounting depreciation over allowable depreciation. This is divided by ACQ_t to obtain s_{2t}. If D(x,t) is the formula for ordinary depreciation on asset of age x acquired in year t, the depreciation formula D'(x,t) incorporating the special depreciation is

$$\text{(A10)} \qquad D'(x,t) = \begin{cases} s_{1t} + (1-s_{2t})D(x,t) + s_{2t} & \text{for } x = 0, \\ -s_{1t}/TS + (1-s_{2t})D(x,t) & \text{for } x = 1,..,TS, \\ (1-s_{2t})D(x,t) & \text{for } x > TS. \end{cases}$$

(3) To calculate A, we need to know the stream of nominal investment prior to the start of the data construction period. Rather than "backcasting" the past stream of investment, we truncate the stream of investment at the start of the data construction period and at the same time substitute the book value of capital stock for the value of nominal investment for the first year.

The asset life for tax purposes is taken from Hayashi (1985). It is highly aggregated and assumes the same value for machinery, transportation equipments, and instruments & tools. For z and A two values are calculated for the two depreciation method, the straight line and the declining balance methods. Other reported depreciation accounting methods are ignored. If the company reports both or neither methods, then the simple average of the two values is taken.

Financial Assets and Liabilities Except for stocks of affiliates held by the company, we did not try to convert book values into market values. Bank loans are the dominant component of long term debt in Japan. For the firms in the sample, we calculated the ratio of gross decrease in long term loans to the balance. Its average over the sample period ranges from 0.19 to 0.36, implying that the average maturity on long term loans is relatively short. Furthermore, long term debts (including bank loans) are about one half of short term debts. So for debts the discrepancy between the book value and the market value should not be important. The remaining issue is which balance sheet items should be recognized as assets and liabilities and how the affiliates's stocks should be valued. Financial assets includes: investments in affiliates, construction in progress, intangible fixed assets and deferred charges. Some of the reserves on the balance sheet should be regarded as retention, not debts. We include all reserves except the so-called special reserves as part of gross debt. Because the Japanese financial statements are not consolidated, the market value of affiliates's stocks is a major component of financial assets. From the profit & loss statement we obtain the amount of dividend received from the affiliates stocks. If it is positive, then it is capitalized by the average dividend price ratio for all the dividend-paying stocks on the Tokyo Stock Exchange. This also gives an average of the ratio of the market value to the book value of affiliates stocks for all companies receiving positive dividends from affiliates. This ratio is used to convert the book value of affiliates stocks into a market value for companies receiving zero dividends.

Market Value of Equity This is simply the product of the stock price and the number of shares outstanding. The stock price is the average of daily prices for the first month of the fiscal year. If the stock is not traded for some days within the month, those days are excluded in calculating the average stock price. To account for the fact dividends are paid at the end of the fiscal year rather than at the start of the year, the equity value at the beginning of the fiscal year is multiplied by $1+r_t$ to arrive at the market value of equity.

Implicit Claims and Liabilities other than Depreciation Allowance Under the

Japanese tax law there are a whole host of "tax-free reserves". Let R_t be the total amount credited to the tax-free reserves (other than the special depreciation reserve). This is the amount deducted from taxable income in the previous year. The same amount must be added back to current taxable income. Thus the tax-free reserves represents an interest-free one-year loan granted by the government. Some of the tax-free reserves are accruals and others are retention in nature, but they all represent interest-free loans. It is not possible from the financial statements provided in the Japan Development Bank file to identify all the tax free reserves, because some of the minor tax-free reserves are merged with non tax-free reserves on the balance sheet. We assume that all the so-called special reserves are tax-free reserves. Main components of R_t other than the special reserves are the accrued employees' severance indemnities (retirement reserve) and the allowance for bad debts. For most tax-free reserves, as far as we can tell from the tax code, the amount credited must be added back to the next year's income in full (the notable exception being the special depreciation account, which represents a long term tax-free loan, as we noted above, and which is already incorporated in A_t through s_{1t} in (A10)). We assume that this is the case for all tax-free reserves (except for the special depreciation reserves). Then $\tau_t R_t$ represents the amount owed to the government in year t. On the other hand, since the amount of enterprise tax paid in the previous year (ENT_t) is deductible from income, there is an invisible claim of $\tau_t ENT_t$. The market value of implicit claims, mentioned in Table I, equals $\tau_t \cdot (ENT_t - R_t)$. For more conceptual details, see Hayashi (1985).

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FOOTNOTES

[1] The only exception to our knowledge is Chirinko (1986), who enters individual investments in the same equation. However, it is not clear how identification is achieved if the error term in the equation originates from shocks to adjustment cost functions.

[2] See Jorgenson (1986) for a review of the literature.

[3] Our sample includes Toshiba, Toshiba Machine, and Toshiba Steel. There are eight Hitachi's and thirteen Mitsubishi's.

[4] It is true that the error term v_f+u_{ft} is not a univariate Markov process, which, however, is not inconsistent with the assumption in section 2 that the error term is a part of a multivariate Markov process s_t.

[5] Cash flow is defined as earnings plus accounting depreciation minus income tax.

[6] Estimation of a stock market-Q based equation under imperfect competition can be found in Schiantarelli and Georgoutsos (1987).

TABLE I

MARKET VALUE OF BALANCE SHEET ITEMS[a]

item	77	78	79	80	81	82	83	84	85	86
Assets										
fin. assets excluding stocks of affiliates	44245	45057	47198	52309	54965	60241	61764	66744	71891	71836
stocks of affiliates	7974	11143	13113	16089	18205	20780	25218	33541	41753	48989
nonresidential bldg.[b]	7332	7388	7472	8825	9015	8975	8946	9081	9089	9204
structures[b]	2308	2407	2465	2957	2975	2920	2862	2849	2782	2714
machinery[b]	11307	11145	10676	11449	11986	12552	12883	13136	13821	14080
transp. equipments[b]	149	158	155	165	167	176	175	170	170	164
instruments & tools[b]	1860	1881	1976	2526	2592	2759	2945	3197	3508	3795
land	20414	21062	22121	24195	26616	28805	30473	31827	33016	34403
inventory	16174	14981	14957	19440	20109	21793	21162	21011	22283	19677
present value of tax savings due to depreciation[c]	2685	2484	2576	2606	2456	2912	3530	4031	4665	5116
Liabilities										
gross debt (book value)	64876	65511	66003	72270	76423	81701	83410	87288	91788	90616
equity	33516	35235	42401	44089	58714	62064	71310	95935	102401	113851
tax-adjusted Tobin's q[d]	0.947	0.953	1.181	0.907	1.084	0.919	0.951	1.440	1.526	1.552

[a] Averages over 687 Japanese non-acquiring manufacturing firms, in million yen. The average for the year is over firms whose fiscal year ends between April of the year and March of the following year.

[b] These are valued at tax-adjusted nominal prices (1-z)PK' (see equation (2.2) of the text for the definition of z and PK'). For land and inventories, z = 0.

[c] The market value of tax saving due to depreciation yet to be claimed. It also includes the market value of implicit loans granted by the government through the "special depreciation" and "tax-free reserves" provisions of the Japanese tax code. See Appendix for more details.

[d] The average of tax-adjusted Tobin's q ratio defined by (2.20).

TABLE II

MEANS AND STANDARD DEVIATIONS

PANEL A: HEAVY INDUSTRY (392 FIRMS)

year	g		Q		CF	
	mean	std. dev.	mean	std. dev.	mean	std. dev.
1977	-0.0049	0.108	0.0108	0.828	0.0701	0.081
1978	0.0053	0.105	-0.0306	0.879	0.0904	0.077
1979	0.0116	0.111	0.2098	1.094	0.1173	0.085
1980	0.0693	0.091	0.0011	0.947	0.1123	0.077
1981	0.0470	0.088	0.2430	1.317	0.1152	0.092
1982	0.0229	0.110	-0.0443	1.098	0.1029	0.088
1983	0.0441	0.101	-0.0208	1.323	0.1036	0.089
1984	0.0613	0.107	0.8062	2.381	0.1224	0.092
1985	0.0502	0.096	0.6830	2.487	0.1150	0.088
1986	0.0189	0.140	0.5578	2.381	0.1017	0.091

PANEL B: LIGHT INDUSTRY (295 FIRMS)

year	g		Q		CF	
	mean	std. dev.	mean	std. dev.	mean	std. dev.
1977	-0.0012	0.091	-0.1331	0.621	0.0771	0.072
1978	-0.0139	0.118	-0.0995	0.753	0.0912	0.072
1979	-0.0017	0.114	0.1414	0.977	0.1066	0.071
1980	0.0285	0.077	-0.1242	0.666	0.0867	0.063
1981	0.0014	0.089	-0.1046	0.718	0.0773	0.069
1982	0.0172	0.099	-0.1376	0.846	0.0778	0.068
1983	0.0243	0.097	-0.1341	1.157	0.0822	0.066
1984	0.0187	0.072	0.0296	1.201	0.0932	0.065
1985	0.0357	0.075	0.4521	2.465	0.0909	0.065
1986	0.0100	0.104	0.6384	2.229	0.0985	0.065

TABLE III

PARAMETER ESTIMATES[a]

PANEL A: HEAVY INDUSTRY (392 FIRMS)

	(1)	(2)	(3)	(4)
Instruments besides the constant	lagged and future y,Q	lagged y,Q	lagged y,Q,CF	lagged y,Q,CF
Conditional heteroskedasticity allowed?	No	Yes	Yes	Yes
Years covered by equations	77-86	78-86	78-86	84-86
No. of orthogonality conditions	153	80	116	47
Q77	-0.007	———	———	———
Q78	0.018*	0.027***	0.030***	———
Q79	0.009	0.027***	0.023***	———
Q80	0.026***	0.049***	0.055***	———
Q81	0.013**	0.021***	0.025**	———
Q82	0.022***	0.032***	0.036***	———
Q83	0.014**	0.026***	0.033***	———
Q84	0.016**	0.022***	0.031***	0.029***
Q85	0.001	0.015***	0.025***	0.022***
Q86	-0.001	0.008*	0.018***	0.017**
CF78	———	———	0.26**	———
CF79	———	———	0.31***	———
CF80	———	———	0.23**	———
CF81	———	———	0.17*	———
CF82	———	———	0.22**	———
CF83	———	———	0.18*	———
CF84	———	———	-0.13	———
CF85	———	———	0.09	———
CF86	———	———	-0.06	———
P value for equality of Q coefficients	0.0000	0.0000	0.0000	0.0006
P value for CF coefficients jointly zero	———	———	0.0000	———
J statistic[b]	212	75	95	45
Degrees of freedom	134	63	90	42
P value	0.0000	0.1394	0.3302	0.3453

[a] *** = significant at 0.1%, ** = significant at 1%, * = significant at 5%.

[b] The J statistic is defined in (4.9) of the text.

TABLE III (continued)

PANEL B: LIGHT INDUSTRY (295 FIRMS)

	(1)	(2)	(3)	(4)
Instruments besides the constant	lagged and future y,Q	lagged y,Q	lagged y,Q,CF	lagged y,Q,CF
Conditional heteroskedasticity allowed?	No	Yes	Yes	Yes
Years covered by equations	77-86	78-86	78-86	84-86
No. of orthogonality conditions	153	80	116	47
Q77	0.045***	———	———	———
Q78	0.039***	0.032***	-0.000	———
Q79	0.020**	0.022***	-0.009	———
Q80	0.034***	0.045***	0.030***	———
Q81	0.021*	0.027***	0.013**	———
Q82	0.027***	0.029***	0.025***	———
Q83	0.036***	0.038***	0.040***	———
Q84	0.004	0.006	0.007	0.015
Q85	0.006**	0.010**	0.009***	0.013**
Q86	0.001	0.005	0.008**	0.010
CF78	———	———	0.63***	———
CF79	———	———	0.83***	———
CF80	———	———	0.18**	———
CF81	———	———	0.28***	———
CF82	———	———	0.08	———
CF83	———	———	0.01	———
CF84	———	———	-0.01	0.65**
CF85	———	———	0.05	0.83***
CF86	———	———	-0.04	0.76**
P value for equality of Q coefficients	0.0000	0.0000	0.0000	0.4619
P value for CF coefficients jointly zero	———	———	0.0000	0.0033
J statistic[b]	209	84	120	40
Degrees of freedom	134	63	90	39
P value	0.0000	0.0425	0.0190	0.4246

[a] *** - significant at 0.1%, ** - significant at 1%, * - significant at 5%.

[b] The J statistic is defined in (4.9) of the text.