Evidence on q and Investment for Japanese Firms*

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This paper presents estimates of q from April 1974 to March 1988 for 580 Japanese manufacturing firms. The estimates appear reasonable in several respects. First, the level of q for most firms is just above one. Interestingly, the large jump in the price earnings ratio in 1986 (which had led many to question the rationality of share prices) is not present in q. Second, taxes have important effects on the level of q. Third, the measurement error in q, at least prior to the recent stock market boom, appears to be small. Despite the plausibility of the q estimates, the basic and most tractable model relating investment and q does not fare well. The model's estimated parameters are implausible and unstable, and

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I. INTRODUCTION

Tobin's q is now being used to study a number of different issues in economics. First and foremost are its applications in investment theory. The q theory of investment has become the preferred theoretical model of investment. Over the last 10 years there have been innumerable empirical tests of the q theory.[1] On a lesser scale, q is now being used in the industrial organization literature as a measure of monopoly power, as a summary statistic for corporate performance, and as a predictor of the susceptibility of a firm to a take over.[2] Finally, as the Japanese stock market soared in the late 1980s, several studies have advocated the use of q as a guide for investors seeking to decide if stock prices are too high or too low. As a result of the attention attracted by these studies, Q-reshio (the Japanese word for Q-ratio) has become a buzz word among the investors in the Tokyo Stock Exchange.

Despite this widespread usage, considerable differences in the way in which q is computed remain. One of this paper's purposes is to clarify the issues involved in constructing q, particularly for Japanese data, and to discuss the implications of using alternative approaches in constructing q.

Our discussion is organized around the construction of q for a panel of Japanese manufacturing firms. Our estimates of q appear to be very plausible. For instance, q, using the most widely accepted definition, is slightly larger than one when taxes are taken into account. We also find that q did not soar during the unusual 1986–1987 share price appreciation—thus confirming the common assertion that given recent land price movements, equity price movements are not surprising.

The main purpose of the paper, however, is to use our carefully constructed estimates of q to study the investment behavior of firms. The empirical work provides several insights. First, firm-specific effects are demonstrated to be important; regressions which do not address firm heterogeneity can be fairly misleading. Second, by using the estimation

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[1] For instance, studies using Japanese data include Hayashi (1985), Hayashi and Inoue (1987, 1989), Wakasugi and Kon-ya (1980), Kon-ya and Wakasugi (1982, 1987), Homma *et al.* (1984), and Yonezawa and Maru (1984).

[2] See Lindeberg and Ross (1981), Smirlock *et al.* (1984), Morck *et al.* (1988), Hermalin and Weisbach (1987), McConnell and Servaes (1990), and Hasbrouck (1985).

strategy suggested by Griliches and Hausman (1986) we can identify the measurement error in q. This procedure reaffirms the quality of the estimates of q: the measurement error is small. Third, we find that the boom in the Japanese stock market coincides with a change in the relationship between investment and average q. Taking this change into account, we present a set of estimates for a firm's costs of adjustment which are a bit more plausible than those usually found in the literature. Nevertheless, the estimates are still very high, and we find that the simplest specification of the q theory of investment is rejected by the data.

The remainder of the paper is organized into four sections. The next section discusses the basic difficulties in constructing q and presents our estimates of q. We find that in addition to being quite reasonable, our estimates are easy to reconcile with many of the previous and less plausible estimates of q for Japan. The third section derives the relationship between investment and q that we subsequently estimate. The fourth section reports the results of the empirical tests of this model. Section V contains our conclusions and suggestions for further research.

II. ESTIMATES OF q

There are several definitional and notational conventions which must be established before any estimates can be examined. First, one must decide which assets will be counted as capital in the definition of q. Recall that average q is defined as the ratio of the value of a collection of assets to their replacement cost. One natural assumption would be to calculate q for all assets. However, in studying investment, the choice of assets to include in the definition of capital is translated into an assumption about which assets incur adjustment costs during their installation. Accordingly, many researchers have chosen to use a narrow definition of capital, which excludes some assets, such as financial assets which should be costless to adjust.

We follow this view and define $q1$ as the q that includes only depreciable assets in our definition of capital.[3] Nevertheless, so that we may

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[3] A related problem is the assumption that "capital" is homogeneous and all of its components have the same depreciation rate and the same type of adjustment cost function. If capital is in fact a collection of heterogeneous assets, each of which has a different depreciation rate, then stock market prices will reflect the average value of the different types of assets. More importantly, if the different types of capital have different adjustment cost functions, the simple relation between the average q and investment no longer holds. (See Chirinko (1986) and Wildasin (1984).) While most of the empirical literature about the investment–q relation assumes the homogeneity of the capital, Hayashi and Inoue (1989) and Asako et al. (1989) have recently succeeded in developing a model of investment with multiple capital goods, and their results suggest that the consideration of heterogeneity may be important. Unfortunately, our data set does not contain the information required to investigate this question.

contrast our estimates of q with those in previous studies, we also report estimates of q, labeled $q2$, which treat all assets as capital. It is made clear that in cross-study comparisons these definitional differences can be important.

The last major definitional issue involves taxes. In the presence of corporate profit taxes, depreciation allowances, or investment tax credits, a firm's optimization problem changes and q should be correspondingly redefined. There appears to be widespread agreement that these tax adjustments are important. For instance, Summers (1981), who used U.S. aggregate data, and Salinger and Summers (1983), who used U.S. panel data, reached the same conclusion regarding the importance of the tax correction. Hayashi and Inoue (1989), using a different Japanese data set, also reach this conclusion. To demonstrate the size of these tax effects, we also calculated the q's without the tax adjustment. We refer to these q's as $q1nta$ and $q2nta$ (nta for not tax adjusted).

Our data pertain to those manufacturing firms that are listed on the Tokyo Stock Exchange and whose accounting data are consistently available in all the years from April 1964 to March 1989. Thus the sample omits firms that have been newly listed or delisted from the Tokyo Stock Exchange. We also excluded any firms that have been involved in a merger or spin-off, because of the discontinuities in their accounting data.[4] The firms whose shares were not priced around the accounting year were also dropped.[5] Finally we dropped any companies that have had an absolute value of q (according to our preferred definition) greater than 50.[6] These selection rules leave us with 580 of the 972 manufacturing firms listed on the Tokyo Stock Exchange in March of 1989. Most exclusions, 226 (58% of 392 excluded firms), are due to mergers or spin-offs.

Figures 1–4 plot certain summary statistics for the four definitions of q (two measures of capital, each tax-adjusted or not tax-adjusted). The dates in the figures (and throughout the paper) refer to the accounting years which run between April of one year and March of the following year. For example, the year 1986 implies that the firm's accounting year

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[4] The data come from the Nikkei financial data tapes, which include a flag identifying firms involved in mergers and spin-offs.

[5] As we explain in Appendix 1, we calculate the market value of equities by multiplying the number of outstanding shares at the end of an accounting year by the share price at the beginning of the month after the end of the accounting period. If the share is not priced at the beginning of this month, we go back and use the most recent price, as long as there was not a split, new issue, repurchase, or change in par value in between. When these circumstances arise, we drop the firm from our sample. Twenty firms are excluded because of this criterion.

[6] This does not cause selection bias in our regressions later in the paper. Since q is an explanatory variable in our regressions this rule should only reduce the efficiency of our regression estimates if firms with extreme q's are indeed following the q theory. In any event this rule leads to the omission of 5% of the firms (33 of 613).
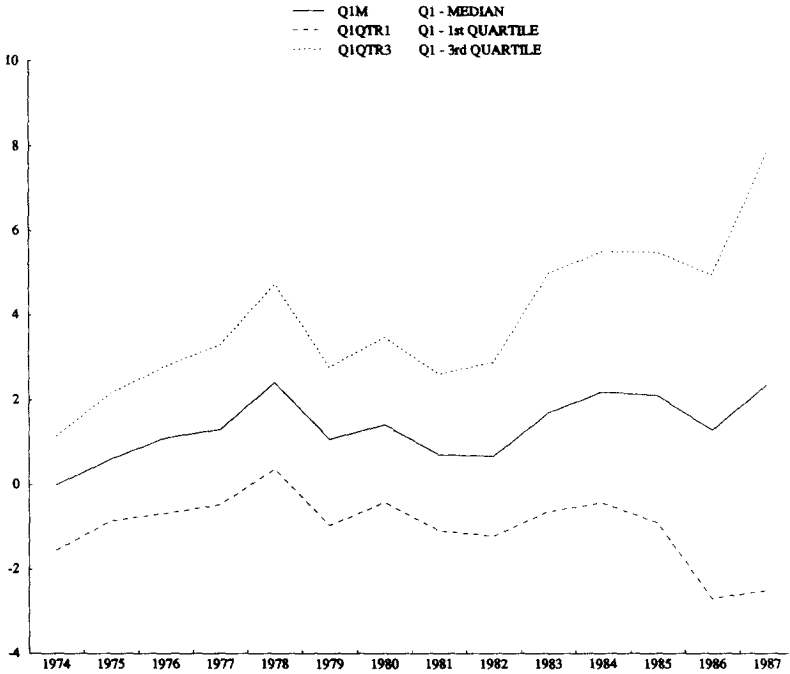
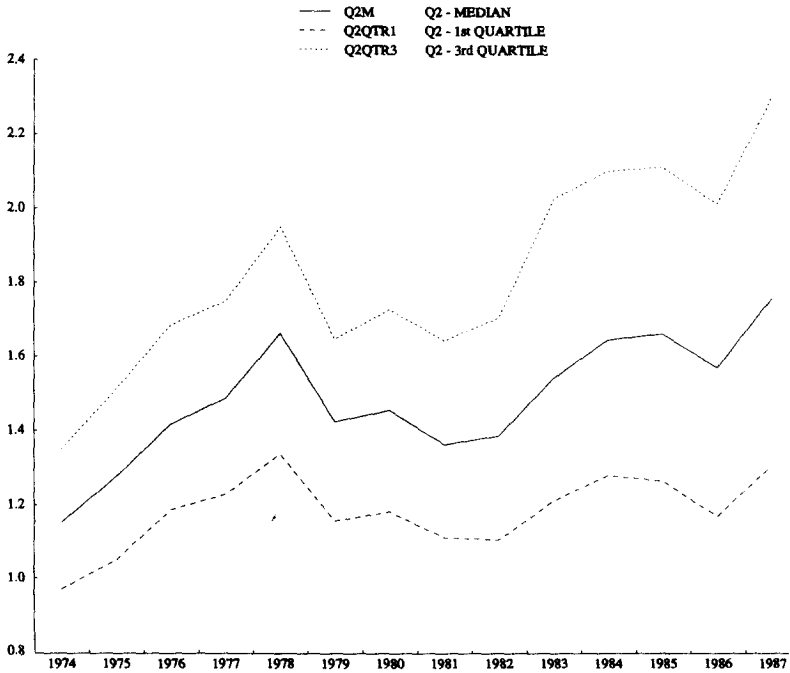FIG. 1. Estimates of $Q1$. See text for definition.
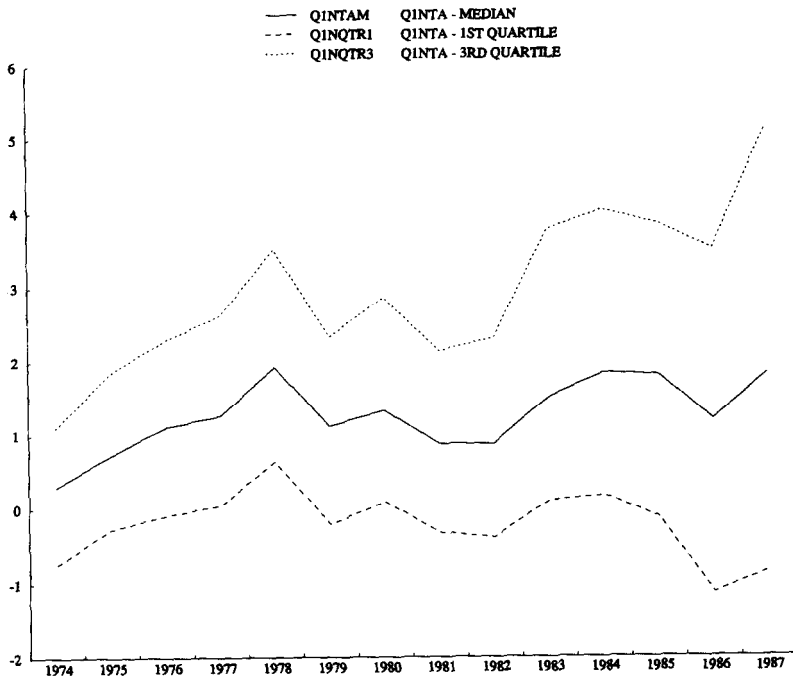
FIG. 2. Estimates of $Q2$. See text for definition.

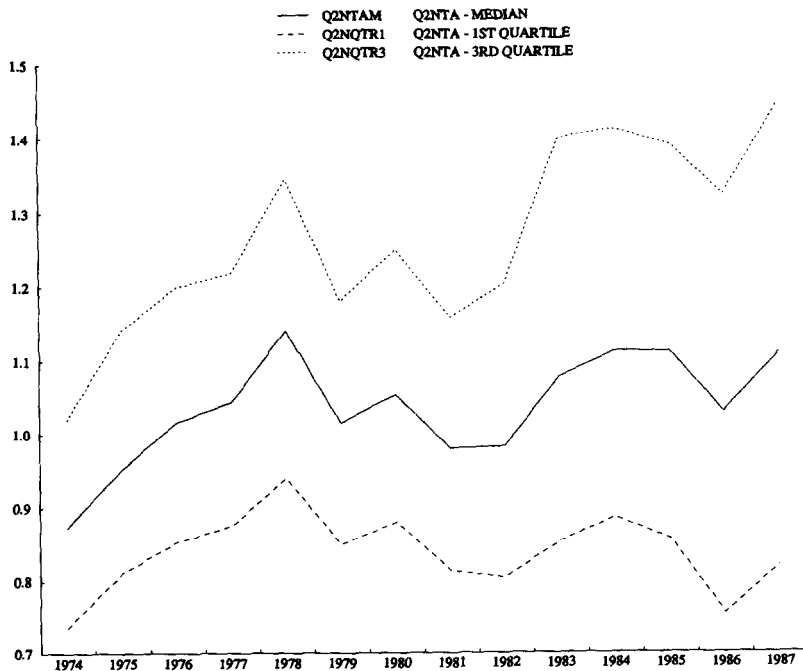FIG. 3. Estimates of Q_1 without any tax adjustment. See text for definition.

FIG. 4. Estimates of Q_2 without any tax adjustment. See text for definition.

ended between April 1986 and March 1987. As the figures show, in terms of the quartiles of the sample distribution, the two definitions of q move quite closely together; the correlations of the quartiles are generally high: for instance, 0.964 (between the medians). Similarly, the correlation calculated using the individual data is also very high: 0.857.

A second observation is that there is a noticeable difference in the levels of the two measures.[7] Below, we see that these level differences associated with alternative definitions carry over to many other studies. The tax adjustment also seems to affect the levels of the estimates but not the time series variation in the q's; the correlation coefficients between the quartiles of tax-adjusted series and not tax-adjusted series range from 0.738 to 0.996, while the correlation coefficients between tax-adjusted q and non-tax-adjusted q using individual data are again very high, 0.985 (between $q1$ and $q1nta$) and 0.981 (between $q2$ and $q2nta$). The tax adjustment tends to make the absolute value of the q's larger. Thus $q1$ exhibits larger variation than the non-tax-adjusted counterpart. Since $q2$ cannot be negative, all the quartiles of $q2$ are larger than those for its non-tax-adjusted counterpart.

In looking at the median values of the q's, we see that they fluctuate around one or a little above one. This is consistent with the q theory of investment. In long-run equilibrium, q must be one or just enough above one to induce the investment needed to offset depreciation. The fact that the estimates of the q's fluctuate slightly above one suggests that in this important sense our estimates of q are "reasonable."

Finally, we note the specific behavior of our estimates during the April 1986 to March 1987 period, when Japanese PEs (Price-Earnings ratios) climbed very rapidly. For instance, according to French and Poterba (1990) the simple, unadjusted PE for the Nomura Research Institute 350 jumped from 29.4 to 58.6 over the course of the 1986 calendar year. They also show that even after making a number of accounting adjustments to make Japanese PEs comparable to U.S. PEs, this doubling in the level of the PE is still evident. As Figs. 1 and 2 show, our estimates of q over this period actually declined. As a mechanical matter, the reason for the decline seems to be the land price surge that occurred during that year. Share prices (as measured by the Tokyo Stock Exchange Index) rose by 22.6%, while a representative land price index for commercial property in the six largest cities rose by an average of 40.8%. On net the increase in land prices meant that measured replacement costs rose faster than firm

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[7] The negative values for $q1$ are possible because the market value of the assets which are not considered capital should not be included in the value of the firm. Estimates of the market value of land are often so large that netting out the value of land can lead to estimates of q which are negative. As shown in Table I, this finding is quite common.

values. In this sense, our findings are consistent with the observation by Poterba and French (1990), that the puzzling behavior of share prices is related to the puzzling movements in land prices.

To further assess the plausibility of our estimates of q we compare them to those found in several other recent studies using Japanese data. Table I shows our yearly estimates of q for the median firm in our sample along with several other authors' estimates. A quick inspection of the table might suggest considerable disagreement over the value of q in Japan. However, most of the differences are easily explained by the data sources and definitional differences. The key differences involve the valuation of land, the treatment of taxes, and the use of aggregate as opposed to micro data.

The clearest differences arises between the studies using aggregate and micro data. As the table shows, q's calculated using aggregate data are usually smaller than those calculated from micro data. The difference arises mainly because of the difficulty in using aggregate equity data to infer the market value of those firms that are not publicly traded; as is widely recognized, the typical method used to extract an estimate of the market value of unlisted firms from aggregate data tends to understate the value of equity for unlisted firms.[8] This in turn leads to underestimation of q. This problem affects the estimates by Homma *et al.* (1984) (row 11) and Hayashi (1985) (row 12) and the first set of estimates from Ueda (1990) (row 9). Note that Ueda's second set of estimates (shown in row 10) is constructed using data for listed firms only and is thus immune to the imputation problem. The difference in the size of his two sets of estimates shows the seriousness of the understatement that can arise from using aggregate data.

Nevertheless, Ueda's second set of estimates is still smaller than ours.

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[8] The approach used by Homma *et al.* (1984, p. 49) to calculate the value of equities for the aggregate economy is representative and shows how the problem arises. Homma *et al.* first calculate the market value per share using data from the stock exchanges. Then, assuming that the average par value of shares for unlisted firms is equal to that for listed firms, they estimate the total number of shares in the aggregate economy. This can be done because they have data on both the equity in par value for the aggregate economy and the average par value for listed firms. Finally the market value of equity for the aggregate economy is calculated by multiplying the estimated total number of shares by the market value per share. As Homma *et al.* point out (p. 167), the problematic assumption is that the average par value of shares for listed firms is equal to that for unlisted firms. Starting in the late 1970's most of the new shares of listed firms have been issues at market price rather than face value. This tends to make the par value of shares for listed firms larger than that for unlisted firms. The assumption of an equal average par value of shares between listed firms and unlisted firms, therefore, leads to an underestimation of the total number of shares in the aggregate economy. This in turn leads to an underestimation of the value of equity for the aggregate economy and hence to a downward bias in the estimates of q.

Study	Fiscal year													
	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
q1 [a]	-0.01	0.60	1.10	1.31	2.41	1.07	1.42	0.71	0.67	1.69	2.20	2.11	1.29	2.35
q2	1.15	1.28	1.42	1.49	1.66	1.43	1.46	1.36	1.39	1.54	1.65	1.67	1.57	1.76
H & I 1 [a]				1.59	1.66	3.35	1.99	2.59	1.72	2.08	5.08	5.74		
H & I 2-1 [b]				0.795	0.766	0.827	0.739	0.872	0.820	0.881	1.047	0.954	0.999	
H & I 2-2 [b]				1.019	1.012	1.270	1.007	1.151	0.967	1.036	1.563	1.580	1.630	
K & W [c]	0.585	0.616	0.648	0.664	0.658	0.643	0.629	0.619	0.626	0.653	0.648	0.641		
Asako 1 [d]				0.692	0.710	0.792	0.639	0.769	0.678	0.781	1.040	0.953	0.960	1.033
Asako 2 [d]				0.753	0.780	1.079	0.764	0.872	0.650	0.761	1.290	1.334	1.238	1.194
Ueda 1 [e]	0.386	0.343	0.412	0.386	0.488	0.456	0.402	0.411	0.374	0.468	0.565	0.605	0.870	
Ueda 2 [e]							0.747	0.901	0.859	1.04	1.27	1.28	1.73	
Homma [f]	-0.56	0.15	0.37	0.23	0.44	0.16	-0.09	0.49						
Hayashi [g]	-1.128	-0.188	0.068	-0.101	0.084	-0.188	-0.483	0.108						

[a] Hayashi and Inoue (1987). Data correspond to the average of q for 611 manufacturing firms. They assume that some of the firm's assets can be adjusted without any cost.

[b] Hayashi and Inoue (1989). Data supercede H & I 1 and are calculated for 614 manufacturing firms. The definition of capital is expanded to include land and inventories as capital. H & I 2-1 estimates are constructed using data from the balance sheet of a representative firm in each year. The data for this synthetic firm are constructed by first averaging each of the balance sheet items across firms and then constructing q. H & I 2-2 estimates are the average of q's calculated for individual firms.

[c] Kon-ya and Wakasugi (1987). Data pertain to 814 firms from all industries. The definition of capital treats all assets as capital and no tax adjustments are made in constructing q. The q's are constructed using a representative firm calculation similar to that in H & I 2-1.

[d] Asako et al. (1989). Data represent estimates for 534 manufacturing firms, and the definition of capital includes depreciable assets, land, and inventories (as in H & I 2). The two sets of estimates also follow H & I 2, with Asako 1 corresponding to the representative firm and Asako 2 showing averages of individual firm-level q's. They estimate the value of land by calculating the product of the area owned by the firm and the price of land. The price series used accounts for variations in land use and region, allowing for 144 different prices each year.

[e] Ueda (1990). The Ueda 1 estimates are calculated using data from the National Income Accounts. The Ueda 2 estimates are constructed using aggregate data for listed firms. Neither of these estimates include any tax adjustments.

[f] Homma et al. (1984). Estimates are made using industry-level data, with q defined similarly to our $q1$. Estimates here are for the manufacturing sector and are calculated under the assumption that the market and book values of land are identical.

[g] Hayashi (1985). Estimates are based on national-level data and correspond to a definition of q close to that of our $q1$.

This further difference is due to the fact that he does not make any tax adjustments. As we now discuss, the failure to correct for taxes also biases the estimates of q downward. Note that the other study that does not make any tax corrections, Kon-ya and Wakasugi (1987) (row 6), also finds very low estimates of q. As shown in Figs. 1–4, the tax adjustment tends to make the absolute value of the q's increase. If we do not correct for taxes, our estimates of $q2$ drop from around 1.5 to around 1.1 (see Figs. 3 and 4). Summers (1981), using the U.S. aggregate data, finds similar patterns. So it is not surprising that Ueda's second estimates are lower than ours and we would expect that the estimates would be fairly close if he made any tax adjustments.

The absence of tax adjustments alone does not seem to explain the difference between the estimates of Kon-ya and Wakasugi and our estimates. Another factor responsible for their low estimates seems to be their method of aggregation. They report q's calculated as the ratio of sums of balance sheet items. If we compare two series presented in Hayashi and Inoue (1989) (rows 4 and 5), it appears that this way of calculating q tends to result in lower estimates of q. The second series of Hayashi and Inoue (1989), which is the average of individual q's, provides estimates which are very similar to ours and are noticeably higher than the estimates calculated from the aggregated firm-level data. The same relative size effect can be seen in the two sets of Asako *et al.* (1989) estimates (rows 7 and 8).

Finally by comparing the estimates of Hayashi and Inoue (1989) with those of their earlier study (Hayashi and Inoue (1987) (row 3)), we can see the importance of evaluating the market value of land when we calculate q's for Japanese firms. In the earlier study (Hayashi and Inoue (1987)), the authors started from the assumption that the market value of the land was equal to the book value in one year. They then made a LIFO-type correction for the rest of the sample. Thus if the market value of the land was larger than the book value in the base year, which is likely to be true, they would underestimate the market value of the land throughout the sample period. This explains why their estimates of q were so high.

In their subsequent work (Hayashi and Inoue (1989)), they calculate the market value of the land in a base year (1969) by multiplying the book value of the land by the book-to-market conversion factor, which is calculated using the National Income Accounts data. They then use a LIFO-type adjustment to construct a market value series for land that is corrected for inflation, land sales, and land purchases. This procedure is similar to our approach, which is spelled out in Appendix 1. Their estimates and ours are very similar.

Asako *et al.* (1989) (rows 7 and 8) do an even more sophisticated land correction. They divide each firm's land holdings into several parts,

which are each valued using separate land price series that account for land use and location. Their divisions include three potential uses (factories; offices and other uses; and forests, farms, and mines) and vary according to 48 locations (one for each of the 47 prefectures and a catchall for unclassified locations). These estimates, which account for 144 different types of land, are also reasonably close to our estimates.[9]

III. THE RELATIONSHIP BETWEEN q AND INVESTMENT

We now derive the relationship between q and investment. The motivation for the actual equation we estimate comes from the firm's maximization problem and the constraints it faces. We assume that a firm is interested in choosing its capital stock to maximize its discounted present value, taking into account that capital is costly both to purchase and to install and that depreciation will occur. Formally, we assume that the firm's problem is

$$\text{Max } V_t = E_{t-1} \left\{ \sum_{j=0}^{\infty} \{\pi_{t+j-1}(K_{t+j-1}) - C(I_{t+j}, K_{t+j-1}) \right.$$

$$\left. - p_{k,t+j-1}/p_{g,t+j-1} \cdot I_{t+j}\} \cdot \beta^j \right\} \tag{1}$$

$$\text{subject to } K_{t+j} = (1 - \delta) \cdot (K_{t+j-1} + I_{t+j}). \tag{2}$$

Note the timing convention that is implicit in this formulation. We assume that production and sales take place throughout each period.[10] Since the data we use are measured at the end of each accounting year, we equate the beginning of one period with the end of the previous period. Thus $\pi_{s-1}(K_{s-1})$ is the real profits of the firm, net of any costs for variable factors such as labor, at the end of period $s - 1$ (or equivalently at the beginning of period s).[11] We also assume that investment, denoted I_s, takes place at the beginning of the period and that the corresponding

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[9] We suspect that our estimates are slightly higher than the Asako *et al.* estimates because our initial estimates for the market value of land held by each company may be too low. The basis of the suspicion is that we use a simple average price in establishing the initial values. Because a disproportionate number of listed firms have land in the Tokyo area, the average price we used may be too low.

[10] Technically, this means that we should discount some of the current receipts since they are not all in hand at the beginning of the period. For tractability, we ignore this problem.

[11] Throughout the remainder of the discussion we use the terms "at the end of period $s - 1$" and "the beginning of period s" interchangeably.

relative price of capital is $p_{k,s-1}/p_{g,s-1}$. Similarly, we assume that the firm incurs certain costs for adjusting its capital stock and that the costs occurring at the beginning of the period are measured in terms of output and are given by $C(I_s, K_{s-1})$. Finally, we assume that the firm discounts the future at a constant rate of β per period and that depreciation is exponential and occurs at rate δ.

The first-order conditions for the firm's optimal investment dictates that

$$E_{t-1}\{-(p_{k,t+j-1}/p_{g,t+j-1}) - C_1(I_{t+j}, K_{t+j-1}) + \lambda_{t+j}\} = 0 \quad (3a)$$

$$E_{t-1}\{\pi'_{t+j}(K_{t+j}) - C_2(I_{t+j+1}, K_{t+j}) - \lambda_{t+j}/(\beta(1 - \delta)) + \lambda_{t+j+1}\} = 0, \quad (3b)$$

where $i = 1, 2, \ldots, \infty$ and λ_{t+j} denotes the Lagrange multiplier on the capital accumulation constraint. So λ_{t+j} is "marginal q," the shadow value of additional capital at the beginning of period $t + j$. The subscripts on the C function refer to the partial derivatives with respect to the corresponding arguments and π' denotes the first derivative of the profit function. There are two alternative approaches to testing this model of behavior. One strategy is to find a proxy for marginal q and estimate Eq. (3a). As we see shortly, the approach pioneered by Hayashi (1982) is to adopt certain assumptions about the firm's production function and cost-of-adjustment function so that Eq. (3b) can be used in conjunction with stock market data to construct a valid proxy for marginal q.[12]

A second strategy is to use Eq. (3a) to eliminate marginal q from Eq. (3b) and then to directly estimate the resulting equation. Estimation of that equation would require specific assumptions regarding the form of the profit function so that π' can be calculated. We pursued this strategy in previous versions of this study and found very disappointing results—implausible estimated parameters and rejections of the model's orthogonality restrictions. To save space these results are omitted from this version of the paper but interested readers can find more details in our working paper (Hoshi and Kashyap (1990)).

To relate investment and average q (instead of marginal q) we assume that the profit function is first-order homogenous in capital and that the cost-of-adjustment function is homogeneous of degree one in its arguments. Under these assumptions, we can show that the marginal q, λ_t, is related to the expected value of the firm, V_t, as follows[13]:

$$\lambda_t K_{t-1} = V_t.$$

[12] Ueda and Yoshikawa (1986) point out that this strategy depends on the absence of delivery lags. If delivery lags are present, then the expected value of q at the time when orders must be placed will be the key determinant of investment. As they indicate, with delivery lags, any variables that are useful for forecasting q will affect investment.

[13] See Hayashi (1982) for a proof.

Thus we can rewrite (3a) to get

$$C_1(I_t, K_{t-1}) = \lambda_t - (p_{k,t-1}/p_{g,t-1}) \tag{3a'}$$
$$= \frac{p_{k,t-1}}{p_{g,t-1}} (q_t^a - 1) = Q_t,$$

where $q_t^a = p_{g,t-1} V_t/(p_{k,t-1} K_{t-1})$ is the average q at the beginning of period t.

Below we assume that $C(I_{it}, K_{it-1})$ is given by

$$C(I_{it}, K_{it-1}) = \frac{1}{2} b_1 \left(\frac{I_{it}}{K_{it-1}} - u_{it} \right) I_{it}. \tag{4}$$

This function satisfies the homogeneity condition mentioned earlier and permits tractability; under this formulation $b_1 * I_{it}/K_{it-1}$ is the amount of output foregone per marginal unit of investment. The shock to the cost of adjustment, u_{it}, can be further decomposed so that

$$u_{it} = \alpha_i + \nu_t + \varepsilon_{\text{industry } i} + \nu_{it}. \tag{5}$$

For clarification, note that a positive u_{it} is a favorable shock to the firm in that it reduces the amount of output that must be foregone when investment occurs. Here we assume that the shocks to the cost of adjustment function have several components, namely, α_i, a firm-specific factor; ν_t, a year-specific factor; $\varepsilon_{\text{industry } i}$, an industry-specific factor; and finally η_{it}, a completely random factor affecting firm i in year t. By including these components in u_{it} we allow for efficiency differences across firms, industries, and years. We further assume that the marginal q used by the firm in making its investment decision is uncorrelated with anticipated components of any of these shocks.[14]

With $C_1(I_t, K_{t-1})$ substituted for, Eqs. (3a') and (4) imply the following estimable equation relating investment and average q:

$$\frac{I_{it}}{K_{it-1}} = \frac{1}{b_1} Q_{it} + \frac{1}{2} u_{it}. \tag{6}$$

The results from the estimation of this equation are given in the next section.

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[14] Hayashi and Inoue (1987, 1989) make the alternative assumption. They assume that the shocks to the cost-of-adjustment function are incorporated into the beginning of the period stock prices. In this case q will be endogenous and we would need to use instrumental variable estimation.

IV. EMPIRICAL RESULTS

A key issue in the empirical work is the potential correlation between the disturbances in Eq. (6) and Q.[15] To handle the error components structure of the disturbance, estimation proceeds in several steps. First, we use OLS to estimate the equation in a levels form. By including dummies for each year and industry we can test whether these factors are important. Next we can reestimate the same equation using first differences of all the data. Assuming the q theory of investment is correct, the coefficient on Q in the level and first-difference regressions will be the same if Q is perfectly measured and there are no firm-specific effects which are correlated with Q. If there are firm-specific effects which are correlated with Q, then the two estimates will differ because the first-difference regressions eliminate the firm-specific components of u_{it} and the level regressions do not. If Q is measured with error (and the error is independently identically distributed) then the first-difference regression should produce an estimate closer to zero than the level regression. This will occur because the bias induced by measurement error depends on the ratio of the variance of the measurement error to the variance of the regressor. First differencing a serially correlated variable, like Q in our sample, will increase the noise to signal ratio (as long as the measurement error is not negatively serially correlated). Fortunately, as Griliches and Hausman (1986) point out, this same insight suggests a method for bounding the effect of measurement error. By using two estimators that control for firm-specific effects but have different noise to signal ratios it is possible to uncover the influence of measurement error. A convenient alternative to the first-difference regression for this purpose is the "long-difference" regression, where data many periods apart are differenced, i.e., $x_t - x_{t-k}$, $k > 1$ is used. This transformation is useful because it should preserve most of the signal in the regressor and is easy to carry out.

Table II reports several different estimates of the relationship between investment and Q. Different rows in the table correspond to alternative transformations of the data—levels, first differences, and long differences. The dependent variable is investment in depreciable assets normalized by its shock at the beginning of the period. The regressions described in the table include dummies for yearly and industry effects. These dummies are generally quite significant.

By comparing the different rows in the table it is possible to determine the importance of firm-specific effects and measurement error. The estimates of $1/b_1$ increase when the regressions use data in first differences instead of levels. This would be possible if the firm-specific effect, α_i,

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[15] As defined in (3a'), Q is $((q_t^a - 1) \cdot p_{k,t-1})/p_{g,t-1}$.

Data	Period of estimation	Coefficient on Q[b]
Levels	1975–1988	0.0015 (0.0004)
1st difference	1976–1988	0.0047 (0.0009)
3rd difference	1978–1988	0.0051 (0.0007)
5th difference	1980–1988	0.0028 (0.0007)
7th difference	1982–1988	0.0021 (0.0007)
9th difference	1984–1988	0.0028 (0.0007)
11th difference	1986–1988	0.0008 (0.0007)

[a] Regressions also include industry and yearly dummies. See the text for a further description of the data.

[b] We use $q1$ to construct Q. Standard errors are shown in parentheses.

were known to be negatively correlated with Q. Indeed, there is an a priori reason to suspect that Q and α_i might be negatively correlated. Recall from the definition of the adjustment cost shocks that firms with large α_i can make large adjustments to their capital stock quite "cheaply." Hence if Q is high, it will quickly be reduced since such a firm can easily take advantage of any favorable investment opportunities. On the other hand, if α_i is low, the firm will tend to invest more slowly. So if Q starts out high it will tend to stay high. According to this view, Q and α_i should be negatively correlated and the estimates of $1/b_1$ should increase when we use first-differenced data instead of levels.

The relation between the first-differences and long-differenced regressions is more puzzling. As mentioned above under normal circumstances where Q is positively correlated, we would expect measurement error to lead to an increase in our estimate of $1/b_1$ when we move from first differences to long differences. This pattern is not evident in the regressions in Table II.

One possible explanation would be that there has been a structural shift in the coefficients. As is well known, the boom in the Japanese stock market over the last several years has produced movements in stock prices which completely swamp any movements over the earlier years. Our estimates of q do not move one for one with stock prices, because the replacement cost of firms (particularly that of land) also increased during this period. However, the q's in the late 1980s tend to be consistently higher than those in the early 1980s, suggesting the possibility of bubbles in stock prices in recent years. If the stock market boom is based on bubbles, then the relationship between marginal and average q will be

TABLE III
PREBOOM YEARS: REGRESSIONS RELATING INVESTMENT AND
Q USING A PANEL OF 580 JAPANESE FIRMS[a]

Data	Period of estimation	Coefficient on Q[b]
Levels	1975–1982	0.0033 (0.0008)
1st difference	1976–1982	0.0074 (0.0020)
3rd difference	1978–1982	0.0098 (0.0016)
5th difference	1980–1982	0.0104 (0.0024)

[a] Regressions also include industry and yearly dummies. See the text for a further description of the data.

[b] We use $q1$ to construct Q. Standard errors are shown in parentheses.

broken. As always, when a firm's stock price is assumed to have a bubble, it is not clear what strategy the firm's management should follow to exploit this information. However, if the firm chooses to make decisions only on the basis of fundamentals, then marginal q (not average q) is the relevant determinant of investment. In this case, the relationship between average q and investment would differ before and after the boom years. Intuitively, since average q would exceed marginal q, we might expect that as we add more observations from the boom period the estimates of $1/b_1$ would shrink in order to compensate for the growth in the nonfundamental portion of average q. This is indeed the pattern that is present in the table; in moving from first-difference estimation to estimation with longer differences, the proportion of the observations from the boom period in the sample increases and the estimate of $1/b_1$ declines.

To further investigate this possibility, we split the sample to separate the period before and after the stock market boom started. We take April 1983 as the beginning of the stock market boom. Table III compares the level, first-difference, and long-difference regressions for the preboom years (fiscal years 1975 to 1982 in our notation). In moving from levels to first-differences regression, the estimate of the coefficient on Q increases. This suggests the importance of firm-specific effects. In contrast to the results obtained using the entire sample, in moving from first differences to longer differences, the estimate of $1/b_1$ increases, suggesting that some measurement error is present in Q. As pointed out by Griliches and Hausman (1986), the first-difference and long-difference estimates can be combined to produce a consistent estimate of the variance of the measurement error. Since we have emphasized the integrity of our estimates of q, we report the implied measurement error variance which can reconcile the estimates from the first-difference and fifth-difference estimates. Assum-

ing that the measurement error in Q is i.i.d., the implicit estimate of the variance of this measurement error is 1.357. The total variance in Q for this period is 18.196, which implies the noise–signal ratio of 7.5%. We can do similar calculations using the first-difference estimate and any long-difference estimate. We also calculated the implicit estimate of the variance of the measurement error using second-, third-, and fourth-difference estimates. The estimates range between 0.9687 and 1.7827, which implies noise–signal ratios between 5.3 and 9.8%.[16] Collectively, these results suggest that during this nonboom period, our estimates of q appear to be relatively precisely measured.

Griliches and Hausman (1986) also suggests a way to get a consistent estimate of $1/b_1$, taking the effect of any measurement error into account. Again assuming that the measurement error in Q is i.i.d., when we use the first-difference estimate and the fifth-difference estimate, the consistent estimate of $1/b_1$ is 0.0122. Experiments using the other long-difference estimates suggest that the true $1/b_1$ lies somewhere between 0.0112 and 0.0197.

The coefficient in these regressions is the inverse of the parameter in the adjustment cost function. The estimates in Table III imply that this parameter is between 96 and 135, while the consistent estimates that take the effect of measurement error into account suggest that b_1 is between 50 and 89. One way to put this estimate in perspective is to evaluate the adjustment cost function (4) at typical levels of investment. For instance between fiscal years 1976 and 1982 the mean value of $(I/K) * I$ was 735.3 million yen (while average cash flow over this period was 3653.8 million yen). Assuming the average shock is zero, a value for b_1 of 50 implies that average adjustment costs were five times greater than average annual cash flow. So even though our lowest estimates are noticeably lower than many in the literature, they still imply extraordinarily high adjustment costs.

The regression results for the boom period are reported in Table IV. Again the coefficient estimate increases when we move from the levels regression to the first-difference regression, suggesting that important firm-specific effects are present. But, in contrast to the results for the pre-boom period, the coefficient estimate falls as the difference gets longer. This suggests that the difference among the estimates cannot be explained by a simple form of measurement error in Q; if we try to estimate the

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[16] These calculations depend on the coefficient estimates and the variances of $(Q_{it} - Q_{it-1})$, $(Q_{it} - Q_{it-2})$, $(Q_{it} - Q_{it-3})$, $(Q_{it} - Q_{it-4})$, and $(Q_{it} - Q_{it-5})$. The respective variances are 5.710, 8.158, 11.413, 12.235, and 10.328. The coefficient estimates using the second-differenced and fourth-differenced data, which are not reported in the table, are 0.0111 and 0.0094, respectively.

TABLE IV

BOOM YEARS: REGRESSIONS RELATING INVESTMENT AND Q
USING A PANEL OF 580 JAPANESE FIRMS[a]

Data	Period of estimation	Coefficient on Q[b]
Levels	1983–1988	0.0014 (0.0004)
1st difference	1984–1988	0.0043 (0.0011)
3rd difference	1986–1988	0.0041 (0.0009)
5th difference	1988	0.0003 (0.0009)

[a] Regressions also include industry and yearly dummies. See the text for a further description of the data.
[b] We use $q1$ to construct Q. Standard errors are shown in parentheses.

variance of the measurement error assuming an i.i.d. error, we get either a negative estimate or a noise–signal ratio greater than 100%. Thus the result suggests that the q theory as we have implemented it does not satisfactorily describe the data during this period.

To summarize, the results from the preboom period are mildly encouraging. The measurement error in Q, if any, seems to be small, while the estimate of $1/b_1$ is at the higher end of the range of other published estimates. However, the cost of adjustment parameter, b_1, still seems to be too large. The performance of q theory in the boom period is much less promising: even allowing for the possibility of measurement error in Q, the q theory does not seem to fit the data.

As a final test of the q specification, we consider whether q is a sufficient statistic for investment. This requirement is akin to an actual test of the simple theory since the mere implausibility of the cost of adjustment parameter would be less troubling if Q summarized the primary movements in investment. We focus our test on the 1975–1982 period, since this is the period when the theory has the most success. Our test checks whether firms are acting as if they are liquidity constrained by examining whether cash flow influences investment.

Table V shows the results from adding a lagged measure of cash flow normalized by capital stock to the basic q model. The regressor we add is defined as the previous year's after-tax income plus depreciation less total dividends paid out, all divided by the beginning of period capital stock. The table shows that this variable is quite significant. Of course, the interpretation of this reduced form regression is unclear; cash flow is likely to be correlated with a number of other variables so that its significance could easily be due to the presence of another omitted variable. In any event, even if there is no structural interpretation to these regres-

TABLE V
REGRESSIONS RELATING INVESTMENT, Q, AND CASH FLOW USING A PANEL
OF 580 JAPANESE FIRMS[a]

| | | Coefficient on Q and cash flow[b] | |
Data	Period of estimation	Q	Cash flow
1st difference	1976–1982	0.0054 (0.0018)	0.0450 (0.0215)

[a] Regressions also include industry and yearly dummies. See the text for a further description of the data.
[b] We use $q1$ to construct Q. Standard errors are shown in parentheses.

sions, they do suggest that the simplest and most tractable assumptions relating investment to Q are inappropriate.

As mentioned above, an alternative approach to testing the maximizing model underlying the q theory is to directly test the investment Euler equation. In our working paper (Hoshi and Kashyap (1990)) we report the results from this exercise. The results were also quite troubling for the simple version of the q model. Briefly, we found that the estimated parameters of that model, particularly the discount rate, were implausible. For instance, the discount factor, β, was often estimated to be negative. If this problem was corrected, say by fixing β at more reasonable values, the model's orthogonality restrictions were typically strongly rejected.

V. CONCLUSIONS AND FUTURE RESEARCH AGENDA

This paper has presented our estimates of q for Japanese firms. We have also uncovered several results that merit further consideration. The investment–Q relation does not appear to be stable. The recent increase in the Japanese stock price appears to have disrupted the link between average q and investment. Similarly, the most straightforward implementation of the q theory is rejected. Given the recent declines in share prices it will be interesting to see if the pre-stock market boom relationship reappears.

Despite these disheartening results, it is hard to give up on the theory. As Keynes pointed out in the "General Theory of Employment, Interest and Money" (1936, p. 151), the basic motivation behind the theory is very compelling: "there is no sense in building up a new enterprise at a cost greater than that at which a similar existing enterprise can be purchased [through the stock market]." Thus it is important to be sure that the simplifying assumptions that were maintained in this study are not the

only cause for our results. Interestingly, the recent study by Hayashi and Inoue (1989) finds somewhat more encouraging results when they allow for heterogeneity in different types of capital. For instance, they do not find any breakdown in the investment–Q relationship during the stock market boom years. Nevertheless, their estimates still imply very large adjustment costs. Perhaps further work will yet be able to save the q theory.

Appendix 1: Construction of q

This appendix describes our construction of a tax-adjusted q for each firm. Throughout this appendix we maintain the Hayashi (1982) assumptions which guarantee the equality of marginal and average q. Under these assumptions q can be written as

$$q_t = \frac{p_{g,t-1}V_t - \tau_t A_t}{(1 - \tau_t z_t)p_{k,t-1}XK_{t-1}}, \tag{A1}$$

where $p_g V$ is the market value of the firm, τ is the effective tax rate, z and A are the present discounted values of future depreciation allowances for today's investment and investments made in the past, respectively, p_k is the price of capital, and XK is the market value of capital. We ignore any investment tax credits, because they have been very rare in Japan. We divide the remaining part of this appendix into two parts. The next subsection explains details of our calculation of $p_{g,t-1}V_t$ and $p_{k,t-1}XK_{t-1}$. Section B describes our tax adjustments, i.e., how to calculate τ_t, z_t, and A_t. More details on these calculations can be found in the working paper version of this paper.

A. Calculating Market Values

The descriptions of the conversions between book and market values are presented separately for each of the major balance sheet items.

Short-term Liabilities and Long-term Liabilities. We rearrange short-term and long-term liabilities into two categories. Some of these liabilities require interest payments. We form one category for all of the interest-bearing liabilities—within this category, all distinctions between debt and borrowing are dropped. The remaining liabilities are put into a category called non-interest-bearing liabilities. For lack of a better assumption, the market value of non-interest-bearing liabilities is taken to be their book value. The market value of the interest-bearing liabilities is calculated by dividing the interest payments of the firm by a properly averaged interest

rate. The average interest rate, ra_t is given by

$$ra_t = \frac{rs_t BS_t + rl_t BL_t}{BS_t + BL_t},$$ (A2)

where rs_t and rl_t are the short-term and long-term interest rates, respectively, and BS_t and BL_t are the short-term and long-term interest bearing liabilities in book value. So ra is a weighted average of short-term and long-term interest rates, where the weights are determined by the proportions of long-term and short-term interest-bearing liabilities that the firm holds. (Homma et al. (1984) also use this strategy.)

If a firm's interest-bearing liabilities mostly consisted of long-term debt of differing maturities, our estimation procedure might produce a bad approximation of the market value of these liabilities. Fortunately, for most of the firms in our sample, the majority of their interest-bearing liabilities are short-term liabilities and most of the long-term interest-bearing liabilities are long-term borrowing. Thus it is unlikely that our approximation will lead to a large error.

Equity. The market value for equity is calculated as the number of shares outstanding at the end of the accounting year times the price of a share. For the price of a share, we used the stock price at the beginning of the month immediately following the last day of the accounting year. If the share is not priced at the beginning of the month, we go back and collect the most recent price available, unless there was a split, a new issue, a repurchase, or a change in par value in between.

Inventories. For some methods of inventory valuation, the book value of inventories can be significantly different from the market value. There are several ways that firms may value their inventories. The legal methods of valuation for Japanese firms are (i) FIFO, (ii) LIFO, (iii) average method, (iv) individual method, (v) latest cost method, and (vi) sales price method. Some companies use different methods for different types of inventories.

Since we can decompose the total inventories into four parts, we compute the market value for each category of inventories separately. The categories which we can separately identify are (a) inventories of finished goods, (b) inventories of work in progress, (c) inventories of raw materials, and (d) other inventories. For category (d), no information about the accounting method is available so we assume that the market value of these goods is the book value.

In our sample, more than half of the companies use only the average method for the evaluation of their inventories of finished goods, work in progress, and raw materials. This method uses an average price for the

inventories over the accounting period to obtain an end-of-period value. Thus the book value calculated by this method should be close to the market value. In fact, we assume that all accounting methods except LIFO produce book values which are close to the market value. In the presence of persistent inflation, the book value of inventories evaluated using LIFO can be quite different from the market value. Accordingly, for the few firms in our sample, approximately 5%, who use LIFO we adjust the book values of inventories.

To do so, it is assumed that at the end of the first year of the sample, somewhere between April 1964 and March 1965, depending on when the accounting year ends, the book and market values of inventories are equal. From the next year onward, the market values of inventories are adjusted in one of two ways, depending on whether inventories increased or decreased.

When the firm increases its inventories from one period to the next, any additions are assumed to be recorded on the books at the prevailing market value. The sum of these additions and the inflation-adjusted market value of the inventories which were carried forward from the previous period give this period's market value for inventories. When the firm decreases inventories, we assume that the cleared inventories are 1 year old and make the appropriate correction for inflation. Since the average replacement period for inventories is about 1 year for most of the industries, this assumption seems reasonable. (See Homma *et al.* (1984, Table 2-6, pp. 58–59).)

If a company uses both LIFO and another accounting method to evaluate the inventories, we assume that half of the inventories are evaluated using LIFO and the other half are valued using the other method. The information about the accounting method for inventories is available for each year. Thus our valuation scheme properly tracks changes in a firm's accounting method.

Land. Since the value of the land is recorded using the price when it was purchased, the valuation of the land is treated in a LIFO fashion. The market value of land in the base year is found by multiplying the area of land owned by the firm by the price for land. This approximation is exact if there is no spatial variation in land prices. We made a crude correction for spatial variation by using separate prices for the land owned by the firms in the paper and pulp industries and the clay, glass, and stone industries since the land owned by these types of firms tends to be located in areas with systematically lower land prices (see Wakasugi and Kon-ya (1980, pp. 15–16.))[17] We also chose this approach because the other feasi-

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[17] We thank Fumiko Kon-ya for kindly providing us with the land price series.

ble assumption, that the book and market values were equal at some point in our sample, seemed dubious.[18]

The first period in which land holdings are available is the accounting year ending between April 1973 and March 1974. So for the land valuation we had to use a base year of 1973 in our recursion—in all other recursive calculations we use the fiscal year 1964 as the initial year. The one complication with the recursion is that to correctly adjust for inflation we need to know the holding period for land which is sold. We assume that land which is sold was bought at the most recent price the firm paid for any land acquisitions. Our final assumption is that the first time any land was sold, the land being sold had been acquired in 1973. Given these assumptions, the recursion for the market value of the land, $LANDY_t$, following 1973 is

$$LANDY_t = \begin{cases} LANDY_{t-1} \dfrac{LANDP_t}{LANDP_{t-1}} + DELLAND_t \\[1em] \qquad\qquad\qquad\qquad \text{if } DELLAND_t \geq 0 \\[1em] LANDY_{t-1} \dfrac{LANDP_t}{LANDP_{t-1}} + DELLAND_t \\[1em] \qquad\quad \times \dfrac{LANDP_t}{LANDPB_{t-1}} \quad \text{if } DELLAND_t < 0 \end{cases} \tag{A3}$$

$$LANDPB_t = \begin{cases} LANDP_t & \text{if } DELLAND_t \geq 0 \\ LANDPB_{t-1} & \text{if } DELLAND_t < 0, \end{cases} \tag{A4}$$

where $DELLAND_t = LAND_t - LAND_{t-1}$ (change in the book value of land); $LANDP_t$ = the price of land at time t; and $LANDPB_t$ = the price at which land was last bought.

Depreciable Assets. Since the capital stock is also recorded using the price when it is purchased, we have to make some adjustments to the book value numbers in order to calculate the market values. Our reevaluation method is essentially a LIFO-type recursion which is augmented to take depreciation into account.

We are interested in correcting for economic depreciation, which is assumed to be exponential so that the same proportion of the capital stock depreciates every year.[19] We also assume that there is a firm-specific rate

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[18] In an earlier draft we actually tried this assumption and found that the market value of land was estimated to be less than 15% of the market value of total assets for each firm in each year. This seemed implausible to us.

[19] Note that as Chirinko (1987) emphasizes this assumption is critical to make the calculation tractable. Without it the entire age profile of the capital stock must be known.

which is constant over the sample period. To estimate this rate, δ_{econ}, we use information on the accounting depreciation which each firm has claimed. In estimating δ_{econ} we distinguish two cases depending on the accounting method of depreciation that a firm uses. In the first case, where the firm uses the exponential depreciation, we estimate the economic depreciation rate to be

$$\delta_{\text{econ}} = \frac{1}{25} \sum_{t=64}^{88} \frac{Dep_t}{K_t + Intank_t + FInv_t + Dep_t}, \tag{A5}$$

where K_t, $Intank_t$, $FInv_t$, and Dep_t stand for the stock of the depreciable assets, the intangible assets, the financial investment, and the depreciation, respectively, in accounting year t. Since the depreciation reported by a firm includes the depreciation not only in depreciable assets but also in intangible assets and the financial investment, we take the sum of all three types of assets as the base in calculating δ_{econ}. The implicit assumption here is that the depreciation ratio for this broadly defined capital measure is the same as that for the depreciable assets. Note that Hayashi and Inoue (1989) went to great trouble to avoid having to make this assumption.

In the second case, where the firm uses straight line depreciation, the calculation is trickier. Essentially we want to infer the economic depreciation rate which would produce the same total amount of depreciation as has been typically claimed by the time an asset is scrapped. Of course this will depend on how much of the asset is depreciated and the length of time over which the asset is depreciated. We begin by estimating the average life of the capital, L, to be

$$L = \frac{1}{25} \sum_{t=64}^{88} \frac{K_t + Intank_t + FInv_t + Dep_t}{Dep_t}. \tag{A6}$$

Let α be the ratio of the salvage value of the capital to its initial value. Then the economic depreciation is calculated as the value of the exponential depreciation rate δ that would leave exactly α of an investment after L years. Thus,

$$\delta_{\text{econ}} = 1 - (\alpha)^{1/L}. \tag{A7}$$

We assume that α is 0.1, which is the ratio of salvage value to initial value for fixed tangible assets that is mandated by Japanese tax law.[20] Using

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[20] See Ministry of Finance, Tax Bureau (1985, p. 82).

these estimates for δ_{econ}, we can calculate the market value of depreciable assets, XK_t through the following recursion:

$$XK_t = \left(XK_{t-1} \frac{p_{k,t}}{p_{k,t-1}} + I_t\right)(1 - \delta_{\text{econ}}). \tag{A8}$$

The assumption here is that depreciation occurs at the end of the period. I_t is the investment in depreciable assets. Since we do not have independent estimates for investment expenditure, I_t is imputed from changes in the book value of capital—of course, with a correction for depreciation. So I_t is

$$I_t = K_t - K_{t-1} + \gamma Dep_t, \tag{A9}$$

where γ is defined as the fraction of depreciation that occurs for depreciable assets. Hence γ is estimated as

$$\gamma = \frac{1}{25} \sum_{t=64}^{88} \frac{K_t}{K_t + Intank_t + FInv_t}. \tag{A10}$$

Even if investment expenditure data were available, this method of measuring investment might still be preferred since it necessarily imposes consistency between the capital and investment measures.

Quick Assets, Other Current Assets, Intangible Assets, Financial Investment, Deferred Cost, Construction in Progress, and Special Reserves. For these items, the book value is assumed to be equal to the market value. This assumption seems to be reasonable for all these items except intangible assets. For intangible assets, this assumption is made because we do not know of any way to accurately calculate their market value.

B. Tax Adjustment

Taxes change a firm's investment decision by directly reducing the benefits of profits and by allowing the firm to claim certain depreciation allowances. The first step in correcting q for taxes is to calculate the effective tax rate that applies to a firm's profits. In Japan, there are four kinds of profit taxes: (i) the corporate income tax, (ii) the prefectural inhabitants tax, (iii) the municipal inhabitants tax, and (iv) the enterprise tax. The enterprise tax requires special treatment, since any enterprise tax paid in one year is deductible from the tax base of the next year.[21] Let

[21] The discussion here follows Hayashi and Inoue (1987).

us use v to stand for the enterprise tax rate. We also call the sum of the first three kinds of tax the "corporation tax" and use u to denote the corresponding corporation tax rate. In terms of this notation, the "effective" tax rate, τ, will be

$$\tau = (u + v) - (u + v)v(1 + r)^{-1} + (u + v)v^2(1 + r)^{-2} + \cdots \quad \text{(A11)}$$

An example may help to clarify this formula. Suppose that in this period the firm pays $(u + v)$ in taxes. In the next period, because the enterprise tax v will be deductible, the firm will save $(u + v)v$. However, this term must be discounted because the savings do not occur until the next period. Since the firm will save $(u + v)v$ of the enterprise tax in the second period, these taxes will not be deductible in the third period, and therefore the firm loses $(u + v)v^2$. . . . . The expression in (A11) can be simplified to

$$\tau = (u + v)(1 + r)/(1 + r + v). \quad \text{(A12)}$$

We used Industry Aggregate Data in the NEEDS COMPANY database to calculate u, v, and hence τ. Using the (medium-level-classified) industry data, we calculated u as the ratio of the payments of corporation taxes to the taxable income in the corresponding accounting year. Similarly v is calculated as the ratio of the payment of enterprise taxes to the taxable income. Then we calculated τ using (A12). These industry-specific tax rates are assigned to each firm accounting to their medium (two digits) industry classification.

The next step is to identify the value of the depreciation allowances that a firm accumulates when it invests. The depreciation allowances from both actual past and potential current investments affect the firm's current investment decision. The marginal cost is now lower because if the firm invests now it will acquire a stream of depreciation allowances. We define z_t to be the present discounted value of the depreciation allowances that the firm can claim for one unit of investment today. Thus z_t is

$$z_t = \sum_{s=t}^{\infty} D(t, s)(1 + r)^{-(s-t)}, \quad \text{(A13)}$$

where $D(t, s)$ is the depreciation that the firm can claim at time s for the investment made at time t. As before, $D(t, s)$ will differ according to which accounting method a firm uses. For a firm using exponential depreciation, $D(t, s) = \delta(1 - \delta)^{s-t}$. Thus z_t is given by

$$z_t = \frac{\delta(1 + r)}{r + \delta}. \quad \text{(A14)}$$

For a firm using straight-line depreciation, $D(t, s) = 1/L$ for $0 \le s - t \le L - 1$, and $D(t, s) = 0$ for $s - t \ge L$. Thus z_t is given by

$$z_t = \frac{(1 + r)(1 - (1 + r)^{-L})}{rL}.$$ (A15)

The depreciation allowances accumulated from past investments matter because they are assets which will be reflected in the stock market valuation of the firm. However, for the purposes of a current investment decision their value is irrelevant. Hence, in calculating marginal q the presence of these assets must be taken into account. We use A_t to stand for the present discounted value of the depreciation allowances that the firm can claim for any investments it has made in the past. Thus A_t is

$$A_t = \sum_{s=t}^{\infty} (1 + r)^{-(s-t)} \left[\sum_{n=-\infty}^{t-1} D(n, s)p_{k,n}I_n \right].$$ (A16)

Rather than having to solve this complicated expression, we can use the fact that A_t and A_{t+1} are very closely linked. Specifically,

$$A_{t+1} = (1 + r) \left[A_t + z_t p_{k,t}I_t - \sum_{n=-\infty}^{t} D(n, t)p_{k,n}I_n \right].$$ (A17)

We have already seen how to calculate z_t and $p_{k,t}I_t$. Recognizing that $\sum_{n=-\infty}^{t} D(n, t)p_{k,n}I_n$ is equal to the depreciation that the firm claims in year t, we can use (A17) to calculate A_t recursively, once we have an initial value A_0.

To calculate an initial value for A we need to know each firm's depreciation claims for any capital that was accumulated prior to the start of our sample. This can be calculated if a firm's historical investment is known or can be estimated. We backcast the investment for each firm by assuming that prior to the start of our sample, the nominal investment rate for each firm was 19.7% (which was the rate of growth for the nominal investment for the Japanese economy as a whole between 1950 and 1964). Using these assumptions we solve for A_0.

When g is the growth rate of nominal investment, the initial value for A for firms using exponential depreciation is

$$A_0 = \frac{\delta \cdot (1 - \delta) \cdot (1 + r)}{(g - \delta) \cdot (r + g)} I_0.$$ (A18)

For firms using straight-line depreciation, A_0 is given by

$$A_0 = \frac{(1 + g)^n \cdot (1 - (1 + g)^{-L})}{1 - (1 + g)^{-1}} \cdot \frac{1 - (1 + r)^{-L}}{1 - (1 + r)^{-1}} \cdot \frac{I_0}{L}. \qquad (A19)$$

Thus given a value for I_0 we can calculate A_0. The initial investment number I_0 which is consistent with the assumption of constant growth of investment is

$$I_0 = \frac{g + \delta}{1 - \delta} K_0. \qquad (A20)$$

Since our calculation of A_0 is made for 1964 and q is not calculated until 1974, the impact of A_0 on the q's we calculate should be small.

APPENDIX 2: SOURCE OF DATA

All the data used in our calculation were obtained from NEEDS Database. The balance sheet data and stock price data were taken from the NEEDS COMPANY database. Other price data and interest rates were taken from the NEEDS CENT database. Wholesale price indices are used for the price of finished goods inventories for firms in each industry. The wholesale price index for investment goods is used for the price of new capital. For the price of raw material inventories, input price indices are used. The average of finished goods price and the raw material price is applied for the price of work in progress. We used the land price index for commercial areas for our land price index. For firms that have their main offices in one of the six prefectures that have the six largest cities in Japan, we used the land price index for commercial areas in the six largest cities. The average rate for loans and discounts made by all types of banks is used for the short-term interest rate. For the long-term interest rate, which is used in the calculation of z and A, the yield on Nippon Telegram & Telephone bond was used.

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