

Firm Investment and Financing in Imperfect Markets: Estimation Using Tobin's Q

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This paper presents a model of firm investment and financing in which market imperfections exist in both real capital and financial capital markets. Under these conditions the use of Tobin's q to explain investment is examined. Test results suggest that imperfect markets may be at least partly responsible for the uneven record of the q model in empirical research on investment.

Introduction

Early studies of firm investment described the relationship between investment and its explanatory variables as a technological phenomenon. However, for many years research on investment has been guided by Tinbergen's observation that "it is almost a tautology to say that investment is governed by profit expectations" (1939, p. 34). The problem, of course, is that profit expectations are very difficult to measure, so what we find among the leading models of investment are various proxies for its expected profitability. Tinbergen believed that for most firms the distant future was of little concern, so that realized profit would ordinarily serve as an adequate substitute for expected profit.

The role of market value in measuring profit expectations was first described by Greenspan (1959) and Grunfeld (1960), in whose models investment varied directly with the market value of the firm. Following the work of Brainard and Tobin (1968), Tobin's q —the ratio of the market value of the firm to the replacement cost of its real capital—supplanted the market value variable as a determinant of investment. Hayashi (1982) showed that under perfect markets assumptions q was a sufficient statistic for this purpose.

The application of the q model is based on the proposition that the firm will add to its stock of real capital whenever the marginal addition to the market value of the firm's securities exceeds the replacement cost of the real assets they represent. In practice, secondary markets for real assets are often very limited, in which case investment decisions will involve unrecoverable sunk costs. Postponing such decisions may have the effect of reducing uncertainty about the profitability of investment, so that waiting has a positive value.¹ In addition, investment decisions may be constrained by financial factors. Under perfect markets, the firm's investment and financing decisions will be independent.² However, asymmetric information and taxes give rise to a variety of possible outcomes, including financial practices intended to mitigate the impact of adverse selection and moral hazard on investment.³

¹See Bernanke (1983), Dixit and Pindyck (1994), McDonald and Siegel (1986) and Nickell (1978). Likewise, firms may find it optimal to retain excessive capital for some period of time (Bean, 1989).

²See Modigliani and Miller (1958) and Miller and Modigliani (1961).

³The importance of financial constraints to investment are described in Blundell, Bond, Devereux and Schiantarelli (1992), Bond and Meghir (1994), Fazzari, Hubbard and Petersen (1988) and Whited (1992).

Though widely used in empirical research on investment at both the firm and aggregate level over the past twenty years, Tobin's q has an uneven record. In particular, average q , which is typically used in lieu of marginal q (because of a lack of information about the latter), emerges as only one of a number of determinants of investment. In addition, investment appears to be very sensitive to cash flow, a finding not predicted by the model.⁴ Further, estimated coefficients for the q variable imply implausibly long periods of adjustment in the capital stock.⁵ However, these results may arise, not because the model is inherently wrong, but because it is not sufficiently robust to capture the various conditions under which firms are obliged to operate. The objective of the present study is to examine analytically the impact of market imperfections on the application of Tobin's q . Firm data will then be used to illustrate the importance of including real capital and financial capital market constraints in empirical research on investment.

The Model

The model is based on the stockholder wealth maximization model in which net payments to stockholders—that is, dividends—are considered. In particular, it is assumed that the firm maximizes the present value of the future stream of dividends, S :

$$S = \int_0^{\infty} D(t) e^{-kt} dt, \quad (1)$$

where $D(t)$ denotes the dividends paid out in period t and k is the equity yield required by investors.⁶

To simplify the development of the model it is assumed that the firm produces a single good, $Q(t)$, at time t , from two homogeneous factors, labour, $L(t)$, and real capital, $K(t)$. The firm sells its output at some fixed price, $p(t)$. Similarly, it purchases its variable factor input, labour, at some fixed wage, $w(t)$. Labour services are rented, while the real capital is owned by the firm. When the stock of real capital is not sufficient to provide the quantity of capital services needed for production, the firm may acquire additional real capital at its market price. The quantity of real capital acquired at time t is $I(t)$, while its unit price is $h(t)$. Consequently, expenditure on real capital at time t is $h(t)I(t)$. Thinness in real capital markets is modelled by requiring gross investment in each period to be non-negative; that is, $I(t) \geq 0$.⁷

In addition to the constraint on investment, a financial constraint will be imposed. In particular, dividends will not be allowed to fall below a given threshold. This is motivated by the view that regular dividend payments reduce agency costs at the firm level because managers will be obliged to seek external financing and accept the scrutiny of the market when they do so (Easterbrook, 1984).

⁴See Blundell, Bond, Devereux and Schiantarelli (1992), Chirinko (1993) and Hayashi and Inoue (1991).

⁵The empirical performance of q models is discussed in Blundell, Bond and Meghir (1992), Chirinko (1993) and Scaramozzino (1997).

⁶The appropriate objective for the firm in the presence of agency costs or asymmetric information is a contentious issue. If there is a divergence of interests between stockholders and managers, the latter will seek to maximize their own utility. However, as explained below, regular dividend payments are used to solve the agency problem between managers and stockholders, so that stockholder wealth maximization is the appropriate objective for the firm.

⁷This follows Arrow (1968), Bean (1989) and Scaramozzino (1997). Demers (1991) shows that this constraint accounts for a risk premium in the cost of capital.

Hence $D(t) \geq d$, where d is the lower bound on dividends.⁸

Besides its expenditure on labour and real capital, the firm pays or receives interest on its net debt position. Debt may be positive or negative, depending on whether the firm's liabilities are greater or smaller than its nominal assets. Net outstanding debt at time t is denoted by $B(t)$ and new debt incurred by $b(t)$, while $i(t)$ is the cost of borrowing at t . In order to simplify the development of the model it is also assumed that all external funds are obtained through borrowing.⁹

To summarize, then, the firm will obtain revenue from the sale of its output. From this revenue it must pay the owners of the labour stock for services provided, purchase any real capital needed to obtain the desired level of capital services, pay interest on its net debt position and adjust its borrowing to maintain its investment and dividend plans. Thus, assuming a zero tax rate, dividends are identically equal to¹⁰

$$D \equiv pQ - wL - hI - iB + b - pC(I, K), \quad (2)$$

where $C(I, K)$ is an adjustment cost function for investment, twice differentiable, with the first derivatives and the second own derivatives positive.

The maximization of equation (1) is subject to two technological constraints. The first is a production function specifying the maximum quantity of output obtainable from given inputs of labour and capital, L and K , respectively. In explicit form the function is

$$Q(t) = f[K(t), L(t)] \quad (3)$$

This production function is assumed to be twice differentiable, the first derivatives positive, the second own derivatives negative. This implies diminishing marginal returns with respect to any input. Further, a positive marginal rate of substitution between inputs is assumed.

The second constraint is a function relating the flow of capital services to the real capital owned by the firm. The geometric mortality distribution, which we shall adopt, has been widely used in empirical work, and can be written as follows:

$$dK/dt = I - \delta K, \quad (4)$$

where δ is the rate of replacement, a fixed constant.

The firm is also limited by its borrowing. Borrowing decisions influence the rate at which dividends are paid by affecting the availability of funds. They also influence the rate at which the

⁸This assumption includes, as a special case, the condition that dividend payouts be non-negative.

⁹One theoretical argument for this assumption is that the market views new equity issues as conveying negative signals about firm profitability (Myers and Majluf, 1984). However, the empirical relevance of new equity funds appears to be very modest. In the United States, common stock has seldom accounted for more than ten percent of the total value of new securities issued by nonfinancial corporations in a given year (*Economic Report of the President*, various years). Moreover, this statistic includes stock sold in initial offerings and that issued in connection with corporate reorganizations, business combinations and stock option commitments.

¹⁰The time notation is dropped where no ambiguity occurs.

outstanding debt is changing and thereby the amount of debt that will be outstanding in subsequent periods.

In addition, the maximization of equation (1) is subject to initial conditions on the levels of real capital and outstanding debt at time 0: $K(0)=K_0$, $B(0)=B_0$. Consequently, the initial stock of real capital and the initial debt position are not variables in the maximization problem. Labour inputs are assumed to be perfectly variable and, as such, adjust to the stock of real capital, K .

Optimality Conditions

Let us first summarize the problem which the firm is required to solve:

$$\text{Max } S = \int_0^{\infty} D(t) e^{-kt} dt, \quad (5)$$

where $D=pQ-wL-hI-iB+b-pC(I,K)$, $Q=f(K,L)$ and subject to $dK/dt=I-bK$, $I \geq 0$ and $D \geq d$. Gross investment, I , and new borrowing, b , are the choice variables. The firm's problem is to choose I and b in each period so that equation (1) is maximized. Only the demand for investment will be considered here.

In order to solve this problem we let λ_1 be the Lagrange multiplier pertaining to the constraint on capital accumulation (equation (4)), and λ_2 and λ_3 the Kuhn-Tucker multipliers pertaining to the inequality constraints on investment ($I \geq 0$) and dividends ($D \geq d$). The first order condition for investment can be written as ¹¹

$$\text{Install Equation Editor and double-click here to view equation.} \quad (6)$$

Equation (6) relates the firm's investment decision to the shadow value of capital, λ_1 , and to the shadow costs of the investment constraint, λ_2 , and the dividend constraint, λ_3 . From equation (10), and given the linear homogeneity of $G(I,K)$, the investment-capital ratio is a decreasing function of λ_3 . Relaxing the dividend constraint would result in higher investment spending. When $\lambda_2 > 0$, it follows from the complementary slackness condition on investment, $\lambda_2 I = 0$, and from equation (6) that a higher shadow cost attached to the investment constraint must result in a lower shadow value of capital, λ_1 , or in a higher shadow cost of dividends, λ_3 , or both. Hence, the investment constraint might reduce the attractiveness of capital investment, and exacerbate the opportunity cost of the dividend constraint.

If $\lambda_2 = \lambda_3 = 0$, equation (6) reduces to

$$\text{Install Equation Editor and double-click here to view equation.} \quad (7)$$

Equation (7) should be estimable because λ_1/h is simply Tobin's marginal q and Hayashi (1982) has shown that, under linear homogeneity of the production function and of the adjustment cost function, marginal q is equal to average q . However, if either $\lambda_2 > 0$ or $\lambda_3 > 0$, or both, then equation (7) provides an inadequate description of investment behaviour.

¹¹Allowing external funds to be more costly than internal funds would not alter the first order condition of investment. The firm would issue the smallest amount of debt consistent with the dividend payout requirement. The shadow cost of the latter to the firm, λ_3 , would be affected. However, equation (6) would still be satisfied.

Estimation also requires an empirically operational adjustment cost function. The appropriate choice should be general enough to approximate the actual function in a wide variety of empirical situations. Here we rely on Poterba and Summers (1983) to obtain

$$C(I,K)=\gamma/2K(I/K-\mu-\varepsilon)^2, \quad (8)$$

where ε is a firm-specific random disturbance and μ is the desired investment-capital adjustment. The first order condition given by equation (6) then becomes

$$I/K = \mu + \gamma^{-1} (1 + \lambda_3) [\lambda_1/h - I + (\lambda_2 - h\lambda_3)/h](h/p) + \varepsilon \quad (9)$$

If $\lambda_2=\lambda_3=0$, equation (9) simplifies to

$$I/K = \mu + \gamma^{-1} (\lambda_1/h - I)(h/p) + \varepsilon \quad (10)$$

The q model of equation (10) is only valid when neither the investment nor dividend constraints are binding. Attempts to estimate equation (10) for firms for which $\lambda_2>0$ or $\lambda_3>0$, or both, would result in a mis-specified model. The coefficient on the q ratio would be biased, and other variables correlated with the shadow values of the constraints would appear to be significant. In particular, the availability of internal funds could reduce the opportunity cost of the dividend constraint. This could in turn exacerbate the investment constraint, given the interdependence of investment and financing policies. Measures of cash flow could thus be correlated with the unobservable shadow values λ_2 and λ_3 in equation (9).

Hence the q ratio would only be a sufficient statistic for investment, given the capital stock, when neither constraint applies. Otherwise, estimates of equation (14) will be affected by mis-specification and may generate implausible coefficients for q as well as allow excess sensitivity to financial variables.

Data Description

In the model outlined above the investment and financing decisions of the firm are inter-related. One approach to testing the relevance of the investment and dividend constraints is to examine investment behaviour when one or both of the constraints are binding and compare the results with those obtained when the constraints do not apply. The data used for this purpose comprise time series data for each of fifty large nonfinancial corporations over the period 1955 to 1994.¹² Parallel tests were conducted using (estimated) replacement cost and historical cost data to measure capital in the denominator of the q variable. The reason for considering historical cost data derives from Booth's (1981) observation that while replacement cost measures are more likely to approximate the economic concepts of value, income and cost, managers may not fully appreciate the impact of inflation on the firm. In addition, as explained below, whereas the historical cost data are produced by the firms themselves, most of the replacement cost information comprises estimates generated by the author using aggregate price indices.

¹²The original data set used in this study was compiled for the period 1955-1981. It was subsequently updated with data for the years 1982-1994. However, in some instances the nature of a firm's business changed substantially or the firm was acquired by another firm. In these instances the period studied ended in the year preceding the year in which the change in business or acquisition occurred.

Firm data were obtained from the *Value Line* tapes, successive editions of *Moody's Industrial Manual* and company annual reports. The *Survey of Current Business* and its *National Income and Product Accounts Supplement* provided the data required to compute price indices. Annual data were used to measure the variables. Although quarterly or monthly observations are sometimes employed to estimate models of investment, they were not available in the detail that the measurement rules employed here required. In addition, the use of annual data avoided seasonal variations in investment expenditures.

The initial criterion employed in selecting individual firms was the availability of (S.E.C. (1976) mandated) replacement cost information for 1976 and subsequent years. Since the S.E.C. requirement only applied to firms with inventories and fixed assets totalling more than \$100 million (at historical cost) and comprising more than ten percent of total assets, the sample may be loosely described as comprising large, publicly traded nonfinancial corporations. In addition, firms were chosen from a diverse group of industries and, as a result, have a wide range of investment and dividend rates.

For the years prior to 1976 and, in some cases, after 1981, firm-supplied replacement cost data were not available. In order to obtain estimates of firm capital on a replacement cost basis, historical cost data were adjusted using an output price index for inventory and a capital goods price index for fixed assets. The details of the adjustments can be obtained from the author.

Methodology and Results

The model is predicted to provide an appropriate description of firm investment only when the shadow costs of the constraints on investment and dividends, λ_2 and λ_3 respectively, are equal to zero. In order to distinguish those firms for which $\lambda_2 > 0$ or $\lambda_3 > 0$ or both from those for which $\lambda_2 = \lambda_3 = 0$, we assume that the constraints are least likely to be binding for those firms with high investment rates and dividend payout ratios. The critical threshold used in each case is the median. Utilizing a threshold that is well away from the origin reduces the likelihood that high-investment, high-dividend firms would have been constrained. In addition to considering (i) low investment and (ii) low dividend payout firms (relative to the median), we also consider the following categories: (iii) low investment or low dividend payout; (iv) low investment and high dividend payout; (v) high investment and low dividend payout; and (vi) high investment and high dividend payout. For all categories but the final one at least one of the constraints could have been binding. Only for the final category is equation (10) expected to provide an adequate explanation of investment.

In order to estimate equation (10) we use a distributed lag function of the form

$$\kappa_t = \alpha + \sum_{\tau=0}^2 \beta_{\tau} q_{t-\tau} + \alpha_3 \kappa_{t-3}, \quad (11)$$

where $\kappa_t = I_t/K_t$ is the investment rate for t , and K_t and q_t are beginning of period values. The choice of the current and two immediately past values for q_t , with all prior values represented by κ_{t-3} , is suggested by previous evidence on average project completion times and capital expenditure adjustment practices (see Chamberlain and Gordon (1989)).

The regression results for the various cases considered using historical cost data are summarized in Table 1. Columns (i) through (vi) correspond to the six cases identified previously.

For each case the number of firms examined, a summary of the numbers of correctly-signed coefficients and correctly-signed coefficients significant at the five percent level, and median R^2 and regression standard error statistics are presented. Columns (i) and (ii) summarize the results for those firms for which investment and dividends, respectively, are expected to be constrained. Generally, the q model does not perform well for these groups of firms, with median R^2 values of 0.255 and 0.252. While approximately five-eighths of the coefficients for q_t and q_{t-1} have the expected positive sign, in each case very few are significant at the five percent level. This is in keeping with the possibility that there is a positive shadow value attached to the investment constraint (in column (i)) and the dividend constraint (in column (ii)).

Though the results are poor, they only consider one constraint at a time. Hence, in columns (iii) to (vi) we consider both constraints jointly, as is implied by equation (10). Column (iii) presents a summary of the regression estimates when at least one constraint could have been binding. The proportion of correctly-signed coefficients, if anything, tends to be slightly smaller

Table 1
Estimation Results Summary for Equation (11)
Using Historical Cost Data

	(i)* $\kappa_i \leq \kappa_{med}$	(ii)* $\theta_i \leq \theta_{med}$	(iii) $\kappa_i \leq \kappa_{med}$ or $\theta_i \leq \theta_{med}$	(iv) $\kappa_i \leq \kappa_{med}$ and $\theta_i > \theta_{med}$	(v) $\kappa_i > \kappa_{med}$ and $\theta_i \leq \theta_{med}$	(vi) $\kappa_i > \kappa_{med}$ and $\theta_i > \theta_{med}$
No. Firms	25	25	37	13	13	13
$\alpha_1 > 0$	17	16	23	7	6	10
$\alpha_2 > 0$	14	13	17	4	3	10
$\alpha_3 > 0$	11	10	14	3	4	7
$\alpha_4 > 0$	10	10	15	5	6	7
$\alpha_1 > 0$ $t > t_{.95}$	2	2	2	1	0	4
$\alpha_2 > 0$ $t > t_{.95}$	0	3	5	1	0	2
$\alpha_3 > 0$ $t > t_{.95}$	0	1	3	2	0	2
$\alpha_4 > 0$	0	0	3	1	0	2

$t > t_{.95}$						
Median R^2	0.255	0.252	0.244	0.237	0.208	0.388
Median SER	0.0479	0.0491	0.0572	0.0392	0.0475	0.0262

* κ_i and θ_i are the mean investment rate and dividend payout ratio, respectively, for firm i , and κ_{med} and θ_{med} are the medians of the mean investment rates and dividend payout ratios for all firms in the category indicated.

than is the case when only one constraint is considered. Likewise, very few are statistically significant. Columns (iv) and (v) consider the low investment, high dividend and high investment, low dividend cases. Again, the q model performs poorly, suggesting that both constraints are important. This inference is also supported by the results for the high investment, high dividend firms reported in column (vi). Here most of the regression coefficients have the correct positive signs. While the number of correctly-signed coefficients significant at the five percent level is still small, the proportion is consistently higher than for any of the other cases. Moreover, the median R^2 value is a relatively high 0.388.

The results obtained using replacement cost data, which are reported in Table 2, generally mirror their historical cost counterparts. Cases (i) through (iii) tend to produce correctly-signed

Table 2
Estimation Results Summary for Equation (11)
Using Replacement Cost Data

	(i)* $\kappa_i \leq \kappa_{med}$	(ii)* $\theta_i \leq \theta_{med}$	(iii) $\kappa_i \leq \kappa_{med}$ or $\theta_i \leq \theta_{med}$	(iv) $\kappa_i \leq \kappa_{med}$ and $\theta_i > \theta_{med}$	(v) $\kappa_i > \kappa_{med}$ and $\theta_i \leq \theta_{med}$	(vi) $\kappa_i > \kappa_{med}$ and $\theta_i > \theta_{med}$
No. Firms	25	25	37	13	13	13
$\alpha_1 > 0$	15	16	21	5	6	10
$\alpha_2 > 0$	18	17	22	5	4	9
$\alpha_3 > 0$	17	16	21	5	4	7
$\alpha_4 > 0$	13	14	18	4	5	9
$\alpha_1 > 0$ $t > t_{.95}$	2	2	2	1	0	6
$\alpha_2 > 0$	2	2	3	1	0	4

$t > t_{.95}$						
$\alpha_3 > 0$	0	2	2	0	0	2
$t > t_{.95}$						
$\alpha_4 > 0$	0	0	3	1	0	2
$t > t_{.95}$						
Median R^2	0.288	0.292	0.251	0.222	0.147	0.356
Median SER	0.0449	0.0426	0.0488	0.0415	0.0514	0.0271

* κ_i and θ_i are the mean investment rate and dividend payout ratio, respectively, for firm i , and κ_{med} and θ_{med} are the medians of the mean investment rates and dividend payout ratios for all firms in the category indicated.

coefficients, though, again, few are statistically significant. As was the case with historical cost data, the performance of the model is also poor when only one of the constraints is considered (cases (iv) and (v)). Finally, though less likely to be correctly signed, roughly one-half of those coefficients in column (vi) are significant. The median R^2 statistic for this case, at 0.356, is also somewhat higher than those obtained for cases (i) through (v). This, again, suggests that both constraints are important.

Summary

The purpose of this paper was to show that the q model is unlikely to provide an adequate description of the investment behaviour of firms whose investment and financing practices are constrained by imperfect market conditions. The existence of these constraints may be responsible for the mixed results obtained using the q model in previous empirical research on investment. The use of q in the present study to examine the investment behaviour of fifty large nonfinancial corporations also appears to support this view. Interpreting a low investment rate or dividend payout ratio as a proxy for a binding constraint on investment or dividends, we find that the model performs poorly when either constraint is imposed. In contrast, the q model works reasonably well for high investment, high dividend firms, which are less likely to have been affected by constraints. At the same time, even in the latter case, much of the variation in the dependent variable remains unexplained. In terms of the model presented here, this may be partly because of the inference that the Kuhn-Tucker multipliers for the high investment, high dividend firms are equal to zero. Previous work indicating the importance of measures of cash flow suggests the possibility that the availability of internal funds is correlated with the unobservable shadow values. The inclusion of cash flow or other liquidity measures as additional explanatory variables in the present framework may be a useful direction for future research.

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