Revised on December 28, 2007

Estimating Capital Investment with Financial Constraints:

Comparison of Tobin's *q* and Real Options Approaches

ASSA Conference
New Orleans, 2008

Hirokatsu Asano
Department of Economics
Asia University
Tokyo, Japan

JEL Code: C23, C24, E22, G31

Abstract: This paper investigates irreversible investment with financial constraints by comparing two approaches based on Tobin's *q* and the real options theories. The paper examines capital investment in two distinct periods. Tobin's *q* approach shows different results between the two periods. However, the real options approach yields estimates which are similar for the two periods and compatible with theory. In point of fact, the real options approach shows that liquidity positively affects investment for financially constrained firms for both periods. Thus, in this paper, the real options approach is more appropriate to analyze irreversible investment with financial constraints than Tobin's *q* approach.

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I. Introduction

This paper investigates capital investment with financial constraints by comparing approaches based on two strains of theory: Tobin's q theory and the real options theory. There are many empirical analyses based on Tobin's q theory, some of which focus on investment of financially constrained firms. Since the mid-1980's, a new strain of investment research has developed. It is an application of options pricing theory and therefore called the real options theory of capital investment. The paper examines investment of the U.S. firms for two periods: the years 1972-1986 and the years 1986-2000, and finds that the real options approach yields similar results for two examined periods but Tobin's q approach yields different results for the same periods.

Jorgenson (1963) developed a neoclassical model of capital investment and showed that a firm's optimal stock of capital was found by equating the marginal product of capital to the user cost of capital. In his model, a firm maximized the present value of profits over an infinite time horizon. The user cost of capital was a function of the discount and depreciation rates, the inflation rate of capital goods, and applicable taxes. On the other hand, Tobin (1969) theorized that the optimal investment was a function of q

which was the ratio of the market value of a firm to the replacement cost of the firm's existing capital stock.

Jorgenson's neoclassical theory was characterized as the "marginal" concept, while Tobin's *q* theory was based on the "average" concept. However, Hayashi (1982) showed that these two strains of theory were mathematically equivalent under assumptions such as perfectly competitive markets and linearly homogeneous technology. Another assumption was symmetric information between insiders and outsiders of a firm. Then, empirical research of *q* theory has employed average *q*, because marginal *q* is difficult to observe.

In his review paper, Chirinko (1993) showed that the existing analyses of capital investment were unsatisfactory. The author pointed out, among others, that the neoclassical models treated delivery lag inconsistently. The delivery of new capital goods was instantaneous in theory but empirical models introduced *ad hoc* delivery lags. The author further pointed out that empirical analyses based on Tobin's *q* theory were also unsatisfactory because they yielded low R^2 and strongly autocorrelated residuals. The only relevant variable for the optimal investment was *q* in theory, but estimated coefficients for other variables such as cash flow or liquidity were often significant.

Fazzari, Hubbert and Peterson (1988) considered effects of financial constraints on capital investment and developed their *q* model with the cash-flow variable. The authors incorporated asymmetric information between insiders and outsides of a firm into analysis. In their analysis, they classified firms by the dividend-income ratio. They assumed that a firm with a low dividend-income ratio faced higher costs for external funds so that the firm was financially constrained. Then, they found that, for financially constrained firms, investment was affected by their cash flow.

The real options theory of capital investment is an application of options pricing theory or stochastic dynamic programming to capital investment with adjustment costs. In addition to financial constraints, there are other adjustment costs of investment such as irreversibility and fixed costs of investment. When investment is irreversible or a firm cannot sell its used capital, the firm should be concerned with holding too much capital stock in the future. With too much capital, the marginal product of capital is low so that the resale of its used capital is desirable. But, because of irreversibility, the firm cannot sell its used capital. In such a case, the firm should consider not only how much to invest but also when to invest. By waiting, the firm acquires more information for investment decisions. The real options theory incorporates the value of waiting into analysis of investment decisions.

McDonald and Siegel (1986) developed a theoretical model incorporating the value of waiting into irreversible investment. The authors applied stochastic dynamic programming to irreversible investment, and showed that the marginal product of capital is higher than the user cost of capital for irreversible investment. The value of waiting was the analogy with the value of financial options.

The solution of the real options theory is usually called a barrier control (e.g., Dixit and Pindyck, 1994). When the point representing state variables, some of which are stochastic, is located in the so-called continuation region, control variables remain unchanged. And the continuation region is surrounded by the so-called barriers. However, once the point of the state variables reaches a barrier, the control variables change so that the point of the state variables moves along the barrier. In the case of capital investment, the state variables are capital stock and variables representing economic conditions surrounding a firm. And one of the control variables is capital investment. The solution of the real options theory is characterized as Markovian (e.g., Stokey and Lucas with Prescott, 1989). Even though the model setup of the real options theory is dynamic, the solution is a time-invariant function and the arguments of the function include only current variables but no lagged variables.

Holt (2003) applied the real options theory to investment with financial constraints. In order to avoid bankruptcy, a firm should have held certain amount of liquidity. When the firm held sufficient liquidity, it would contemplate investing or paying dividends. In Holt's model, there were two barriers: one for investment and the other for dividends payment. These barriers crossed at a critical stock of capital goods. Below the critical stock, the investment barrier was located below the dividends barrier so that the firm invested without paying dividends when its liquidity reached the investment barrier. Or, small firms preferred investing to paying dividends. On the contrary, above the critical stock, the dividends barrier was located below the investment barrier so that large firms were likely to pay dividends rather than investing.

Estimations of investment based on the real options theory require incorporating the barrier control solution. Therefore, this paper employs sample selection models with two selection equations. One selection equation is for investment decisions, and the other equation is for dividends decisions. The paper focuses on firms which invest without paying dividends. Those firms are regarded as small in Holt's sense and their investment should be restricted by their liquidity. Thus, the paper examines whether liquidity significantly affects investment for small firms. Because the paper employs only observations of firms which invest without paying dividends, ordinary least squares estimators may suffer from the sample selection bias. Therefore, the paper corrects the bias by the principle proposed by Heckman (1979).

The estimations based on the real options theory exclude lagged variables from regressions in accordance with its Markovian solutions. The exclusion of lagged variables is contrasting to the conventional q models, and may cause a different process in residuals than the q models. The q models are known to show strong autocorrelation in residuals. When autocorrelated explanatory variables are omitted from regressions, they are included in disturbance terms and the omission of relevant variables should cause significant autocorrelation in residuals. All of the explanatory variables in this paper actually show strong autocorrelation. Therefore, strong autocorrelation in residuals may be a sign of misspecification in econometric models. Therefore, the paper examines the autocorrelation in residuals.

Section II and III present estimations based on Tobin's *q* and real options approaches, respectively. Both estimations examine investment of the U.S. firms in two period: the years 1972-1986 and the years 1986-2000. Section VI concludes and appendix describes data.

II. Tobin's *q* Approach

Fazzari, Hubbert and Peterson (1988, thereafter FHP) investigated financially constrained investment. Their approach was based on Tobin's *q* theory. When a firm paid high dividends, the firm could finance its investment by reducing its dividends. On the other hand, if the firm paid low dividends, the firm should have relied on external sources of finance which were costly. Or, outsiders of the firm may have regarded low dividends as a bad signal of the firm's future prospects. As a result, for the firm paying low dividends, external sources of finance are limited and such firms should have been financially constrained for investment. FHP examined firms in the entire U.S. manufacturing sector and employed the dividend-income ratio for their classification criterion. Their panel data were balanced and contained observations of 15 years from 1970 to 1984. Out of 422 firms, 49 firms were classified as financially constrained. Their baseline regression equation can be written as follows:

$$(1)\quad \frac{I_{it}}{K_{i,t-1}} = \beta_0 + \beta_1 Q_{it} + \beta_2\left(\frac{CF_{it}}{K_{it}}\right) + dummies + u_{it}$$

where *I*, *K*, *Q* and *CF* stand for investment, capital stock, *q* and cash flow, respectively. Subscripts *i* and *t* index firm and time, respectively; *u* is a disturbance term; β's are coefficients. Two coefficients β_1 and β_2 are expected to be positive. The dummy variables include firm and year dummies. In their analysis, FHP estimated equation (1) and several other specifications by the method of ordinary least squares (OLS). Those specifications were equation (1) without the cash-flow variable and equation (1) with lagged variables. In addition, they estimated equation (1) by the instrumental variable (IV), the first difference (FD) and the second difference methods.

The analysis in this section also estimates equation (1) with the same specification as FHP's analysis. In addition, the analysis estimates the equation by the IV and the FD methods as well as the fixed effects (FE) and Heckman's two-step (Heckit) methods. The selection rule for the Heckit method is whether a firm is classified as financially constrained. Because constrained firms are not randomly selected, all estimation methods except the Heckit method may suffer from the sample selection bias. Therefore, the analysis employs the Heckit method which adds a correction term or the inverse Mills ratio (λ) to equation (1). The analysis examines firms in the entire U.S. manufacturing sector in two 15-year periods: the years 1972-1986 and the years 1986-2000. The dataset is a balanced panel.

Table 1 shows OLS estimates of Tobin's *q* approach. For the first period (1972-1986), the estimated coefficients for the *Q* variable are positive and significant, and dropping the *CF* variable decreases the *R* squared (R^2) from 0.475 to 0.272. When the analysis adds the lagged *CF* variables, the ratio of the estimated coefficients for the current and the first-lagged *CF* is about four. These results are similar to FHP's analysis. However, adding the lagged *Q* variable lowers the estimated coefficient for the current *Q*, which contradicts FHP's analysis. The estimated coefficients of autocorrelation in residuals are always significant.

However, the second period (1986-2000) shows contrasting results. Although the estimated coefficients for the *Q* variable remain positive and significant, the estimated coefficients for the current *CF* variable are insignificant in two of three estimations, and R^2's are very low. In addition, the estimated coefficients for the current *CF* are all negative, which is incompatible with theory. In other words, the analysis fails to show that the cash flow significantly affects investment for financially constrained firms.

Estimated coefficients of autocorrelation in residuals are also insignificant.

Table 2 shows estimates of alternative methods: the IV, the FD, the FE and the Heckit methods. FHP's analysis included the IV and the FD methods and showed that the estimates of both methods were similar to OLS estimates. However, in this analysis, FE estimates are similar to OLS estimates, but the other three estimates are different from OLS estimates. Similarly to Table 1, the estimates for the current *CF* variables are positive and significant in the first period, but are negative and mostly insignificant in the second period. In addition, the Heckit estimate for the correction term is statistically significant in the first period. Therefore, the selection bias cannot be ignored for the first period. However, the estimate for the correction term is insignificant in the second period. Thus, the analysis finds that the estimations based on Tobin's *q* approach show different results between the two periods. The analysis yields estimates similar to FHP's analysis for the first period but different from FHP's analysis for the second period. Especially, the estimates for the *CF* variable show contradicting results between the two periods and they are negative in the second period, which is incompatible with theory.

III. Real Options Approach

The approach in this section is based on the real options theory of investment. Because the real options theory yields the barrier control solution, sample selection models (SSM) are appropriate econometric models. The analysis in this section deals with two decision equations: the one for investment decision and the other for dividends decision. The analysis therefore employs a sample selection model with two selection equations.

The solution of dynamic programming is characterized as Markovian. In other words, the solution is a time-invariant function without lagged variables. Consequently, the econometric model of the analysis exclude lagged variables. The regression equation in this section can be written as follows (see, for example, Vella 1998, p.154 for sample selection models with multiple selection rules):

$$(2)\quad Y_{it} = \gamma_0 + \gamma_1 Log\,Re_{it} + \gamma_2 Log\,Co_{it} + \gamma_3 Log\,K_{it} + \gamma_4 Log\,F_{it} + \eta_1 \hat{\lambda}_{1,it} + \eta_2 \hat{\lambda}_{2,it} + dummies + v_{it}$$

if firm i invests without paying dividends at time t. Variable Y is the measure of capital investment whose derivation is shown in the appendix. Variables *Re*, *Co* and *F* stand for sales revenue, operating costs and liquidity, respectively; $\hat{\lambda}$'s are the estimated correction terms; v is a disturbance term; γ's and η's are coefficients. Two coefficients γ_1 and γ_4 are expected to be positive, while two coefficients γ_2 and γ_3 being negative. The analysis also estimates equation (2) without the correction terms ($\hat{\lambda}$'s) for comparison. However, the analysis does not include any lagged variables.

The analysis examines firms in two U.S. industries: the communications equipment manufacturing industry (SIC 3661) and the semiconductor manufacturing industry (SIC 3674), in two periods: the years 1972-1986 and the years 1986-2000. The analysis examines these two U.S. industries rather than the entire U.S. manufacturing sector because market conditions or production technologies are different from industry to industry. Such industry characteristics may result in different investment behaviors among industries. The dataset is an unbalanced panel.

Table 3 shows estimates based on the real options approach. For both industries in both periods, the estimated coefficients for the *F* variable are always positive. And, for the semiconductor manufacturing industry (NAICS 3764), they are significant. Thus, liquidity positively affects capital investment for financially constrained firms. Also, the estimates for the *K* variable are always negative and significant. Therefore, smaller firms are likely to invest disproportionately. The estimated coefficients for the *Re* and *Co* variables are mostly insignificant. Contrasting to Tobin's *q* approach which shows difference estimates between the two periods, every estimate of the real options approach shows similarities in its value and significance between both periods. In addition, R^2's are also similar between the two periods, and the estimated coefficients for autocorrelation in residuals are insignificant for all estimations.

For the communications equipment manufacturing industry (SIC 3661), all SSM estimates of the coefficients for the *Re*, the *Co*, the *K*, and the *F* variables are greater in absolute value than the corresponding OLS estimates, which suggests that the sample selection bias lowers the magnitudes of these estimates even though the estimates for the correction terms are insignificant. All estimated coefficients show the expected signs. For the semiconductor manufacturing industry, the estimated coefficients for the *Re* and the *Co* variables are also significant in the second period and show the expected signs. Therefore, the industry's investment became more sensitive to revenue and costs in the second period. Thus, the real options approach yields similar results between the two periods, contrasting to Tobin's *q* approach. Especially, the analysis shows that liquidity positively affects investment for financially constrained firms, which is compatible with theory.

IV. Concluding Remarks

This paper investigated capital investment with financial constraints by comparing Tobin's *q* and the real options approaches. The analysis based on the real options approach showed similar results for the two periods, but the analysis based on Tobin's *q* approach showed different results between the periods. The real options approach corrected the sample selection bias and yielded residuals which were not autocorrelated. On the other hand, Tobin's *q* approach showed, in the first period, that estimates were compatible with theory, that the sample selection bias was significant, and that residuals were autocorrelated. However, in the second period, most results disappeared. Thus, the real options approach was more appropriate than Tobin's *q* approach for analyzing irreversible investment with financial constraints.

The analysis based on Tobin's *q* approach showed that many estimates were significant for the first period. Namely, the *Q* and *CF* variables positively and significantly affected investment; the estimates for the lagged variables were often significant. However, the estimates for the selection bias and residual's autocorrelation were also significant. On the other hand, for the second period, most estimates were insignificant. Although the estimated coefficient for the *Q* variable remained positive and significant, the estimated coefficients for the *CF* variable were negative and mostly insignificant. The negative estimates for the *CF* variable were incompatible with theory. Also, the estimates of the selection bias and residual's autocorrelation were insignificant in the second period.

On the other hand, the analysis based on the real options approach showed that estimates were similar for both periods and compatible with theory. Namely, the estimates for liquidity were always positive and often significant, and the estimates for capital stock were negative and significant. The estimated coefficients for autocorrelation in residuals were insignificant. The analysis detected the sample selection bias for the communications equipment manufacturing industry. For the semiconductor manufacturing industry, the analysis found that investment became sensitive to sales revenue and operating costs in the second period.

Data Appendix

Standard and Poor's Compustat provides the financial data for this paper. The data items are Cash and Short-Term Investment (item 1), Receivables (item 2), Current Liabilities (item 5), Total Asset (item 6), Property, Plant & Equipment (net PPE, item 8), Sales (item 12), Depreciation & Amortization (item 14), Income before Extraordinary Items (item 18), Income before Extraordinary Items Adjusted for Common Stock Equivalents (item 20), Common Dividends (item 21), Price of Share (item 24), Common Shares Outstanding (item 25), Capital Expenditure on PPE (item 30), Cost of Goods Sold (item 41), Rental Expense (item 47), Common Equity (item 60), Deferred Taxes (item 74), and Acquisitions (item 129). If Acquisitions exceed 10% of net PPE, the corresponding data are removed from the data set.

For Tobin's q approach, the variable Q is defined as follows:

(A-1) Q = (Total Asset + Price of Share × Common Shares Outstanding − Common Equity − Deferred Taxes) / Total Asset.

The Q variable is measured at the beginning of the fiscal year. This definition is similar to Kaplan & Zingales (1997) who also investigated financially constrained investment. The measurement of investment is defined as the ratio of Capital Expenditure on PPE to net PPE, and the CF variable as the ratio of Income before Extraordinary Items plus Depreciation & Amortization to Net PPE. If a firm's dividend-income ratio, which is the ratio of Common Dividends to Income before Extraordinary Items, is below 0.1 for 10 years in the examined 15 years period, then the firm is classified as financially constrained. For the first period, 91 of 325 firms are classified as financially constrained. For the second period, 109 of 196 firms are classified as financially constrained. When a firm has 15 years data for one period, the firm is included in the data set so that the data set is balanced. Table A-1 shows the size of financially constrained and unconstrained firms.

For the real options approach, the capital stock variable K is net PPE adjusted by the real stock of capital and the historical cost of capital stock for the corresponding industry. Then, the measurement of investment is defined as follows:

(A-2) $$Y_{it} = Log\left(\frac{K_{i,t+1}}{K_{it}}\right) + \hat{\delta}$$

where $\hat{\delta}$ is the estimated rate of depreciation. This measurement is based on Abel and Eberly (1998) whose model is also an application of the real options theory to irreversible investment with fixed costs of investment. The estimated rate of depreciation is the 15 years average of the ratio of the current cost of depreciation to that of capital stock. When Y is less than the one standard error of the mean, Y is assumed to be zero. The sales revenue (Re), operating costs (Co), liquidity (F), current liabilities (CL), and rental expense (Rl) variables are respectively Sales, Cost of Goods Sold, Cash & Short-Term Investment plus Receivables, Current Liabilities, and Rental Expense divided by the Producers Price Index. And, the stochastic state variable representing economic conditions is assumed to be a product of the *Re*, the *Co*, and the *K* variables. If a firm invests without paying dividends, the firm is classified as financially constrained for that year. The same firm may be classified financially constrained for some years but unconstrained for other years. For the communications equipment manufacturing industry, 120 of 217 observations and 136 of 258 observations are classified as financially constrained for the first and the second period, respectively. The number of financially constrained firms is 21 for the first period and 20 for the second period. For the semiconductor manufacturing industry, 116 of 169 observations and 334 of 514 observations are classified as financially constrained for the first and the second period, respectively. The number of financially constrained firms is 12 for the first period and 38 for the second period. When a firm contains at least 10 years data in the examined 15 years period, the firm is included in the data set so that the data set is unbalanced. Table A-2 shows the size of classified firms.

The calculation of correction terms for the real options approach is based on estimates of the bivariate probit model (e.g., Greene 2003). This paper assumes a joint normal distribution for two disturbance terms in the investment and dividend decision equations. For the communications equipment manufacturing industry, the explanatory variables are the *Re*, *Co*, *K* and *F* variables. And, for the semiconductor manufacturing industry, the explanatory variables contain the *CL* and *Rl* variables in addition to the *Re*, *Co*, *K* and *F* variables.

Table A-3 shows the estimated autocorrelation coefficient of every variable. The estimates for the dependent variable of Tobin's q approach decreases from 0.694 in the first period to 0.115 in the second period, even though both estimates are statistically significant. However, the dependent variable for the real options theory shows similar values between two periods. The estimated autocorrelation coefficient of every explanatory variable is about 0.8 or higher regardless of the approaches and the periods.

REFERENCES

Abel, Andrew B. and Eberly, Janice C. "The Mix and Scale of Factors with Irreversibility and Fixed Costs of Investment." *Carnegie-Rochester Conference Series of Public Policy*, June 1998, 48, pp. 101-35.

Chirinko, Robert S. "Business Fixed Investment Spending: Modeling Strategies, Empirical Results, and Policy Implications." *Journal of Economic Literature*, December 1993, 31(4), pp. 1875-1911.

Dixit, Avinash K. and Pindyck, Robert S. *Investment under Uncertainty*, Princeton, NJ: Princeton University Press, 1994.

Fazzari, Steven M., Hubbert, Robert G. and Petersen, Bruce C. "Financing Constraints and Corporate Investment," *Brookings Papers on Economic Activity*, 1988, 1, pp. 141-95.

Greene, William H. *Econometric Analysis*, 5th ed. Upper Saddle River, NJ: Prentice Hall, 2003.

Hayashi, Fumio. "Tobin's Marginal q and Average q: A Neoclassical Interpretation." *Econometrica*, January 1982, 50(1), pp. 213-24.

Heckman, James J. "Sample Selection Bias as a Specification Error." *Econometrica*, January 1979, 47(1), pp. 153-61.

Holt, Richard W.P. "Investment and Dividends under Irreversibility and Financial

Constraints." *Journal of Economic Dynamics and Control*, January 2003, 27(3), pp. 467-502.

Jorgenson, Dale W. "Capital Theory and Investment Behavior." *American Economic Review*, May 1963, 53(2), pp. 247-59.

Kaplan, Steven N. and Zingales, Luigi. "Do Investment-Cash Flow Sensitivities Provide Useful Measures of Financial Constraints." *Quarterly Journal of Economics*, February 1997, 112(1), pp. 169-215.

McDonald, Robert and Siegel, Daniel. "The Value of Waiting to Invest." *Quarterly Journal of Economics*, November 1986, 101(4), pp. 707-27.

Stokey, Nancy L., Lucas and Robert E. Jr. with Prescott, Edward C. *Recursive Methods in Economic Dynamics*, Cambridge, MA: Harvard University Press, 1989.

Tobin, James. "A General Equilibrium Approach to Monetary Theory." *Journal of Money, Credit, and Banking*, February 1969, 1(1), pp. 15-29.

Vella, Francis. "Estimation with Sample Selection Bias: A Survey." *Journal of Human Resources*, Winter 1998, 33(1), pp. 127-69.

Table 1. Estimates of Tobin's *q* Approach (1)

	Baseline	Without *CF*	With lagged variables	
	OLS	OLS	OLS	OLS
(1972-1986)				
Q_{it}	0.054 (0.006)***	0.034 (0.007)***	0.037 (0.006)***	0.036 (0.006)***
$Q_{i,t-1}$				0.026 (0.006)***
$(CF/K)_{it}$	0.268 (0.012)***		0.161 (0.016)***	0.193 (0.013)***
$(CF/K)_{i,t-1}$			0.042 (0.018)**	
$(CF/K)_{i,t-2}$			-0.004 (0.014)	
R^2	0.475	0.272	0.387	0.410
AC in Residuals	0.174 (0.026)***	0.175 (0.024)***	0.140 (0.031)***	0.152 (0.029)***
(1986 – 2000)				
Q_{it}	0.042 (0.013)***	0.040 (0.013)***	0.032 (0.008)***	0.016 (0.009)*
$Q_{i,t-1}$				0.020 (0.010)**
$(CF/K)_{it}$	-0.002 (0.001)		-0.001 (0.001)	-0.002 (0.001)***
$(CF/K)_{i,t-1}$			-0.003 (0.001)**	
$(CF/K)_{i,t-2}$			0.004 (0.002)*	
R^2	0.095	0.094	0.153	0.149
AC in Residuals	-0.003 (0.016)	-0.002 (0.016)	-0.042 (0.027)	-0.041 (0.025)

Notes

(1) Dependent variable: $(I_{it} / K_{i,t-1})$

(2) Firm and Year dummy variables are omitted from the tables.

(3) Standard errors in parentheses

(4) Retention ratio is above 0.9 for at least 10 years in the examined 15 years.

(5) ***: 1% significance level, **: 5% significance level, *: 10% significance level

Table 2. Estimates of Tobin's *q* Approach (2)

	Baseline IV	Baseline FD	Baseline FE	Baseline Heckit
(1972-1986)				
Q_{it}	0.138 (0.019)***	0.036 (0.006)***	0.054 (0.006)***	0.054 (0.011)***
$(CF/K)_{it}$	0.262 (0.033)***	0.257 (0.015)***	0.268 (0.012)***	0.350 (0.023)***
$\hat{\lambda}_{it}$				-0.545 (0.068)***
R^2	0.246	0.243	0.353	0.395
AC in Residuals	0.155 (0.026)***	-0.342 (0.026)***	0.332 (0.026)***	0.884 (0.013)***
(1986 – 2000)				
Q_{it}	0.060 (0.017)***	0.062 (0.016)***	0.042 (0.013)***	0.037 (0.013)***
$(CF/K)_{it}$	-0.004 (0.001)***	-0.001 (0.002)	-0.002 (0.001)	-0.002 (0.001)
$\hat{\lambda}_{it}$				-0.277 (0.244)
R^2	0.127	0.053	0.025	0.094
AC in Residuals	0.004 (0.014)	-0.226 (0.018)***	0.032 (0.015)**	0.014 (0.016)

Notes

(1) Dependent variable: $(I_{it} / K_{i,t-1})$

(2) Firm and Year dummy variables are omitted from the tables.

(3) Standard errors in parentheses

(4) Retention ratio is above 0.9 for at least 10 years in the examined 15 years.

(5) ***: 1% significance level, **: 5% significance level, *: 10% significance level

Table 3. Estimates of Real Options Approach

	SIC 3661		SIC 3764	
	SSM	OLS	SSM	OLS
(1972 – 1986)				
Log Re_{it}	0.998 (0.597)*	0.154 (0.208)	-0.121 (0.349)	0.021 (0.243)
Log Co_{it}	-0.861 (0.595)	-0.099 (0.185)	0.044 (0.316)	-0.097 (0.225)
Log K_{it}	-0.680 (0.226)***	-0.432 (0.068)***	-0.250 (0.095)***	-0.243 (0.068)***
Log F_{it}	0.636 (0.504)	0.244 (0.096)**	0.289 (0.093)***	0.259 (0.080)***
$\hat{\lambda}_{1,it}$	1.759 (1.966)		-0.038 (0.248)	
$\hat{\lambda}_{2,it}$	0.231 (0.516)		0.187 (0.383)	
R^2	0.598	0.580	0.519	0.516
AC in Residuals	-0.061 (0.105)	-0.053 (0.103)	0.049 (0.102)	0.040 (0.103)
(1986 – 2000)				
Log Re_{it}	-0.349 (0.501)	0.054 (0.205)	0.290 (0.086)***	0.275 (0.083)***
Log Co_{it}	0.405 (0.350)	0.174 (0.200)	-0.159 (0.075)**	-0.141 (0.072)*
Log K_{it}	-0.538 (0.216)**	-0.328 (0.067)***	-0.302 (0.038)***	-0.286 (0.033)***
Log F_{it}	0.429 (0.371)	0.066 (0.075)	0.134 (0.075)*	0.084 (0.035)**
$\hat{\lambda}_{1,it}$	1.036 (1.194)		0.171 (0.292)	
$\hat{\lambda}_{2,it}$	-0.659 (1.221)		0.138 (0.171)	
R^2	0.418	0.410	0.522	0.520
AC in Residuals	-0.153 (0.106)	-0.161 (0.107)	-0.036 (0.058)	-0.042 (0.059)

Notes:

(1) Dependent variable: Log ($K_{i,t+1}$ / K_{it})

(2) Firm and Year dummy variables are omitted from the tables.

(3) Standard errors in parentheses

(4) Data available for at least 10 years in the examined 15 years

(5) ***: 1% significance level, **: 5% significance level, *: 10% significance level

Table A-1. Summary of Examined Firms for Tobin's q Approach

(a) Years 1972 – 1986

	Mean	Minimum	Maximum
Financially Constrained Firms			
$I_{it} / K_{i,t\text{-}1}$	0.325	0.000	6.089
Q_{it}	1.291	0.291	45.48
$(CF / K)_{it}$	0.352	-7.105	13.33
K_{it} (1972)	23.29	0.258	285.8
K_{it} (1986)	116.4	1.325	2,236
Financially Unconstrained Firms			
$I_{it} / K_{i,t\text{-}1}$	0.256	0.002	4.290
Q_{it}	1.245	0.282	11.11
$(CF / K)_{it}$	0.419	-1.026	11.17
K_{it} (1972)	279.5	0.166	12,645
K_{it} (1986)	955.9	0.630	49,289

(b) Years 1986 – 2000

	Mean	Minimum	Maximum
Financially Constrained Firms			
$I_{it} / K_{i,t\text{-}1}$	0.409	0.000	50.14
Q_{it}	2.514	0.360	51.76
$(CF / K)_{it}$	-1.842	-996.3	73.61
K_{it} (1972)	23.5	0.010	414.6
K_{it} (1986)	128.3	0.009	4,258
Financially Unconstrained Firms			
$I_{it} / K_{i,t\text{-}1}$	0.234	-0.009	2.751
Q_{it}	1.592	0.491	10.94
$(CF / K)_{it}$	0.480	-1.124	8.094
K_{it} (1972)	2,423	0.248	49,289
K_{it} (1986)	4,231	0.860	89,829

Note:

(1) Capital stock (K): Million dollars

Table A-2. Summary of Examined Firms for Real Options Approach

(a) Years 1972 – 1986

	SIC 3661			SIC 3674		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
	Investing without Paying Dividends					
Y_{it}	0.359	0.0057	1.798	0.344	0.0087	1.743
Re_{it}	30.50	1.411	178.3	240.1	5.601	1,635
K_{it}	1.897	0.0101	15.22	27.32	0.0355	238.0
	Investing while Paying Dividends					
Y_{it}	0.216	0.0044	1.714	0.216	0.0167	0.471
Re_{it}	2,355	8.270	16,464	2,304	61.76	5,538
K_{it}	186.9	0.0724	1,170	177.3	4.418	452.9
	Not Investing					
Y_{it}	-0.198	-1.607	0.0006	-0.266	-1.882	-0.0022
Re_{it}	50.01	2.647	396.3	303.7	5.351	2,940
K_{it}	3.409	0.0112	27.49	27.32	0.254	248.4

(b) Years 1986 – 2000

	SIC 3661			SIC 3674		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
	Investing without Paying Dividends					
Y_{it}	0.348	0.0078	2.200	0.290	0.0080	2.040
Re_{it}	98.37	1.871	1,849	319.6	0.8530	4,101
K_{it}	4.003	0.0255	65.48	41.32	0.00676	529.1
	Investing while Paying Dividends					
Y_{it}	0.218	0.0079	1.261	0.266	0.014	0.844
Re_{it}	2,920	5.597	17,754	6,125	117.8	25,407
K_{it}	138.1	0.185	486.1	628.2	6.363	2,865
	Not Investing					
Y_{it}	-0.242	-4.883	0.0067	-0.244	-1.787	0.0072
Re_{it}	420.6	3.017	22,821	204.9	0.8905	7,641
K_{it}	16.36	0.0344	653.0	24.56	0.0174	845.8

Note:

(1) Sales revenue (*Re*) and capital stock (*K*): Millions of 1982 dollars

Table A-3. Estimated Autocorrelation Coefficient of Variables and Standard Error

(a) Tobin's q Approach

(1972 – 1986)		
$(I_{it} / K_{i,t-1})$	0.694	(0.010)***
Q_{it}	0.824	(0.007)***
$(CF / K)_{it}$	0.771	(0.009)***
(1986 – 2000)		
$(I_{it} / K_{i,t-1})$	0.115	(0.012)***
Q_{it}	0.851	(0.012)***
$(CF / K)_{it}$	0.943	(0.017)***

(b) Real Options Approach

	SIC 3661		SIC 3674	
(1972 – 1986)				
Y_{it}	0.582	(0.067)***	0.630	(0.062)***
Log Re_{it}	1.044	(0.009)***	1.032	(0.005)***
Log Co_{it}	1.043	(0.011)***	1.029	(0.006)***
Log K_{it}	0.913	(0.024)***	1.073	(0.015)***
Log F_{it}	1.063	(0.019)***	1.040	(0.010)***
(1986 – 2000)				
Y_{it}	0.596	(0.092)***	0.668	(0.044)***
Log Re_{it}	1.052	(0.010)***	1.026	(0.003)***
Log Co_{it}	1.051	(0.012)***	1.026	(0.003)***
Log K_{it}	0.962	(0.024)***	1.027	(0.007)***
Log F_{it}	1.058	(0.016)***	1.039	(0.007)***

Note

(1) ***: 1% significance level, **: 5% significance level, *: 10% significance level