R&D adjusted q theory for fixed capital investment Evidence from macroeconomic aggregated US data[1]

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Abstract

We propose an error correction model that removes the effect of market valuation of intangible capital, R&D investment, to investigate q theory for fixed capital investment. This model has high explanatory power for aggregated US data.

keywords : Tobins q ; R&D investment ; investment function ; error correction model
JEL classification number : E22 ; G31 ; C32

1. Introduction

Simple q theory for investment does not perform well in empirical research. There are several explanations or modifications for this problem:

1) measurement errors in q: *e.g.*, Erickson and Whited (2000);
2) nonlinear relationships between q and investment: *e.g.*, Barnett and Sakellaris (1998);
3) role of cash flow or financial frictions: *e.g.*, Cooper and Ejarque (2003), Cummins et al. (2006), Hennessy et al. (2007); and
4) roles of intangible assets: *e.g.*, Almeid and Campello (2007), Megna and Klock (1993).

We focus on the role of intangible assets, especially market valuation of R&D investment. Of course, in the US accounting system, R&D investment has been treated as capital on balance sheets since 2002, but there may be a gap between listed values and market valuation (see Hall (1993) or Chan et al. (2001)).

Such a gap between listed values and market valuation should affect q. Because q theory is based

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１）本稿は、前川が関西大学の在外研究期間中（2007年９月～2008年９月）に共著者と行った研究成果をまとめた論文である。在外研究の機会を与えていただいた大学ならびに経済学部の諸先生方に御礼申し上げたい。

on the view that fixed investment depends on the market value of capital, market valuation of capital affects the explanatory power of q. Therefore, if R&D investment were to create a gap between listed values and market valuation, it would be necessary to remove it when estimating an investment function based on q. In the present paper, we propose an error correction model that removes the effect of market valuation of R&D investment and increases the power of q theory to explain fixed capital investment.

In Section 2, we describe the data used in this paper. In Section 3, we formulate our model and apply it to US data. Finally, in Section 4, we discuss issues for further research.

2. Data and model

First, we describe the variables that relate to q theory in Figures 1 and 2: q, I/K, Cash/K, and R&D/K in the United States since 1960. Their definitions and data sources are explained in Table 1. As Figure 1 shows, the relationship between q and I/K is vague. It is obvious, however, that Cash/K and I/K are strongly correlated. This is one reason why many empirical studies support investment functions based on cash flow rather than q. On the other hand, Figure 2 implies that q and R&D/K are correlated, and since the 1980s this correlation has strengthened greatly.

Based on those movements of the variables, we applied unit root tests（Dicky–Fuller Tests）and cointegration tests for q, I/K, Cash/K, and R&D/K. We found that I/K has no unit root, but other variables—q, Cash/K, and R&D/K—have unit roots. Moreover, the results of Johansen's tests（with lag 1）tell us that there must be fewer than two cointegrating relationships among q, Cash/K, and R&D/K. Therefore, we further applied cointegration tests between q and R&D/K. The result of Johansen's test（with lag 1）suggests that there is a cointegrating relationship between q and R&D/K. We can thus assume that these two variables are cointegrated. Table 2 shows the results of these tests.

Tobin's q is defined as the ratio of corporate value（V）, consisting of the market value of stock and debt, to value of tangible assets（K）that companies have for production. This definition means that q is regarded as the marginal productivity of tangible assets. Today, however, when information technology is indispensable to economic activities and develops rapidly, the market must value a company that eagerly invests in research and development and must accumulate what we call "knowledge capital." Grilliches'（1981）study was one of the earliest papers to point out this problem.

In this paper, we consider that corporate value consists of two parts: one from tangible capital and the other from intangible capital:

$$V = V_1(\text{ from tangible capital }) + V_2(\text{ from intangible capital }).$$

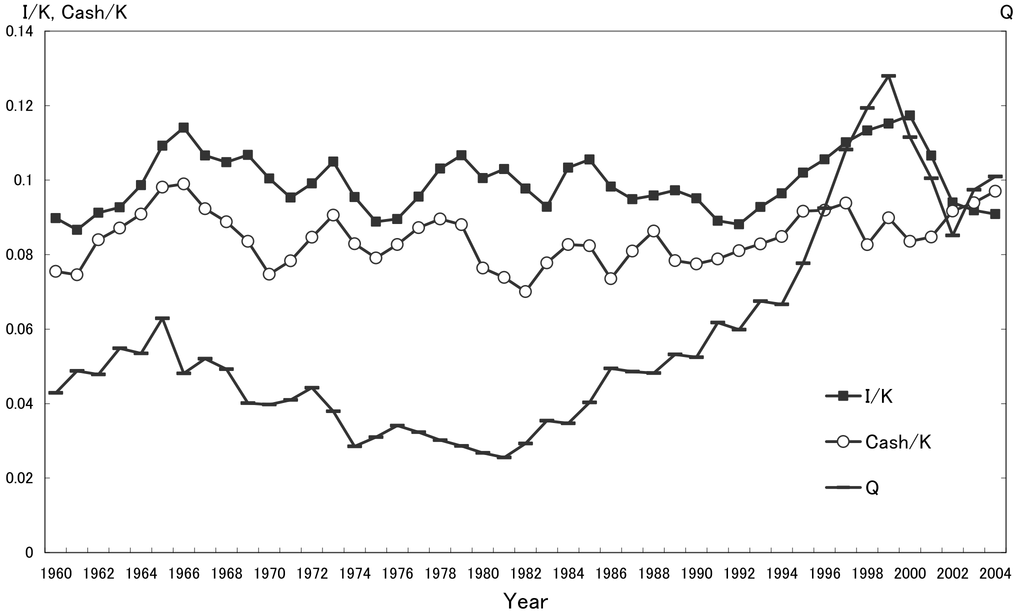

Figure 1 Changes of I/K, Cash/K, and Q

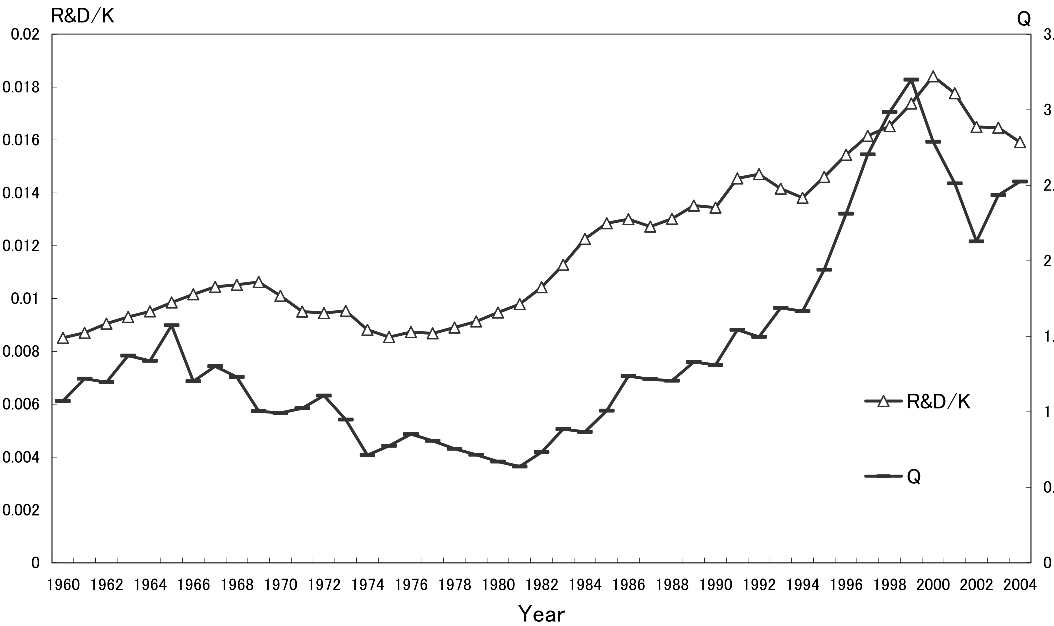

Figure 2 Changes of R&D/K and Q

Table 1 Variables and Data Sources

Variables and their definitions	Sources
q =（V + B）/ PIK	
V: Corporate valuation = Dividend / Dividend yield	Dividend: “Net Corporate Dividends（Total Industry）” in *National Income and Product Accounts*（Bureau of Economic Analysis）
	Dividend yield: “Dow Jones Industrial Average Dividend Yield”
B: Debt valuation = Interest payment / Bond rate	Interest payment: “Net Interest Payments（Total Industry）” in *National Income and Product Accounts*（Bureau of Economic Analysis）
	Bond rate: “BAA Corporate Bond Rate（average）”
PIK: Value of tangible capital	“Private Nonresidential Fixed Assets” in *National Income and Product Accounts*（Bureau of Economic Analysis）
I/K	
I : Private investment	“Private Nonresidential Investment” in *National Income and Product Accounts*（Bureau of Economic Analysis）
K: Tangible capital	“Private Nonresidential Fixed Assets” in *National Income and Product Accounts*（Bureau of Economic Analysis）
Cash/K	
Cash : Cash-flow = Corporate profits after tax + Corporate capital consumption allowances - Dividend	Total industries” “Corporate profits after tax,” “Corporate capital consumption allowances,” “Dividend” in *National Income and Products Accounts*（Bureau of Economic Analysis）
R&D/K	
R&D: R&D investment	“R&D Investment（Business）” in *Industry Economnic Accounts, Research and Development Satelite Accoutns 2007* （Bureau of Economic Analysis）

Table 2 Results of Unit Root Tests and Cointegration Tests

(a) Unit Root Tests (Dickey-Fuller Test): 1960–2004

	I/K	Q	Cash/K	R&D/K
Test Statistics	–3.414	–1.276	–2.723	–2.470
P-Values	0.005	0.894	0.227	0.343
Number of Lags	5	5	2	3

(b) Cointegration Test among Q, Cash/K, and R&D/K with constant and time trend: 1961–2004

	Engle-Granger	Johansen Test					
		Lag 0			Lag 1		
		H0：r=0	H0：r<=1	H0：r<=2	H0：r=0	H0：r<=1	H0：r<=2
Test Statistics	–2.340	22.521	7.545	1.703	42.064	11.218	4.559
P-Values	0.768	0.509	0.682	0.188	0.007	0.366	0.003

(c) Cointegration Test between Q and R&D/K with constant and time trend: 1961–2004

	Engle-Granger	Johansen Test			
		Lag 0		Lag 1	
		H0：r=0	H0：r<=1	H0：r=0	H0：r<=1
Test Statistics	–1.924	7.989	1.956	10.911	4.027
P-Values	0.802	0.647	0.157	0.392	0.042

We can then decompose q to two corresponding parts:

$$q = \frac{V}{K} = \frac{V_1}{K}\left(\text{ from tangible capital }\right) + \frac{V_2}{K}\left(\text{ from intangible capital }\right)$$

$$= q_1(\text{ from tangible capital}) + q_2(\text{from intangible capital}).$$

q_1 represents the classical q that Tobin's q theory regards as a major factor upon which fixed investment depends. q_2 is another q that reflects market valuation of R&D investment in knowledge capital. According to Grilliches（1981）and the empirical result that q and R&D/K are co-integrated, we consider q_2 to be a function of R&D investment:

$$q_2 = b_1 + b_2 * (R \& D). \quad (1)$$

According to the q theory, and the fact that I/K does not have a unit root, we consider I/K to be a function of q_1, and q_1 to be an I（0）variable. We substitute equation（1）into this relationship:

$$\begin{aligned} \frac{I}{K} &= a_1 + a_2 * q_1 \\ &= a_1 + a_2 * \{q - b_1 - b_2 * (R \& D)\} \\ &= (a_1 - a_2 * b_1) + a_2 * \{q - b_2 * (R \& D)\} \end{aligned} \quad . \quad (2)$$

This model is a simple error correction model, revealing that classical q theory works when we use an adjusted q that removes the effect of R&D investment from the estimated value of q.

3. Empirical analysis

In estimating the error correction model explained above, we formulate a base model by adding some explanatory variables. Our base model is as follows:

$$\begin{aligned} I/K_t = \alpha + \beta\left(q_{t-1} - \gamma\, R\&D/K_{t-1}\right) + \delta\Delta q_{t-1} + \eta\, I/K_{t-1} + \phi\Delta\, R\&D/K_{t-1} + \theta\Delta\, Cash/K_{t-1} \\ + \delta_2\Delta q_{t-1} + \eta_2\, I/K_{t-1} + \phi_2\Delta\, R\&D/K_{t-1} + \theta_2\Delta\, Cash/K_{t-1} \end{aligned} \quad . \quad (3)$$

We propose that a significantly positive estimation of β would demonstrate the validity of q theory. We also propose that a significantly positive estimation of γ would support the view that the modification of q explained in Section 2（equation（2））is appropriate.

Moreover, we consider changes in the relationship between q and R&D/K during the sample period（1963–2004）to estimate the explanatory power of q for I/K more clearly. Figure 3 plots the relationship between q and R&D/K and indicates that q and R&D/K may have been more strongly correlated after 1981. Based on those observations, we estimate equation（3）in three periods: 1963–2004（whole period）, 1963–1981, and 1983–2004. In each period, we select the explanatory variables according to estimated t-values of the coefficients and choose the models with minimum AIC. Table 3 presents the results of these periods. Each period has two models. Line（1）shows the result of the model with all variables, and line（2）shows the result of the model with the significant variables and minimum AIC after selecting variables.

Table 3 shows the result for the whole period, which is that β is positive and significant at the 10% level. Moreover, it is clear that γ is significantly positive, so we can say that the explanatory power of q becomes significantly robust when the market valuation of R&D/K is modified. We also find that the results of line（2）, the effective models, are different in each period. The results in the period 1963–1981 reveal that the adjusted q is not significant

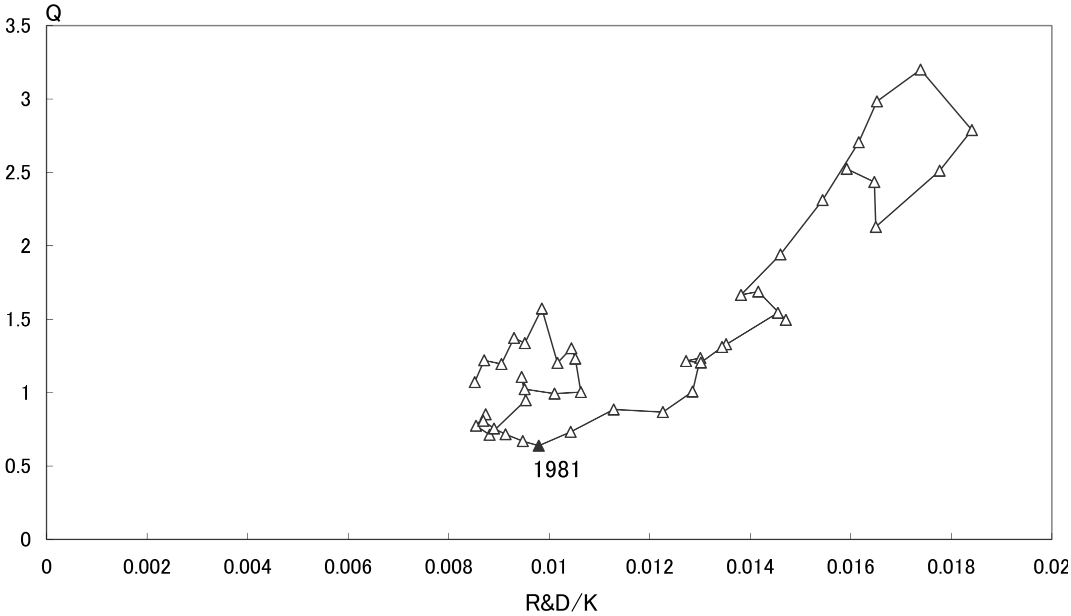

Figure 3 Q and R&D/K

but q(–1) and I/K(–1) are significant. On the other hand, the results in the period 1983–2004 show that the adjusted q rather than q(–1) has significant explanatory power. We believe that such different results reflect the fact that the market evaluated intangible assets more than it did previously. In addition to those findings, we can also point out that the adjusted R-squared values of the models in period 1983–2004 are higher than 0.9. This means that the recent models with adjusted q have greater explanatory power.

4. Conclusion

We propose an error correction model to adjust for the effects of R&D investments on q and estimate the q theory investment function for tangible capital using US macroeconomic data. Despite the fact that many previous studies have failed to support the q theory, our result shows that the adjusted q theory explains well the relationship between q and corporate investment. This result indicates that q theory works well when we consider explicitly the difference between the theoretical assumptions and real market valuation. Based on those findings, we insist that we should consider market valuation of intangible assets when we estimate q and investment functions based on q theory.

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Table 3 Estimation Results for I/K Equation

Variables ＼ Years	1963-2004		1963-1981		1983-2004	
	(1)	(2)	(1)	(2)	(1)	(2)
Constant	0.4164	0.0411	0.0394	0.0225	0.0929	0.0891
	(2.885)	(3.062)	(1.426)	(1.717)	(3.527)	(5.987)
q(−1)	−0.0047	0.0046	0.0060	−	0.0162	0.0156
	(1.894)	(1.981)	(0.558)	−	(3.070)	(5.055)
R&D/K(−1)	258.821	260.682	231.773	−	291.434	291.928
	(3.734)	(3.809)	(0.403)	−	(12.884)	(15.057)
Δq(−1)	0.009	0.0092	0.0306	0.0282	−0.0009	−
	(2.019)	(2.479)	(2.019)	(4.212)	(−0.181)	−
I/K(−1)	0.735305	0.7418	1.1469	0.7936	0.478832	0.4666
	(4.119)	(4.433)	(2.413)	(6.052)	(2.508)	(4.380)
ΔR&D/K(−1)	0.2093	−	−1.366	−	0.0887	−
	(0.119)	−	(−0.247)	−	(0.066)	−
ΔCash(−1)	0.186	0.1883	−0.7309	−	0.518	0.530
	(1.309)	(1.350)	(−1.281)	−	(3.933)	(5.155)
Δq(−2)	0.0087	0.0088	0.0265	0.0190	0.0094	0.0099
	(1.867)	(1.977)	(1.808)	(3.155)	(1.989)	(2.934)
ΔIK(−2)	−0.0758	−0.077	−0.451	−	−0.0346	−
	(−0.388)	(−0.401)	(−0.865)	−	(−0.190)	−
ΔR&D/K(−2)	−0.2432	−0.2087	−2.204	−	2.1870	2.1003
	(−0.149)	(−0.132)	(−0.381)	−	(1.414)	(1.602)
ΔCash(−2)	0.2289	0.0254	−0.0022	−	0.4002	0.4127
	(0.175)	(0.199)	(−0.004)	−	(2.542)	(3.996)
Adj. R-squared	0.734	0.742	0.555	0.707	0.911	0.930
AIC	−168.127	−169.117	−72.861	−77.883	−96.530	−99.478
D.W.	1.863	1.866	2.301	2.220	2.440	2.387

Note: The values in parentheses are t-statisitcs.

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